CULTURE OF CRAYFISH IN THE NORTH CENTRAL REGION

Chairperson: Paul B. Brown, Purdue University

Extension Liaison: Jeff Gunderson, Minnesota Sea Grant Extension, Duluth

Funding Request: $50,000

Duration: 2 Years (September 1, 1992 - August 31, 1994)

Objectives:

1. To complete a study of the status of the crayfish industry in the north central states, relative to its extent, culture operations in use, market characteristics, and problems which need to be addressed by research.
2. To complete a report on indigenous crayfish species appropriate for culture in the North Central Region, to include species life histories, ranges of distribution, economic assessment of appropriate culture production systems, a bibliography of pertinent literature, and a summary of critical information gaps.
3. To conduct preliminary trials evaluating the performance of several promising indigenous species in pond culture.

Proposed Budgets:

Institution	Principal Investigator	Objec-tive(s)	Year 1	Year 2	Total
Purdue University	Paul B. Brown	1-3	$10,446	$10,432	$20,878
Kansas State University	Harold E. Klaassen	1-3	$7,554	$7,568	$15,122
Southern Illinois University	Robert J. Sheehan	1-3	$7,000	$7,000	$14,000
		TOTALS	**$25,000**	**$25,000**	**$50,000**

Non-funded Collaborators:

Institution	Collaborator
Minnesota Sea Grant Program	Jeff Gunderson
Southwest Missouri State University	Robert Wilkinson
University of Minnesota-Duluth	Carl Richards

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JUSTIFICATION

The production of crayfish for human consumption consistently ranks as one of the largest aquacultural industries in the U.S. Most of the production occurs in Louisiana and contiguous states as a seasonal crop, typically available from December through May, and most of that crop is consumed in those states. The seasonality of production is due, in large part, to biological characteristics of the southern species that comprise most of the production--red swamp (*Procambarus clarkii*) and white river crayfish (*P. zonangulus*, or *P. acutus acutus*). Additionally, culture techniques employed in that industry (relatively shallow ponds) limit production to the cooler months. The seasonality of the southern crop and lack of supply outside the primary producing states has limited market expansion in the past and those are the primary reasons aquaculturists in the Midwest appear to have an opportunity. Native midwestern crayfish, primarily members of the genus *Orconectes*, deposit eggs in late winter to early spring and the young grow through the summer and fall. Thus, aquaculturists in this region have an opportunity to fill a market niche in one of the country's largest aquaculture industries with a native species during the portion of the year there is no competition for fresh product.

Crayfish supplies from the South are typically in the range of 27-54 million kg (60-120 million pounds) per year. Supplies are from both aquaculture operations and natural populations, primarily the Atchafalaya basin. Recent published reviews of that industry are numerous (Huner and Barr 1984; Avault and Huner 1985; Huner 1990; Huner and Romaire 1990) and will not be discussed here except to identify those characteristics that indicate the opportunity for aquaculturists in the North Central Region.

Southern Production

Red swamp and white river crayfish lay eggs beginning in late fall and the young hatch and grow through the winter and spring. This primary reproductive period is typically followed by pulses of egg laying through the following spring, but the relative contribution to the population of different reproductive periods is largely unknown. The southern crayfish industry depends on the multiple waves of reproduction, and, thus, multiple waves of recruitment into the harvest, exhibited by the red swamp crayfish *P. clarkii* (Huner and Barr 1984). A possible impediment to midwestern crayfish aquaculture is that *P. acutus, O. virilis*, and *O. immunis* show only single periods of reproduction during the year in the Midwest (Page 1985). Although polyculture has not been utilized to any great extent in U.S. commercial aquaculture, it could be an approach for overcoming this problem. Polyculture could simulate the multiple pulses of reproduction essential to red swamp crawfish producers in the South, because some midwestern species of aquacultural interest are fall spawners (e.g., *P. acutus*), whereas some, such as *O. immunis* and *O. virilis*, are spring spawners (Page 1985). Also, crayfish producers may have a lesser degree of control over species composition than other aquaculturists, because crayfish, unlike fish, can migrate over land to enter new aquatic habitats. Thus, polyculture, whether intended or not, is not only a possibility, but perhaps likely in the Midwest. It should be noted that southern culturists produce more than one species; *P. acutus* comprises in excess of 10% of the harvest from commercial crayfish ponds in the South. Reproductive periods obviously limit production seasons as they can in the Midwest, but other factors also contribute to the seasonal nature of the industry.

A typical crayfish pond is shallow (approximately 0.3 m deep) and most of the industry practices double-cropping of rice and crayfish. Planting rice requires a dry pond bottom; thus, ponds are typically drained and dried during a portion of the year. At this time, the southern species burrow and become relatively inactive. Inaccessibility during the summer and fall obviously limit the production season.

Management of water quality has become an important area of investigation as most producers feel that water movement can enhance production. Aeration of the water is often accomplished as the water is moved from one end of the pond to the other; thus, improving dissolved oxygen levels. While growth of crayfish is rapid relative to other aquatic animals (Lutz and Wolters 1986), there is some uncertainty regarding nutritionally-important foods of crayfish.

Crayfish are polytrophic and potential food items include aquatic microbial colonies, phyto- and zooplankton, other benthic invertebrates, fresh and decaying macrophytes, fish, and other crayfish. However, there have been few controlled studies designed to identify which levels of the trophic chain are nutritionally important. It is generally agreed that a detrital-based system should be established to provide food (Robinson 1989). Detailed nutritional research began only recently with crayfish (Brown et al. 1986; Davis and Robinson 1986; Brown et al. 1989a), but the early production studies have yielded promising results. Preliminary feed trials indicated yields could be increased by feeding relatively low amounts of feed offered at infrequent intervals (10-40 kg/ha/4-7 days, unpublished data from DuPont de Nemours, Inc.). Recently, scientists have been suggesting that harvesting may be a nutritional input for crayfish. Harvesting crayfish is typically done with specialized traps and baits, and they may indeed serve as a nutritional source, particularly for young crayfish not removed from the pond with the trap.

In most aquaculture production systems and species combinations, feeds comprise the bulk of the production costs. However, harvesting of crayfish comprises the bulk of production costs and is labor intensive. Economic analysis of crayfish culture indicates that harvesting is approximately 60% of production costs in the South. Specialized vehicles for harvesting have been an ongoing area of development and new baits are under evaluation. Bait manufacturers include small feed mills located in close proximity to the production areas, but also include several large companies (e.g., DuPont de Nemours and Purina Mills).

Markets for crayfish have historically been near production areas. However, new markets have been identified that offer good potential. Native European crayfish populations were decimated by an introduced fungus (*Aphanomyces astacii*) that left high demand, but little supply. Thus, there appears to be an export market for crayfish. Additionally, "Cajun" food retail outlets have been expanding in many parts of the U.S. and crayfish are a staple in those new restaurants.

North Central Region

Crayfish of the genus *Orconectes* are the dominant macrocrustacean in most aquatic habitats in the North Central Region. Reproductive biology of orconectid crayfish is offset from the primary spawning period of southern species, with egg laying occurring in late winter to early spring. Juveniles then grow through the summer and fall. However, other than reproductive seasons and a few distribution studies, we know relatively little about the aquaculture potential of native midwestern crayfish.

Hobbs and Jass (1988), working in Wisconsin, and Page (1985), working in Illinois, have published recent distributions of crayfish and provided information on general life histories. Momot and Aiken, working with Canadian populations of *O. virilis*, have provided a great deal of information on life history characteristics of wild populations of orconectid crayfishes in oligotrophic bodies of water (cf, Aiken 1965; Aiken 1968a; Aiken 1968b; Momot 1967; Momot 1978; Momot 1984; Momot and Gowing 1977). However, extrapolation of those data to highly eutrophic culture situations is difficult and possibly misleading.

Several commercial fisheries have been established in Wisconsin and Minnesota, and have been successful in the short-term. That harvest has been marketed primarily in European countries. Native midwestern crayfish take on an appearance similar to that of the European crayfish (*Astacus astacus*) when cooked by traditional methods; southern species have been marketed, but primarily as a frozen product. Thus, there appears to be a waiting market for our native species. However, we know relatively little about production characteristics of the candidate species. Stein and Murphy (1975) reported the nutritional composition of *O. propinquus*, but there appear to be no other reports for orconectid crayfishes.

Symposia held in recent years (the first at Southwest Missouri State University and the second at Southern Illinois University) have attracted 80+ interested individuals each time. Thus, there is interest in crayfish aquaculture in this region. Additionally, crayfish aquaculture appears to be beneficial on a more important level. We have a great deal of agriculture knowledge and expertise in this region, but relatively little aquacultural knowledge or expertise. Crayfish are easier to raise than fish and serve as a good model species with which to learn aquaculture. Crayfish are "more forgiving" than fish. That is, they are more tolerant of handling, can avoid poor water quality by exchanging atmospheric oxygen, and there are few diseases that affect North American crayfishes raised in freshwater.

Bait Production

In addition to the potential of producing crayfish for the human food market, there is considerable potential for producing crayfish for the bait market in the Midwest. Fishing is a major recreational activity in and around the Great Lakes and crayfish have been an important bait in many areas. One of the largest aquaculture industries in Indiana is the production of soft-shell crayfish as bait. Our survey of current producers should provide some quantification of that segment of the crayfish industry and current methods in practice.

RELATED CURRENT AND PREVIOUS WORK

Harold Klaassen at Kansas State University, working with *O. nais* reared in existing farm ponds, has provided a more realistic view of the culture potential of orconectid crayfish than the studies of wild populations from oligotrophic conditions. Following are the Masters theses that have resulted from this line of research.

Ingelin (1984) studied the growth and distribution of unexploited crayfish populations in farm ponds. He found that the growth in high density populations stopped in mid summer resulting in small stunted individuals. He also found the crayfish were distributed in the shallow water around the edge of the ponds in summer due to low dissolved oxygen in the deeper water.

Loring (1987) worked on the fluctuations of crayfish populations in a small prairie stream. He found wide fluctuations in response to hydrologic events. Densities of *O. nais* reached levels as high as $59/m^2$.

Kichler (1987) evaluated crayfish survival in winter conditions. In the laboratory he simulated winter conditions with low temperatures and various levels of low dissolved oxygen. Crayfish survival was greater than 50% for 3 days at a level as low as 0.04 mg/L dissolved oxygen (4 °C) but they did not survive past 12 days.

Money (1988) worked on the reproduction of *O. nais*. Gonad development was followed in both males and females. The fecundity to body size relationship was determined. Most egg laying occurred in March and April. Hatching occurred 1 to 2 months later.

There have been other non-thesis crayfish studies done in ponds at Kansas State University including trapping success using different baits, growth rates under heavy harvest levels, determination of yield under heavy harvest, and growth rates at various density levels. Yields of 200-1000 kg of crayfish/ha/year were achieved. Also very fast growth was observed at low stocking densities.

Laboratory studies included the determination of crayfish growth rate at different temperatures. Fastest growth was found to occur between 24-28 °C. Currently, in-lab feeding studies are being conducted using formulated pellets to evaluate protein levels and types.

Paul Brown at Purdue University provided evidence that: 1) traditional baits and traps from the South were effective in harvesting crayfish and those commercially-available baits were more effective than gizzard shad (*Dorosoma cepedianum*, Brown et al. 1989b); 2) the culture potential of *O. virilis* appears promising (production figures ranged 400-800 kg/ha) when fed common agricultural forages (Brown et al. 1990a); and, 3) consumption of aquatic macrophytes was relatively low (average 0.2% of body weight per day) and those items may not be an major source of nutrients for *O. virilis* (Brown et al. 1990b). Additional studies have been conducted or are in progress at Purdue that include evaluation of additional feeds and feeding strategies in research ponds, nutritionally-important, naturally-occurring foods for juvenile crayfish, studies of the essentiality of vitamins C and A, fecundity measurements and optimal temperature for growth of juvenile *O. virilis* and *O. immunis*.

Robert Sheehan and colleagues at Southern Illinois University-Carbondale have been studying polyculture of *P. zonangulus*, *O. virilis* and *O. immunis* in culture ponds with or without supplemental aeration. Early results from those studies suggest that aeration may be beneficial in this region. Additional work has been focused on genetic differences among crayfish populations.

Jeff Gunderson, affiliated with Minnesota Sea Grant and the University of Minnesota's Natural Resources Research Institute (NRRI), Duluth, has been establishing *O. immunis* in wild rice fields. Preliminary results have been encouraging and several demonstration sites have been established. Additionally, he has been involved in soft-shell crayfish evaluations in conjunction with Phil Devore and Carl Richards of NRRI.

All four groups have observed rapid rates of weight gain in orconectid crayfishes and have suggested that marketable-size animals can be obtained within one growing season (Brown et al. 1990a; Sheehan et al. 1991).

ANTICIPATED BENEFITS

Results of this cooperative project will serve as an important initial step in exploring the feasibility of crayfish aquaculture in the North Central Region. Objectives 1 and 2 have been designed to collate existing information on species and culture practices in use in the region that will help new aquaculturists and identify future research needs. Results from Objective 3 have been designed to: 1) simultaneously compare potential species in the same culture situation; 2) continue the investigation of farm-pond culture of *O. nais*; and, 3) continue the evaluation of polyculture of selected species. Extension publications resulting from the first two objectives will be made available and fill an important gap in our ability to respond to queries from potential crayfish aquaculturists. Additionally, results from Objective 3 will help define optimal culture conditions and species for the region.

OBJECTIVES

The objectives of this cooperative project are:

1. To complete a study of the status of the crayfish industry in the north central states, relative to its extent, culture operations in use, market characteristics, and problems which need to be addressed by research.

2. To complete a report on indigenous crayfish species appropriate for culture in the North Central Region, to include species life histories, ranges of distribution, economic assessment of appropriate culture production systems, a bibliography of pertinent literature, and a summary of critical information gaps.

3. To conduct preliminary trials evaluating the performance of several promising indigenous species in pond culture.

PROCEDURES

Status of the crayfish industry in the North Central States (Objective 1)

Jeff Gunderson, Aquaculture Extension Specialist, Minnesota Sea Grant, Duluth, MN, and Extension Liaison to this group, has initiated a survey of the crayfish industry in the North Central Region. Results of that survey will serve as the basis of that report. Additionally, attendees at a symposium held at Southern Illinois University last year will be contacted regarding their activities. Purdue University anticipates hosting the third regional symposium in July, 1992 and attendees at that meeting will serve as a source of information.

Responsibility for completing the report will lie with Paul Brown and Jeff Gunderson, with supplemental inputs from the other members of the work group.

Reports on appropriate indigenous crayfish species (Objective 2)

Based on adult size, preferred habitats, reproductive season and potential, and other biological characteristics, several crayfish species are known to have culture potential in the north central states. Much of that information can be found in existing taxonomic keys and their associated distribution maps (Hobbs and Jass 1988; Page 1985). The information provided by those documents has been an important source of information in initial studies, but can also be apparently contradictory depending on sites of collection. For example, Page (1985) found *O. virilis* in lentic habitats in Illinois, but Hobbs and Jass (1988) found the same species in a wide variety of habitats in Wisconsin. Similarly, there has been a great deal of information developed on wild populations of orconectid crayfishes in a variety of habitats ranging from lentic to lotic habitats. Those data indicate that crayfish production levels can range from 28 kg/ha (Momot 1978) to 1000 kg/ha (Threinen 1958). However, data collected from wild populations may not be directly comparable to data collected from culture ponds in which various level of management are practiced.

The available information described above will be used to develop an extension bulletin on key biological characteristics that should be considered when selecting appropriate species for aquacultural development in the North Central Region. Paul Brown and Jeff Gunderson will be primarily responsible for this document, with supplemental inputs from the other members of the work group.

Preliminary trials in pond culture (Objective 3)

Several common and promising crayfish species will be evaluated for pond culture in the north central region. This will be divided among the three co-investigators.

Production trials will be conducted at Purdue University under the direction of Paul Brown. Those studies will be conducted during the spring, summer, and fall of both years of this proposal and will be conducted as follows.

Sexually-mature adult crayfish will be obtained from sources in Indiana or from collaborators in other states. We have identified sources of *O. virilis, O. immunis*, and *O. rusticus* in Indiana, and have received commitments from collaborators to supply us with *O. immunis* from northern Minnesota and *O. longidigitus* from Missouri. In the first year of this project, those four species will be grown in experimental culture ponds currently in use at Purdue. This experimental approach will allow comparisons of several of the potential species under similar culture situations. All species will be obtained in fall 1992, transported to

Purdue University, and each species or geographically-distinct group will be maintained in existing tanks. Water temperature will remain cold (15-18 °C) until the following February. At that time, water temperature will be increased to induce egg laying. This approach has been used successfully in Purdue's laboratory with *O. virilis*, *O. immunis*, *P. clarkii* and *P. zonangulus*. This will help in timing of egg laying and eventual hatching so that studies may not be confounded by dramatically different sizes of juveniles stocked into our ponds. If problems develop or certain species do not lay eggs using this method, berried females (sexually-mature females carrying eggs) will be obtained from the same collaborators.

Prior to stocking juvenile crayfish, all pools will be fertilized with both inorganic fertilizer (20-20-20) at 40 kg/ha, and organic fertilizer (alfalfa meal) then stocked with *Daphnia magna* from Purdue's laboratory as well as a mixed culture of zooplankton from a nearby pond. Total length (measured from the tip of the rostrum to tip of the telson) data will be collected with dial calipers from a subsample of juveniles of each species or geographic group, and total wet weight will be recorded from a subsample of juveniles that have been blotted dry then weighed on an analytical balance. Known numbers of juvenile crayfish of each species will be stocked into triplicate pools approximately three weeks after zooplankton inoculation. We are currently evaluating stocking densities, several types of feed and feed rates, and will use the results of those studies to guide this research. Feeds used during the production season will be one of the better ones currently under evaluation and feed allotment and frequency will be conservative to avoid water quality problems. During both years, studies will be initiated in March or April, depending on hatching and water temperatures, and harvested in October.

Experimental units are 2.0 x 2.7 x 0.3 m (L x W x D), have plastic liners on the bottom and contain approximately 4 cm of additional pond mud. Barriers will be constructed to prevent movement of crayfish from their respective pools. We are currently evaluating stocking density as a function of feed inputs and will use a stocking density in our proposed studies that promotes maximum survival.

During the second year, we anticipate continuing our evaluations of first-year growth with promising species from the first year's evaluation and incorporating other potential species. If we can locate a source of adults, we will evaluate *P. gracilis*, *P. clarkii*, and *P. zonangulus* (or *P. acutus acutus*) in addition to one or more of the more promising species from the first year for research continuity.

All pools will be drained at the end of the production season, and final numbers, weight, and sex will be determined for each replicate. Resulting data will be statistically analyzed as a completely randomized design (one-way analysis of variance).

Orconectes nais will be evaluated in Kansas. This species is by far the most common large species found in ponds over much of the state. Based on our past research and its ubiquitous nature it has demonstrated that it is well suited to pond culture. It is capable of reaching large sizes. Individuals with carapace length of over 50 mm (26/kg or 12/lb) consistently keep showing up in numerous populations.

A culture technique involving a single generation treated as an annual crop will be evaluated. This is a technique often used in pond fish culture. This method was proposed by Klaassen in 1986 as a reasonable approach to crayfish culture in the central states. Since then a write-up of this approach has been distributed to many potential crayfish culturists. Unfortunately, the workability of this approach has not been tested. We propose to evaluate this procedure.

Three small farm ponds in the size range of 0.1-0.2 ha (¼-½ acre) will be selected. Any existing fish and/or crayfish populations will be eliminated in May 1993. In June these ponds will be stocked with YOY *O. nais* at a rate of $3/m^2$. Every two weeks throughout the growing season the ponds will be checked. A sample of 100 crayfish will be seined, measured (carapace length) and returned to determine growth rate. The water quality will also be monitored at those times. Temperature and dissolved oxygen profiles will be taken and surface alkalinity and hardness will be determined. Secchi disc readings and chlorophyll a will be measured by Standard Methods as an indicator of productivity level (APHA et al. 1989).

In late September a population estimate by a mark and recapture method will be done in each pond to determine summer survival. Samples will be collected by seining and marking will be done by clipping off half of a back leg.

The following spring (1994) growth determinations and water quality measurements will be continued. Also at this time reproduction will be monitored (egg laying and hatching). At the end of May to the first week in June the ponds will be trapped heavy with Gee minnow traps with 4 cm funnel openings. We have found that almost all adults can be trapped out of a small pond in a short time. Effectiveness of the trapping will be checked by extensive seining. This adult removal will be an evaluation of the yield as well as a check on the winter survival. In the past we have found winter survival to be a critical factor.

After the adult harvest is complete the new YOY will be poisoned out with a chemical like fenthion. After the ponds are non-toxic (end of June) they will be restocked with 3/m^2 YOY crayfish from another brood pond. These will be checked for two months (to August) as in the previous year to determine if the new crop follows the same pattern.

P. acutus, *O. virilis*, and *O. immunis* will be evaluated for their potential as midwestern culture species in a polyculture situation at SIUC. Two management strategies will also be examined. One will employ feeding formulated feeds in perpetually filled ponds. Crayfish yields of 1,122 to 2,942 kg/ha have been reported in the South using a similar strategy (D'Abramo and Niquette 1991). The second method will employ fall-winter draining, planting of a winter-weather crop (such as canola or winter wheat), spring flooding, and harvest via trapping. The water-level management scheme is expected to influence population dynamics of the polyculture crayfish community. *P. acutus* and *O. immunis* are secondary burrowers, better adapted to pond draining than *O. virilis*, considered a tertiary burrower.

All three species have been stocked in six 0.12 ha ponds by SIUC, and all three species have successfully reproduced in the ponds for two years. This will facilitate evaluations of growth and harvest of the three species under the two management strategies, supplemental feeding, reproductive success under the two strategies, and the economics of the two strategies.

SIUC is currently in its second of three years of evaluating production approaches employing feeding of formulated feeds and pond aeration/destratification. Although production has been encouraging, it is uncertain whether the extra expense involved in the use of formulated feeds and intensive water-quality management is warranted.

Ponds used in the study will be standard fish culture ponds with a maximum depth of 2 m. Three ponds will be aerated with air-lift pumps or some other type of aeration/circulation device, based on SIUC's current studies of pond aeration/destratification systems. Triplicate unaerated ponds, drained in the fall, planted with a cover crop and flooded again the following spring, will be evaluated for comparison. The cover crop to be planted in the fall (probably a rapid-growing, low-temperature strain of winter wheat or canola) will be chosen, based on estimates of production, period of growth, and lodging rate, following discussions with SIUC crop specialists currently conducting strain evaluations at our latitude and longitude.

The fed ponds will receive a feed formulated as per D'Abramo and Niquette (1991). The feed will be fed at rates commensurate to amounts the crayfish will consume and to the maintenance of good water quality (at least 3 mg/L DO); approximately 10-20 kg/ha/day. Feeding rates will be modified as needed (on the basis of water quality data) to minimize occurrences of oxygen depletions (<3 mg/L DO). Vertical DO and temperature profiles will be determined at 0.25 m intervals and at the pond bottom in the deepest area in each pond at sunrise each month. DO will also be measured at two other locations in each pond in shallow water near the bank every other day at sunrise. Other water quality parameters (pH, ammonia, nitrite, nitrate, hardness, and alkalinity) will be determined from water samples taken 0.3 m from the bottom in each pond every seven days using Standard Methods (APHA, et al. 1989). Water quality will be assessed more frequently as necessary during the study.

Crayfish in the ponds will be harvested and weighed initially about every other week during the production season. Harvest frequency will then be adjusted commensurate with yield. Harvestable size crayfish will be captured using a 1.91 cm bar mesh seine in the ponds receiving formulated feeds and by baited trap in the cover-crop ponds. Harvested crayfish will be removed from the ponds. A subsample of these will be used to determine what percentage of the whole body is abdominal muscle ("tail meat"). Weekly samples of crayfish will also be taken using baited minnow traps, (with the throats opened to 3 cm), a small mesh dipnet, and through short small-mesh seine hauls to determine size distribution of the populations comprising the crayfish-polyculture community. The ponds will be drained and all crayfish present will be collected and weighed when yield from the pond indicates that the production season is over.

Both treatments will be randomly assigned to triplicate ponds, and the resulting data will be analyzed as a one-way analysis of variance. If treatment means are significantly different, Duncan's Multiple Range test will be used to separate mean values.

FACILITIES

Purdue, Kansas State, and Southern Illinois Universities all have experimental research ponds for use in these studies. The ponds at Purdue are identical to those used in previous studies (Brown et al. 1990b) and are in use this year with crayfish. Those at the other two sites have been used in previous and ongoing studies. All three sites have existing wet laboratories that have been used for crayfish studies. Purdue is in the process of designing a new wet laboratory that should be completed by the time this project starts. All three institutions have the necessary field equipment, vehicles, and support staff and equipment for crayfish culture studies.

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Momot, W.T., and H. Gowing. 1977. Production and population dynamics of the crayfish *Orconectes virilis* in three Michigan lakes. Journal of the Fisheries Research Board Canada 34:2041-2055.

Money, J.H. 1988. Aspects of reproduction for the crayfish *Orconectes nais*. Master of Science thesis. Kansas State University, Manhattan.

Page, L.M. 1985. The crayfishes and shrimps (Decapoda) of Illinois. Illinois Natural History Survey Bulletin 33:335-448.

Robinson, E.H. 1989. Practical feeding-crawfish. *In* R.T. Lovell, editor. Nutrition and Feeding of Fish. Van Nostrand Reinhold, New York.

Sheehan, R.J., P.S. Wills, and W.T. Davin. 1991. Crayfish production: a promising enterprise for the Midwest. Pages 219-225 *in* Proceedings of the North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991. Michigan Department of Natural Resources, Wolf Lake Fish Hatchery, Mattawan, Michigan.

Stein, R.A., and M.L. Murphy. 1975. Changes in the proximate composition of the crayfish *Orconectes propinquus* with size, sex and life stage. Journal of the Fisheries Research Board of Canada 33:2450-2458.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	Robert J. Sheehan Southern Illinois University-Carbondale	Aquaculture/Genetics
Indiana	Paul B. Brown Purdue University	Aquaculture/Nutrition
Kansas	Harold E. Klaassen Kansas State University	Aquaculture/Crayfish

PARTICIPATING INSTITUTIONS AND PRINCIPAL INVESTIGATORS

Purdue University
Paul B. Brown

Kansas State University
Harold E. Klaassen

Southern Illinois University-Carbondale
Robert J. Sheehan

PROPOSED PROJECT BUDGET FOR
PURDUE UNIVERSITY

(Brown)

Objectives 1-3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.05	1	0.05	0	0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.25	1	0.25	$5,540	$5,650
d. Prebaccalaureate Students	1	0.50	1	0.50	$2,000	$2,000
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$7,540	$7,650
B. Fringe Benefits (for 2d)					$203	$205
C. **Total Salaries, Wages and Fringe Benefits**					$7,743	$7,855
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$1,000	$500
F. Travel - Domestic (*Including Canada*)					$1,500	$2,000
G. Other Direct Costs					$203	$77
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$10,446	$10,432
TOTAL PROJECT COSTS					$20,878	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR PURDUE UNIVERSITY

A. **Salaries and Wages.** Because of the limited funds allocated to this project, a Graduate Student (0.25 FTE) will be partially funded and the labor requirements supplemented with a Prebaccalaureate Student (0.50 FTE). Responsibilities of the students will be acquisition of broodstock, maintenance during the winter, pond fertilization, stocking juveniles, water quality monitoring, feeding and harvesting.

E. **Materials and Supplies.** We anticipate needing new pond liners prior to initiation of these studies. Additional funds reflect costs of feeds, water quality monitoring chemicals and costs of crayfish.

F. **Travel.** These funds will be used to attend Work Group meetings in both years, and the International Association of Astacology Annual Meeting in 1994 to disseminate our research results. A site for that meeting has not be chosen yet and may be foreign travel.

G. **Other Direct Costs.** These funds will be used to contact Work Group members and apprise the NCRAC of our progress.

PROPOSED PROJECT BUDGET FOR
KANSAS STATE UNIVERSITY (KSU)

(Klaassen)

Objectives 1-3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.05	1	0.05	0	0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students						
d. Prebaccalaureate Students	1	0.25	1	0.25	$4,000	$5,000
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$4,000	$5,000
B. Fringe Benefits (for 2d)					$54	$68
C. **Total Salaries, Wages and Fringe Benefits**					$4,054	$5,068
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$2,000	$1,000
F. Travel - Domestic (*Including Canada*)					$1,000	$1,000
G. Other Direct Costs					$500	$500
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$7,554	$7,568
TOTAL PROJECT COSTS					$15,122	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR KANSAS STATE UNIVERSITY

A. Salaries and Wages. A Graduate Student (0.25 FTE) will assist in experiments conducted at the pond research facility.

F. Travel. Travel costs to and from pond research facility and to Work Group meeting.

G. Other Direct Costs. Telecommunications, repairs, parts and maintenance, photocopying and duplication, and postage/freight.

PROPOSED PROJECT BUDGET FOR
SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE (SIUC)

(Sheehan)

Objectives 1-3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.05	1	0.05	0	0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.25	1	0.25	$5,457	$5,457
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$5,457	$5,457
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$5,457	$5,457
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$500	$500
F. Travel - Domestic (*Including Canada*)					$643	$643
G. Other Direct Costs					$400	$400
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$7,000	$7,000
TOTAL PROJECT COSTS					$14,000	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE

A. Salaries and Wages. A Graduate Student (0.25 FTE) will assist in experiments conducted at the pond research facility.

F. Travel. Travel costs to and from pond research facility and to Work Group meeting.

G. Other Direct Costs. Telecommunications, repairs, parts and maintenance, photocopying and duplication, and postage/freight.

CULTURE OF CRAYFISH IN THE NORTH CENTRAL REGION

Budget Summary for Each Participating Institution at $25.0K for the First Year

	Purdue	KSU	SIUC	TOTALS
Total Salaries and Wages	$7,540	$4,000	$5,457	$16,997
Fringe Benefits	$203	$54	$0	$257
Total Salaries, Wages and Benefits	$7,743	$4,054	$5,457	$17,254
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$1,000	$2,000	$500	$3,500
Travel	$1,500	$1,000	$643	$3,143
Other Direct Costs	$203	$500	$400	$1,103
TOTAL PROJECT COSTS	**$10,446**	**$7,554**	**$7,000**	**$25,000**

Budget Summary for Each Participating Institution at $25.0K for the Second Year

	Purdue	KSU	SIUC	TOTALS
Total Salaries and Wages	$7,650	$5,000	$5,457	$18,107
Fringe Benefits	$205	$68	$0	$273
Total Salaries, Wages and Benefits	$7,855	$5,068	$5,457	$18,380
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$500	$1,000	$500	$2,000
Travel	$2,000	$1,000	$643	$3,643
Other Direct Costs	$77	$500	$400	$977
TOTAL PROJECT COSTS	**$10,432**	**$7,568**	**$7,000**	**$25,000**

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

Institution/Item		Year 1	Year 2
Purdue University			
Salaries and Benefits: SY @ 0.05 FTE		$4,500	$5,200
Supplies, Expenses, and Equipment		$8,000	$6,000
	Total	$12,500	$11,200
Kansas State University			
Salaries and Benefits: SY @ 0.10 FTE		$4,779	$5,250
Supplies, Expenses, and Equipment		$6,000	$6,000
	Total	$10,779	$11,250
Southern Illinois University-Carbondale			
Salaries and Benefits: SY @ 0.10 FTE		$3,080	$3,080
Waiver of Overhead		$3,080	$3,080
	Total	$6,160	$6,160
	Total per Year	$29,439	$28,610
	GRAND TOTAL	**$58,049**	

[1]Since cost sharing is not a legal requirement institutions do not need to maintain documentation.

SCHEDULE FOR COMPLETION OF OBJECTIVES

Objective 1: Completed in Year 1.

Objective 2: Completed in Year 1.

Objective 3: Initiated in Year 1 and completed in Year 2.

LIST OF PRINCIPAL INVESTIGATORS

Paul B. Brown, Purdue University

Harold E. Klaassen, Kansas State University

Robert J. Sheehan, Southern Illinois University-Carbondale

VITA

Paul B. Brown
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EDUCATION

B.S. University of Tennessee, 1981
M.S. University of Tennessee, 1983
Ph.D. Texas A&M University, 1987

POSITIONS

Assistant Professor, Department of Forestry and Natural Resources, Purdue University (1989-present)
Assistant Professional Scientist/Field Station Director, Illinois Natural History Survey (1987-1989)
Research Associate, Texas A&M University (1986-1987)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Membership Concerns Committee (National) 1985-present; Walleye Technical Committee; Fish Culture Section 1985-present; Walleye Technical Committee (North Central Division) 1988-present, Fish Culture Section, Indiana Chapter
World Aquaculture Society
International Association of Astacology
American Institute of Fishery Research Biologists
American Association for the Advancement of Science
Sigma Xi, Gamma Sigma Delta

SELECTED PUBLICATIONS

Brown, P. B., M. L. Hooe, P. Tazik, and W. G. Blythe. 1990. Consumption and apparent dry matter digestibility of aquatic macrophytes by male and female crayfish (*Orconectes virilis*). Aquaculture 89:55-64.

Brown, P. B., M. L. Hooe, and W. G. Blythe. 1990. Preliminary evaluation of production strategies and forages for *Orconectes virilis*, the northern or fantail crayfish. Journal of the World Aquaculture Society 21:53-58.

Brown, P. B., A. Emery, A. L. Lawrence, and E. H. Robinson. 1989. Digestible energy values for red swamp crayfish and evaluation of dietary associative effects in practical feeds. Journal of the World Aquaculture Society 20:122-126.

Brown, P. B., M. L. Hooe, and D. H. Buck. 1989. Preliminary evaluation of baits and traps for harvesting orconectid crayfish from earthen ponds. Journal of the World Aquaculture Society 20:208-213.

Robinson, E.H., D. LaBomascus, P.B. Brown, and T.L. Linton. 1987. Dietary calcium and phosphorus requiremnts of *Oreochromis aureus* reared in calcium-free water. Aquaculture 64:267-276.

Hubbard, D.M., E.H. Robinson, P.B. Brown, and W.H. Daniels. 1986. Optimum ratio of dietary protein to energy for red crayfish (*Procambarus clarkii*). Progressive Fish-Culturist 48:233-237.

VITA

Harold E. Klaassen
Associate Professor of
Fisheries Biology
Kansas State University
Division of Biology, Ackert Hall
Manhattan, Kansas 66506
Phone: (913) 532-6654 or 6615

EDUCATION

B.A. Tabor College, Hillsboro, Kansas, 1957
M.S. Kansas State University, 1959
Ph.D. University of Washington, 1967

POSITIONS

Associate Professor, Kansas State University (1976-present)
Assistant Professor, Kansas State University (1967-1976)
Research Ichthyologist, Kansas Agricultural Experiment Station (1967-present)
Pre-doctoral Associate, University of Washington (1965-1966)
Research Assistant, University of Washington (1960-1965)
Fishery Biologist, University of Washington (1959-1960)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Secretary-Treasurer, North Central Division, 1981-1985; President, North Central Division, 1987-1988; Executive Committee, 1986-1988
Kansas Chapter of the American Fisheries Society: Charter President - 1975 and Executive Committee - 1975-76
World Aquaculture Society
Kansas Academy of Science
Kansas Commercial Fish Growers Association, Bd. of Dir., 1981-84, 1987-90

SELECTED PUBLICATIONS

Nilson, E.B., and H.E. Klaassen. 1988. Aquatic plants and their control, 2nd edition. Cooperative Extension Service, Kansas State University, Manhattan.

Gabelhouse, D.W., R.L. Hager, and H.E. Klaassen. 1987. Producing fish and wildlife from Kansas ponds, 2nd edition. Kansas Department of Wildlife and Parks, Pratt.

Klaassen, H.E., and A.M. Kado. 1979. Distribution and retention of atrazine and carbofuran in farm pond ecosystems. Archives of Environmental Contamination and Toxicology 8(3):345-353.

Klaassen, H.E., and A.H. Townsend. 1974. Age and growth of the channel catfish in Tuttle Creek Reservoir, Kansas. Transactions of the Kansas Academy of Science 76(3):248-253.

Klaassen, H.E., and G.R. Marzolf. 1971. Relationship between distributions of benthic insects and bottom-feeding fishes in Tuttle Creek Reservoir. Pages 385-395 *in* G.E. Hall, editor. Reservoir Fisheries and Limnology. American Fisheries Society Special Publication No. 8. Bethesda.

VITA

Robert J. Sheehan
Assistant Director, Cooperative Fisheries Research Lab and
Associate Professor, Department of Zoology
Southern Illinois University
Carbondale, IL 62901

Phone: (618) 453-6089
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EDUCATION

B.S. Northeastern Illinois University 1973
M.A. Southern Illinois University 1976
Ph.D. Southern Illinois University 1984

POSITIONS

Associate Professor, Department of Zoology, Southern Illinois University, Carbondale (1992-present)
Assistant Professor, Department of Zoology, Southern Illinois University, Carbondale (1986-1992)
Assistant Professor, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University (1983-1986)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Early Life History, Exotic Fishes, Fish Culture, Fisheries Educators, and Water Quality Sections

SELECTED PUBLICATIONS

Krum, H.N. and R.J. Sheehan. In Press. Development of a magnetic activity-detection system. Animal Behaviour.

Sheehan, R.J., P.S. Wills, and W.T. Davin. 1991. Crayfish production: a promising enterprise for the Midwest. Pages 219-225 *in* Proceedings of the North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991. Michigan Department of Natural Resources, Wolf Lake Fish Hatchery, Mattawan, Michigan.

Sheehan, R.J., L.R. Bodensteiner, W.M. Lewis, D.E. Logsdon, and S.D. Scherck. 1990. Long-term survival and swimming performance of young of the year fishes at low temperatures: Links between physiological capacity and winter habitat requirements. Pages 98-108 *in* R. Sauer, editor. Proceedings of the restoration of midwestern stream habitat symposium, rivers and streams technical committee, North-Central Division, American Fisheries Society, Minneapolis, Minnesota, December 4-5, 1990.

Sheehan, R.J., R.J. Neves, and H.E. Kitchel. 1989. Fate of freshwater mussels transplanted to formerly polluted reaches of the Clinch and North Fork Holston Rivers, Virginia. Journal of Freshwater Ecology 5:139-149.

Helfrich, L.A., R.J. Sheehan, and J.S. Odenkirk. 1986. Fishing for sale: fee-fishing opportunities in Virginia. Virginia Cooperative Extensive Service Publication 420-898.

Sheehan, R.J., and W.M. Lewis. 1986. Relationships between the toxicity of aqueous ammonia solutions, pH, ammonia salt formulations, and water balance in channel catfish fingerlings. Transactions of the American Fisheries Society. 115:891-899.

COLLABORATORS

Paul Brown (Purdue University), Robert Sheehan (Southern Illinois University), and Harold Klaassen (Kansas State University) will be primarily responsible for conducting the research, but have commitments from other collaborators as well. Those include Jeff Gunderson (Minnesota Sea Grant Program) who has been conducting a survey of crayfish aquaculture in the North Central Region, Robert Wilkinson (Southwest Missouri State University) who has a supply of *O. longidigitus* in culture ponds and has agreed to supply some of those animals for comparative production studies, and Carl Richards (University of Minnesota-Duluth), who has agreed to supply *O. immunis* from a northern population for comparison with those from the southern portion of the region.