BRIEF HISTORY OF RED CRAWFISH CULTURE

The origin of crawfish culture can be traced back to the late 1700s when plantation gardeners cultured the tasty animals in small ponds as a special delight for their employers. Later the displaced French Acadian farmers found that crawfish were an excellent lagniappe (bonus) crop. As rice farmers, Acadians would flood their fields during the fall and winter months to attract waterfowl for hunting and to level the bottoms. Crawfish would then move quickly into the predator-free ponds and thrive. Thus, when the ponds were drained in the spring, the farmers actually had a bonus crop, or lagniappe.

In the early 1930s, Percy Viosca, a leading Louisiana naturalist, published recommendations for culturing crawfish in ponds. This led to a gradual interest and increase in the culture of crawfish. His interest encouraged others to develop a real industry. The greatest growth in crawfish culture took place after Viosca’s death, in the late 1960s. Since then, many prominent scientists have developed techniques and performed much of the needed basic research in the area of crawfish culture.

Currently about 125,000 (1990) acres are devoted to crawfish culture in Louisiana alone. Growth of the industry is indicated on the accompanying table. As many crawfish are harvested from ditches, bar-pits, and swamps, accurate records pertaining to the total harvest are nonexistent. However, it is estimated that from crawfish ponds in Louisiana about 500 pounds per acre per year are harvested, a total of more than 62,500,000 pounds of crawfish. The expansion of the crawfish industry seems to have leveled off temporarily. But it is believed that the potential of more than 280,000 acres could be developed. This area would probably produce an annual yield of well over 140 million pounds without improvement of current cultural practices.

The culture of red crawfish is expanding to other areas. Expansion into southern Texas was to be expected in view of the extensive culture of rice there and the presence there of the Louisiana Acadian culture. About 6,000 acres are now devoted to crawfish culture in Texas. Elsewhere, Florida has about 2,000 acres and South Carolina has about 1,200 acres. The states of Arkansas, Mississippi, Georgia, North Carolina, and Maryland have identifiable crawfish culture ponds with acreage in the 100-500 range.

LEGAL ASPECTS OF CRAWFISH FARMING

Many prospective crawfish farmers are not aware that there are a number of laws and regulations that apply to crawfish farming. Various subjects that should be considered include: (1) definition of fish farming and a fish farming plan; (2) permit to begin or continue fish farming; (3) permit to drain fish ponds; (4) use of chemicals; (5) processing; and (6) theft. Each local (municipal and parish or county) and state governmental unit differs with respect to the nature of its regulation of aquaculture operations. In addition, there are a number of federal laws and regulations that apply to all areas of the country. An excellent guide for researching legal aspects of aquaculture is the Louisiana Agricultural Experiment Station Bulletin No. 689, “Some Legal Aspects of Catfish and Crawfish Farming in Louisiana: A Case Study,” by Elizabeth Williams, Frank S. Craig III, and James W. Avault Jr. These can be obtained from Louisiana Cooperative Extension Service, Knapp Hall, LSU, Baton Rouge, La. 70803.

Though this bulletin is somewhat dated now, it is still a good guide for those contemplating crawfish culture. Your local Cooperative Extension Service office can assist you in obtaining the most recent legal information available on farming crawfish.

Extension services can also be helpful in informing interested persons of the current status of pertinent laws and regulations. It is important to caution readers that many states have laws that require permits to import nonnative species for culture purposes and often ban such importation.

CRAWFISH CULTURE

The red crawfish is cultured by establishing sustaining populations within shallow (12- to 30-inch) earthen ponds. The basic pattern, as practiced in Louisiana, involves stocking with adult crawfish in late spring, draining in early summer, reflooding in early fall, and harvesting when
numbers justify the effort—as early as November or as late as March. This wet/dry cycle closely simulates the natural hydrological cycle in southern Louisiana.

Holdover adult crawfish and juvenile crawfish (those that had not reached maturity when ponds were drained) compose the initial harvests. The majority of the young-of-the-year crawfish enter the pond in several groups, or waves, of recruitment from the time that the pond is flooded until mid-winter. Each specific group of crawfish may be referred to as an age class. The young-of-the-year age classes will produce the bulk of the crop. Some red crawfish will spawn in ponds in late spring or mid-summer. (Unless water is present, young crawfish from such hatches remain in burrows.) Numbers are not great, and absolute growth is apparently retarded by warm water temperatures (85-90°F) even though the molting rate is rapid. Growth is also slowed in the winter when temperatures fall below 50-60°F.

In regions like Texas and South Carolina, with climates similar to Louisiana's, _Procambarus clarkii_ has been cultured with great success by following the wet/dry cycle employed in Louisiana. In colder regions such as Arkansas and Missouri, growth is greatly retarded by extended low temperatures during the winter. This prevents harvest until middle to late spring.

We know of successful attempts to cultivate _P. clarkii_ using Louisiana methods in Santo Domingo and at higher elevations in Zambia. Thus, these crawfish can be grown in tropical regions.

At present, the wet/dry cycle seems essential for several reasons: (1) it serves to prevent the establishment of predacious fish populations; (2) it phases reproductive activity of the crawfish; (3) it permits the growth of vegetation that will serve as food and substrate; and (4) it permits the cultivation of rice as a grain product.

Most aquaculture involves the stocking of known numbers of young fish or shellfish with total harvest after a period of growth. Yields can be easily predicted. In red crawfish culture, there is no simple relationship between adult crawfish stocked and yield. The artificial production of young red crawfish is possible and is practiced by several hatcheries in California. With current economic constraints, yields are adequate for self-sustaining systems. There are many unexplained pond failures. Currently, all that can be done is to advise the owner to restock the following spring, assuming that the pond will support crawfish. As profit margins increase, there will be increased emphasis on maximizing production to include stocking of young to supplement the natural reproduction and to add supplemental feeds to augment food that is grown in the pond. Prior to pond construction in agricultural areas, soils should be analyzed for residual pesticide levels. Failure to do so could jeopardize a major investment.

**ECONOMICS**

Can one make money in crawfish farming? Certainly, or there would be far fewer than 125,000 acres of land devoted to crawfish farming in Louisiana alone. However, precise economic projections depend on each situation. For example, is the land already owned by the farmer, is it to be leased, or is it to be bought? Will the ponds be built by the owner using his own equipment and labor, by a friend or relative who charges less than a contractor, or by a contractor? To whom will the crawfish be sold? Who will harvest the pond—farm laborers, family, or fishermen who are paid either a flat wage or a percentage (usually half) of the harvest? How large a pond will be built? These and a number of other questions must be considered before one enters the business.

The most complete economic guide to crawfish farming currently available was written by Dr. Lynn E. Dellenberger, entitled _Estimated Investment Requirements, Production Costs, and Break-even Prices for Crawfish in Louisiana, 1987_ (see References for complete citation).

Economies of scale are very clear. That is, costs per acre are significantly reduced as the size of an operation increases. Costs are also lower when crawfish and rice are double-cropped in the same year. Dellenberger and his coworkers compared the costs of producing crawfish as one crop with the costs of production as a double crop in two areas of Louisiana. Table 14a shows investment costs per acre for crawfish production, as well as annual operating costs for ponds with crawfish alone or in combination with rice. Tables 14b and c show break-even prices for these two situations at different production levels. Notice that the costs of production are clearly lower when crawfish and rice are grown in the same pond(s).

Prices paid for crawfish have varied dramatically in the past several years. The main problem is competition within the state from wild basin crawfish. When these are abundant, prices often fall to or near the break-even level. Basin crawfish become abundant in mid-spring, and prices reach their lowest levels then. They are at their maximum in early season. In past years, most ponds

<table>
<thead>
<tr>
<th>Pond Size</th>
<th>Investment Cost/Acre*</th>
<th>Annual Operating Costs</th>
<th>Crawfish &amp; Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 acres</td>
<td>$5124</td>
<td>$1102</td>
<td>$1047</td>
</tr>
<tr>
<td>20 acres</td>
<td>2775</td>
<td>762</td>
<td>659</td>
</tr>
<tr>
<td>40 acres</td>
<td>1639</td>
<td>604</td>
<td>533</td>
</tr>
<tr>
<td>2 x 40 acres</td>
<td>1068</td>
<td>523</td>
<td>436</td>
</tr>
</tbody>
</table>

*Land ownership is assumed.


<table>
<thead>
<tr>
<th>Pond Size</th>
<th>Production Level Lbs/Acre</th>
<th>700</th>
<th>900</th>
<th>1100</th>
<th>1300</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 acres</td>
<td>$1.90</td>
<td>$1.48</td>
<td>$1.21</td>
<td>$1.02</td>
<td>$0.89</td>
<td></td>
</tr>
<tr>
<td>20 acres</td>
<td>1.25</td>
<td>0.97</td>
<td>0.79</td>
<td>0.68</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>40 acres</td>
<td>0.94</td>
<td>0.73</td>
<td>0.65</td>
<td>0.51</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td>2 x 40 acres</td>
<td>0.79</td>
<td>0.61</td>
<td>0.50</td>
<td>0.43</td>
<td>0.37</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Pond Size</th>
<th>Production Level Lbs/Acre</th>
<th>700</th>
<th>900</th>
<th>1100</th>
<th>1300</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 acres</td>
<td>$1.79</td>
<td>$1.39</td>
<td>$1.14</td>
<td>$0.96</td>
<td>$0.83</td>
<td></td>
</tr>
<tr>
<td>20 acres</td>
<td>1.12</td>
<td>0.87</td>
<td>0.71</td>
<td>0.60</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>40 acres</td>
<td>0.83</td>
<td>0.65</td>
<td>0.53</td>
<td>0.45</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td>2 x 40 acres</td>
<td>0.66</td>
<td>0.53</td>
<td>0.43</td>
<td>0.36</td>
<td>0.32</td>
<td></td>
</tr>
</tbody>
</table>

generated the bulk of their revenue over the winter into early spring when prices held at higher levels. However, as the industry entered the 1990s, prices have tended to fall to a season long level. To be sure, larger crawfish have commanded good prices but smaller, peeler crawfish, the bulk of the crop, have not. As a result, average prices have been so low that few farmers, according to the tables presented above, have operated profitable farms.

Farmers located 100 miles or more away from the Atchafalaya basin do not suffer as greatly from competition. Crawfish farmers in Texas, Mississippi, and South Carolina report prices roughly twice those obtained in Louisiana, as there is little competition from native crawfishes in those states.

The crawfish farming sector of Louisiana’s economy currently awaits marketing and production improvement to promote significant expansion (1980). A major target for improvement is the cost of harvesting. Over 60 percent of all operating costs are associated with harvesting, so significant gains in harvest efficiency are essential to the long-term profitability of the industry. Like farmers, processors and marketers face high operating costs, with 40 percent claimed by piece-rate labor. Means must eventually be developed that will bring this cost down to the competitive levels set by other seafood products. Clearly, then, it is an oversimplification to attribute industry problems to either producers or processors.

The secret to success in crawfish culture is good management. Anyone who has ever raised a garden knows that the individual who takes the best care of the garden will produce the highest yields. Aquaculturists who visit their ponds irregularly but expect a crop in the spring are generally disappointed. Conscientious pond owners will know when they will have limited crops before they purchase bait and traps.

A checklist is included in Appendix E. This will be a helpful guide for prospective crawfish culturists.

PONDS

Types

There are two broad categories of crawfish ponds, open and wooded. Most crawfish specialists would then divide these into two subcategories of wooded ponds and four subcategories of open ponds. These depend on the pond soil and the dominant vegetation. These, in turn, influence the general appearance of the water. The accompanying descriptive table is largely derived from a report on pond types written by Donald Gooch, a well-known Louisiana crawfish specialist (Table 15).

No single classification suffices to meet all possible variations. For example, open agricultural ponds take on the characteristics of open highland ponds if crops are not planted each year. Wooded ponds may be partially cleared, so that portions are “open.” However, the preceding system does provide a convenient, functional means to separate pond types. Certainly, modifications are sure to arise. Open ponds of 10 to 20 acres are the most commonly encountered ponds in south Louisiana. A few wooded ponds may approach 1,000 acres in size.

It is common to find reference made to wooded, open, and rice field ponds. This is not a very precise system, which is why we prefer to use the classifications presented in Table 15.
Table 15. Subcategories of wooded and open Louisiana crawfish ponds.

<table>
<thead>
<tr>
<th>Dominant Vegetation</th>
<th>Water Color</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>WOODED Swampland</td>
<td>Usually clear.</td>
<td>Lowland, subject to annual flooding with high organic content in soil. Oxygen problems common.</td>
</tr>
<tr>
<td>Highland</td>
<td>Usually clear but can become muddy late in season.</td>
<td>Well-drained highlands without high organic content in soil. Oxygen problems common.</td>
</tr>
<tr>
<td>OPEN Agricultural</td>
<td>Becomes very turbid in spring.</td>
<td>Crops are grown during summer and harvested before pond is flooded in fall.</td>
</tr>
<tr>
<td>Marsh</td>
<td>Usually clear.</td>
<td>Lowland subject to annual flooding with high organic content in soil. Oxygen problems common.</td>
</tr>
<tr>
<td>Highland</td>
<td>Becomes turbid in spring.</td>
<td>Either cleared highland ponds or agricultural land that is not rotated between crawfish and crops in same year.</td>
</tr>
<tr>
<td>Swampland</td>
<td>Tends to be clear but can become turbid in spring.</td>
<td>This is wooded swamppond pond that has been cleared.</td>
</tr>
</tbody>
</table>

*It has become increasingly popular in recent years to sow rice and/or millet in all varieties of crawfish ponds. Coverage is highly variable and the grain is not harvested.

**Site Selection**

Advisory agencies advocate paid construction in areas with heavy clay or silty clay soils—that is, areas that will hold water. Areas suitable for rice production should also be suitable for crawfish if there is no residual pesticide contamination. However, success is generally assured if the area already has a resident population of red swamp crawfish and/or white river crawfish. Checking drainage ditches and canals for crawfish and looking for burrows is advisable in selecting a site for a pond.

**Construction**

Crawfish ponds are normally built with a minimum depth of 12 inches and a maximum depth of 30 inches. Deeper ponds are needed in climates with greater temperature variations than in the southeastern United States. The levee crown should be at least 12 inches above the full water level. The slope on the inside of the main levee should be 3:1 and on the outside of the levee, 2:1. Levees should be wide enough to permit vehicular traffic. The earth must have enough clay in it to hold water. Sandy soils are to be avoided. It is preferable that the entire pond be drained during the summer. If there are borrow (bar) pits inside the pond, it may be impractical to drain them. Water levels inside the pits should be kept as low as possible.

Ponds are now built with inner baffle levees to insure thorough mixing and flushing of water. These are located 150-200 feet apart and are open at opposite ends (Fig. 60).

It is preferable that a pond be cleared of all trees and brush. If this is too costly, as much clearing as is possible should be done. Clearing should be engineered to facilitate water flow from the source to the drain.

Major levees must be well built if problems from crawfish and rodent burrows are to be avoided. It is not unusual to see ponds with narrow, inexpensive levees that fail because the owner cannot keep water in them.

![Baffle levee in crawfish pond. Photo, J. Huner.](image)
Construction is much easier on existing agricultural lands. Rice fields are especially convenient, as established levee systems are generally available. (Note: we refer here to outer ring levees; inner or contour levees are too low to hold water at necessary depths.)

Wooded ponds and open marsh ponds are notoriously poor producers because of water quality problems. Such areas should be avoided in selecting a pond site. Also, if such areas are designated as “wetlands” by the U.S. Army Corps of Engineers, a permit will be required to construct a pond. Permits are becoming progressively harder to secure.

We do not advocate pond construction in wooded areas or in marshes. Persons considering such areas should be prepared to accept poor yields and constant management problems.

One often overlooked factor in pond siting is soil fertility. There appears to be a direct relationship between pond fertility and production. When fertile topsoil is removed for levee construction, the less fertile subsurface soils are left for the growth of pond cover-forage crops. Thus, where feasible, ponds should be sited in rich soils, and topsoil should be set aside and returned to the pond bottom. If this is not possible, a fertilization-liming program is advisable (see section on feeds and fertilizers).

Before actually building a pond one should consult the county extension service and U.S. Soil Conservation Service for assistance. In addition, the U.S. Soil Conservation Service will survey the site and advise on the feasibility of building a pond. They also prepare pond construction specifications, including pump requirements and drain sizes, which are then relayed to the builder.

WATER MANAGEMENT

Control

A pumping system is needed that can fill and/or flush the pond in four days. Rainfall will reduce pumping, but one should not depend on it when designing pumping facilities. Drains must be large enough to remove rain waters before they overflow the levees. Filter systems are necessary on both inlets and drains to prevent entry of predaceous fish. Baffles will serve to increase oxygen in incoming waters (Fig. 61).

Flooding

If pond flooding begins in early September and ends in early October, there should be 2 to 3 1/2 months of warm weather for crawfish growth prior to December when water temperatures fall below 50 to 55°F. An objection to flooding earlier is that vegetation will decompose so rapidly that it will create anaerobic, oxygen-deficient waters. Filling ponds in September can insure a November/December crop if water quality is carefully controlled and early hatches are successful. Flooding ponds after mid-October invariably reduces the pre-winter growing period and may lead to high mortality of young crawfish in the burrows.

The Louisiana Cooperative Extension Service generally recommends that ponds not be filled until daytime temperatures are in the low to mid eighties (°F) and nighttime temperatures are in the low to mid seventies (°F). This usually occurs from early to mid October.

One major advantage of early flooding is that abundant crawfish yields will begin six to eight weeks before prices are driven down by the harvest of wild crawfish.

Don Gooch has long been an advocate of digging burrows to check for the presence of young crawfish before flooding a pond. There is obvious merit to this undertaking, as it is senseless to flood ponds before large numbers of young are ready to enter open water. However, the dates given above generally seem to coincide with this period. Checking burrows represents a commitment to good management and is encouraged if the time is available.

Some people have successfully used a hose to suck water containing small crawfish from burrows. This technique almost completely eliminates

Fig. 61. Water inlet with fish screen and aeration baffle. Such systems are not as efficient as aeration towers. Photo: J. Lueker.
the need for burrow excavation but does require some skill.

There is no real information about pond flooding dates other than the ones presented above. In northern climates, it is probably best to keep water in a pond during the winter, especially if the frost line extends deep enough to freeze burrows and kill resident crawfish. Even in Louisiana, fish ponds that have been dry through the winter produce fair crops of crawfish in July after being filled in May, but they contained well-established crawfish populations.

Draining

In ponds used only for crawfish culture, draining should begin toward the end of May and be completed by the end of June. Slow draining encourages burrowing and reduces predation by birds and mammals.

In ponds used for raising rice and crawfish in the same year, draining should be completed no earlier than the middle of May and preferably by the end of May. Earlier draining reduces the harvest of crawfish and appears to reduce the numbers of burrowed broodstock for the next season. Rice production, of course, is reduced because the late planting date subjects the rice to adverse growing conditions; however, a compromise must be reached if crawfish and rice are both harvested successfully. In Texas some farmers are satisfied with results obtained when ponds are drained in April and planted with rice by the first of May.

No research has been conducted to determine the best time to drain ponds. It is very clear, however, that they must be drained to kill predators and permit growth of vegetation. Whether this draining has to correspond to the summer months is not well established. It is obviously not possible in northern states where summer is the growing season.

Water Quality

Crawfish can live in almost any fresh or slightly brackish water (see section on ecology). The primary water quality factor limiting crawfish pond culture is dissolved oxygen. When emergent plants and forage plants like rice and sorghum die back in the fall, they rapidly begin to decompose. This occurs again in the spring as water begins to warm. Often the pond water may turn black when much of the available oxygen is used up by the decomposers. There are ways to prevent low oxygen concentrations. Culturists can periodically mow or disk the vegetation during the summer. Leaving it in the field to dry slows down the decomposition process. However, standing vegetation is necessary for maximum crawfish growth, so enough time must be left before flooding for the vegetation to grow at least to a level above the initial flood. Otherwise, it is likely to die when covered with water.

A more effective way of improving water quality is to add inner, low levees to force fresh water to all parts of the pond. This can be done in addition to cutting vegetation periodically.

Most farmers cut or disk lanes through vegetation before flooding ponds. These facilitate harvesting and can also be effective in circulating water. Because water follows the path of least resistance, continuous lanes take oxygenated, fresh water away from vegetated areas that need it most. Therefore, lanes should be arranged so that they are discontinuous and force the water into the standing vegetation as it moves through the pond.

Ponds are now constructed with recirculation systems. Deoxygenated water leaves the pond and returns to the pump via a ring canal or ditch. It is reoxygenated as it passes into the pond through an aerator baffle that consists of several screens of successively smaller mesh from 1 inch to 1/4 inch. Once-through systems are most effective, as recirculated water loses oxygen more quickly to dissolved, decomposing organic matter, but they are more expensive.

Oxygen levels below 2 ppm can be fatal, and ponds should be monitored with oxygen kits or oxygen meters. Several factors should be remembered in checking the DO (dissolved oxygen). Early in the morning, the DO level is usually low. This reduction is caused by the microscopic plants (phytoplankton) that live in the water. These tiny organisms produce oxygen in the presence of sunlight; thus, high levels of oxygen result during the day when the oxygen is being released. At night, green plants must use the oxygen for metabolism; therefore, oxygen levels are lower at night than during the day when phytoplankton produce oxygen. When crawfish are found near the surface clinging to vegetation, the pond is low in oxygen.

To insure minimal dissolved oxygen concentrations, one should begin to flush a pond two weeks after it is flooded. This requires a pumping rate of about 100 gallons per minute per acre for an 18-inch water depth. This should continue until temperatures fall below 65°F (the point at which microbial decomposition of vegetation declines markedly). Additional pumping may be needed as water temperatures rise above 65°F in the spring.
economic factor in crawfish culture. Control of the amounts of vegetation in ponds is critical to insure good water quality and crawfish production. Recent studies suggest that the maximum amount of vegetation, in terms of standing dry weight, that should be present when a pond is flooded is roughly two pounds per square yard (8,800 pounds per acre). Higher levels will almost surely lead to oxygen depletion without high pumping rates. This amount of biomass has, under carefully managed conditions, generated crops of 800-1,500 pounds of red crawfish per acre when crawfish have successfully reproduced and predacious fishes have been controlled.

Methods to reduce pumping costs have been developed. If ponds are filled to depths of 6-10 inches rather than 18 inches, pumping rates of 50-60 gallons per minute are adequate to flush ponds in four days. Water levels are then raised after the weather cools. Furthermore, planting forage crops of rice or hybrid sorghum-sudangrass will insure that vegetation will remain green when the ponds are flooded and that decomposition rates will be greatly reduced.

Use of some semi-aquatic vegetation to provide cover and access to the surface is yet another method to reduce oxygen needs. Semi-aquatic plants like rice and alligator weed are excellent for this because they do not die back after they are flooded. Alligator weed must be carefully controlled because it is so prolific that it can take over a pond. A mixture of semi-aquatic vegetation and annual grasses and sedges is preferable to either group alone (see feeds and fertilization section).

Research has shown that the paddlewheel aerators used in catfish ponds can be effective in aerating and circulating/recirculating water in crawfish ponds. Ponds must be properly engineered with baffle levees and bottom grades.

**Turbid Water**

There is no doubt that turbid water reduces problems associated with filamentous algae and may reduce drastic daily oxygen changes in ponds. However, turbid water is usually associated with little or no emergent vegetation or is obtained by cutting the vegetation before pond flooding. The value of that vegetation is too great to dismiss lightly although it has yet to be fully assessed. It has been our experience that ponds with abundant crawfish eventually become turbid, and ponds without them are not helped by activities designed to increase their turbidity. Turbidity, especially in early fall, is an indication of "overpopulation" and
eventual stunting problems. Further studies on the subject of pond turbidity and its value are clearly needed.

**Sources of Water**

The best water source is a well. Such water is normally free of pesticides and fish, and it may be high in iron content. Where water enters ponds or irrigation ditches, a reddish-brown scum may develop. This occurs where there is too much iron in the water. In such cases, the water should be allowed to run through a settling pond or across the levee before entering the pond, or should be aerated in some way. The iron is bad because it uses up free oxygen in the water. The scum can clog crawfish gills as well as be toxic to them. Most well water will be low in oxygen and should be splashed against some sort of flat surface to oxygenate it as it enters the pond. Well water may also be low in dissolved minerals. If alkalinity or hardness is low, the pond bottom may have to be limed (see feeds and fertilization section). Certainly a complete water analysis should be obtained before well water is used for agriculture.

Surface waters offer all sorts of perils, but they are often the only source of water. Problems that must be guarded against include the following: (1) predaceous fishes can gain access to the pond if proper filtration systems are not employed; (2) ponds are first flooded when surface waters are normally low, and the supply may not be adequate to fill the pond rapidly; (3) surface waters are often low in dissolved oxygen in the fall; and (4) surface waters may be polluted by pesticides from application of such materials on field crops in the area. A crawfish farmer should keep track of what his neighbors are doing and watch the water source for the presence of dead and dying fish.

**Pesticides**

Herman H. Jarboe of the Louisiana State University Agricultural Center has conducted much research into the toxicity of various pesticides to the red swamp crawfish. This section depends heavily on Mr. Jarboe's work.

Crawfish and insects are both arthropods and share very similar physiology and appearance. Thus, it is not surprising to discover that crawfish are generally more susceptible to insecticides than any other pesticides. Crawfish appear to be most sensitive to the synthetic pyrethroid insecticides and those with chlorinated hydrocarbons. The trade names for several synthetic pyrethroid insecticides are Ambush (Permethrin) and Scourge II (Resmethrin + Piperonyl Butoxide). Some common chlorinated hydrocarbon pesticides include Aldrin, Anofex (DDT), Dieldrin (Dieldrin), and Endrin. Chlorinated hydrocarbon insecticides are not commonly used in the U.S. because of major environmental problems. Organophosphate pesticides appear to rank second in terms of their toxicity to crawfish. Trade names for some common organophosphorous insecticides include Guthion (Azinophos Ethyl), Baytex (Fenthion), Niran M-4 (Methyl parathion), and N E-4 (Parathion). An oddity among the organophosphorous insecticides is Cythion (Malathion). It is a very effective, broad-spectrum insecticide, but its toxicity to crawfish is very low.

In general, herbicides are much less toxic to crawfish than insecticides. The exception to this generalization is Gramoxone (Paraquat) which is moderately toxic to crawfish. The application of herbicides for weed control is usually done when there is no water in the pond, thus limiting the potential for crawfish to come in contact with these chemicals. Farmers should be aware that effective herbicides are generally persistent, with residues remaining in the soil for a long time after application. Unfortunately, there are few data regarding herbicide residues in crawfish pond mud.

Fungicides are generally the least toxic of the pesticides to which crawfish may be exposed. Fungicides are often applied directly to seeds, so unless seeds are planted in water or eaten by the crawfish, exposure to herbicides is minimal. Araxon (Araxon 70S Red) is the most lethal of the fungicides tested on crawfish to date.

It should be noted that studies of residual toxicants (pesticides and heavy metals) in wild and cultivated crawfish have shown no levels that would be dangerous to humans. Crawfish are too short-lived, apparently, to accumulate such compounds.

Various factors affect the toxicity of pesticides to crawfish, including crawfish size, water temperature, suspended matter, and pH. Smaller crawfish are generally more susceptible to pesticides. Research to date suggests that the exposure of female crawfish broodstock to pesticides has a negative impact on reproduction. Pesticide toxicity is invariably increased as temperature increases. Suspended materials, both inorganic and organic, in the water decrease the impact of pesticide toxicity by binding the pesticides and preventing them from reaching the crawfish. Pesticide toxicity is radically changed by the influence of pH. Most pesticides exist as two or more chemical substances or isomers, with unique toxicological properties. The isomers are altered by pH, thus altering the
toxicity of the pesticide in question. Several compounds, nontoxic when alone, can have significant negative impacts on crawfish populations when mixed.

Table 16 lists the relative toxicities of a number of commonly used pesticides.

**Crawfish Control Toxicants**

Crawfish are welcome visitors throughout Mississippi, Louisiana, and Texas, but are considered pests in many areas. Any of the toxic insecticides listed in Table 15 can be used to kill crawfish in open water. Another compound, Baytex, is an organophosphate pesticide. It is commonly used to kill crawfish in finfish spawning and fingerling ponds. Good control is achieved at 0.25 ppm. However, the use of this material and the insecticides listed in Table 16 is not approved by the Food and Drug Administration for most fish ponds (and presumably for crawfish ponds). Thus, prospective users of compounds that kill crawfish should check with their county agents before purchasing poisons.

Complete eradication of crawfish is never achieved, as residual brooders escape by burrowing during pesticide application periods. They may also migrate into the ponds from nearby wet areas.

Both turtles and alligators are reptiles that can prove to be nuisances in crawfish ponds. Turtles eat crawfish abdomens that protrude through the mesh of traps, especially in the spring when catches are greatest. Alligators can cause problems by burrowing into levees. They can be beneficial, however, by eating larger predaceous fishes, turtles, nutrias, and muskrats. State game and fish biologists, Soil Conservation Service biologists, and county agents can be of great assistance in dealing with alligator and turtle problems.

The use of conventional crab traps and monofilament gill nets to control turtles has shown promise. So long as crab traps extend one to three inches above the surface, turtles readily enter them and find it almost impossible to exit; they do not enter submerged crab traps. The monofilament gill nets entangle turtles as they forage about in a pond.

Recent studies have indicated that there is less turtle damage during warm weather if traps are baited with grain-based baits or cottonseed cake. The turtles are invariably attracted in greater numbers to traps baited with meat or fish.

**NUISANCE ANIMALS**

Semi-aquatic mammals such as otters, muskrats, and nutrias can become nuisances in crawfish ponds. Otters flatten baited traps, forcing crawfish tails through the mesh, and then eat the tails. An effective method to trap them is to bait a submerged hoop net with fresh fish. Leg-hold traps are not always effective, especially when a novice sets them. A rifle is effective but otters are wary animals and difficult to approach.

Ponds built in marshes and swamps or adjacent to them are havens for wildlife. Nuisance animals are especially bothersome in such ponds.

Muskrats and nutrias are vegetarians with a penchant for burrowing in pond levees. Serious levee damage can result. Trapping and shooting (usually at night) can reduce the damage and their numbers. Another control method involves the use of baits made from grain and impregnated with anticoagulant rodent poisons. The mixture is bound with paraffin. But, since the killing of fur-bearing mammals is strictly controlled in all states, local authorities should be consulted first about the proper methods to control nuisance animals.

**SUBSTRATE**

Substrate is a surface on which an organism grows or is attached. In crawfish ponds substrates are the erect stalks of vegetation. These plants are important for several reasons. First and foremost, they increase the amount of surface area available to each crawfish. Thus the number of crawfish in a given area can be much greater than if no substrate were present. A very good analogy is the building of high-rise buildings to take advantage of limited building space in cities. Substrate, itself, provides both food and a place for epiphyton to grow. The epiphyton is an important food source for crawfish (see life history section). Substrates provide protective cover from predators. Finally, substrates provide crawfish with an avenue to the surface if oxygen levels fall dangerously low. This is especially important as crawfish cannot swim well and stay at the surface like fish.

If all substrate is restricted to annual vegetation, the combined action of natural decomposition and crawfish grazing will destroy it by early April, concentrating the crawfish on the pond bottom. Semiaquatic vegetation such as alligator weed or late-planted rice does not have this same problem.

Aquaculturists who work with freshwater prawns and marine shrimps are developing artificial...
Table 16. Concentrations of pesticides (pounds active ingredient/acre foot) which will kill 50 percent of test crawfish at various time intervals. Pesticides are listed using trade names. The common name is listed in parentheses underneath the trade name.

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>LC50 (lbs. A.I./acre ft. Time Interval (hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td><strong>INSECTICIDE</strong></td>
<td></td>
</tr>
<tr>
<td>Agnotox (Trichlorfuran)</td>
<td></td>
</tr>
<tr>
<td>Aldrin (Aldrin)</td>
<td>2.2</td>
</tr>
<tr>
<td>Allesid (Methoprene)</td>
<td>0.001</td>
</tr>
<tr>
<td>Ambush (Permethrin)</td>
<td></td>
</tr>
<tr>
<td>Anoflex (CDT)</td>
<td>1.6</td>
</tr>
<tr>
<td>Arosurf (Isostearyl Alcohol)</td>
<td></td>
</tr>
<tr>
<td>Azodrin (Monocrotophos)</td>
<td>3.5</td>
</tr>
<tr>
<td>BSC-1 (Bacillus sphaericus)</td>
<td></td>
</tr>
<tr>
<td>Neide</td>
<td>215.4</td>
</tr>
<tr>
<td>Bacillus meso (Bacillus thuringiensis var. israelensis)</td>
<td>280.8</td>
</tr>
<tr>
<td>Baygon (Propoxur)</td>
<td>0.060</td>
</tr>
<tr>
<td>Baylex (Fenthion)</td>
<td>3.9</td>
</tr>
<tr>
<td>Bidrin (Dirifluzon)</td>
<td>15.1</td>
</tr>
<tr>
<td>Bux (Metakamate)</td>
<td>0.761</td>
</tr>
<tr>
<td>Cythion (Malathion)</td>
<td>133.7</td>
</tr>
<tr>
<td>Dibrom (Naied)</td>
<td>16.3</td>
</tr>
<tr>
<td>Diethiol (Dieldrin)</td>
<td>2.0</td>
</tr>
<tr>
<td>Dimecron (Phosphoridon)</td>
<td>54.4</td>
</tr>
<tr>
<td>Durban (Chlorpyrifos)</td>
<td>0.111</td>
</tr>
<tr>
<td>Dylox (Trichlorfon)</td>
<td>1.1</td>
</tr>
<tr>
<td>Endrin (Endrin)</td>
<td>0.136</td>
</tr>
<tr>
<td>Ficam (Bendiocarb)</td>
<td>15.1</td>
</tr>
<tr>
<td>Guathion (Azinphosmethyl)</td>
<td>0.272</td>
</tr>
<tr>
<td>Niram E 4 (Parathion)</td>
<td>0.229</td>
</tr>
<tr>
<td>Niram M 4 (Methyl Parathion)</td>
<td>0.156</td>
</tr>
<tr>
<td>Scourge II (Resmethrin+)</td>
<td>0.002</td>
</tr>
<tr>
<td>Pipemyl (Butoxide 1.3)</td>
<td></td>
</tr>
<tr>
<td>Sevin (Carbaryl)</td>
<td>13.6</td>
</tr>
<tr>
<td><strong>HERBICIDE</strong></td>
<td></td>
</tr>
<tr>
<td>2, 4-D (2, 4-D)</td>
<td></td>
</tr>
<tr>
<td>Basagran (Benzuron)</td>
<td>3777.3</td>
</tr>
<tr>
<td>Bolero (Thiobencarb)</td>
<td>190.7</td>
</tr>
<tr>
<td>Grampoxone (Paraquat)</td>
<td>25.1</td>
</tr>
<tr>
<td>Kinalex (Floalex Ammonium)</td>
<td>14.1</td>
</tr>
<tr>
<td>Modom (Bentox)</td>
<td>5719.1</td>
</tr>
<tr>
<td>Orkam (Malathion)</td>
<td>3638.7</td>
</tr>
<tr>
<td>Oust (Methyl Sulafuron)</td>
<td>&gt;27194.9</td>
</tr>
<tr>
<td>Roundup (Glyphosate)</td>
<td>112.3</td>
</tr>
<tr>
<td>Slam (Propanil)</td>
<td>21.5</td>
</tr>
<tr>
<td>Treflan (Treflan)</td>
<td>35.3</td>
</tr>
<tr>
<td><strong>FUNGICIDE</strong></td>
<td></td>
</tr>
<tr>
<td>Arason (Arason 70 S Red)</td>
<td>32.6</td>
</tr>
<tr>
<td>Benlate (Benomyl)</td>
<td>11.7</td>
</tr>
<tr>
<td>Kocide (Kocide SD)</td>
<td>2800.5</td>
</tr>
<tr>
<td>Orthhegeda (Capan)</td>
<td>7555.5</td>
</tr>
<tr>
<td>Viavex (Vitalax)</td>
<td>42508.3</td>
</tr>
</tbody>
</table>

To convert these values to mg/l divide the number in the table by 2.7195.
substrates for their ponds. This is also being done for crawfish ponds. Inexpensive artificial substrates may someday find their way into crawfish culture ponds.

Smaller crawfish concentrate at the edge of a pond in relatively fine grass such as bermuda grass. Bermuda grass does not die quickly after flooding. Small crawfish avoid areas where thick, heavy stemmed grasses and plants grow because there is little protective cover in such places. Thus, cutting pond edges during the summer dry period will encourage growth of grasses like bermuda grass that is preferred by the small crawfish.

**FEEDS AND FERTILIZERS**

In many aquaculture systems, artificial feeds are used to supplement the natural food supply. Formulated feeds are not used routinely in pond crawfish culture. Instead, a detritus-based ecosystem is established to provide food for the crawfish. When shallow ponds with emergent vegetation are flooded, the annual plants die back at varying rates. As they die the plant tissue is broken down by microbial action. Initially such decomposed plant material, detritus, has a very high ratio of carbon atoms to nitrogen atoms. This is important to animals that live and feed on the detritus. Plants are mostly made up of tough cellulose molecules whose building blocks are carbon atoms. Plants contain very little protein. Protein is made up of carbon and nitrogen atoms. As the detritus is attacked by unicellular decomposers (fungi, bacteria, yeasts, etc.), the carbon-nitrogen ratio falls from a high of 100:1 to a desirable low of 17:1. The decomposers need the carbon for their metabolism. The 17:1 ratio figure represents the point at which detritus will become an especially good food source for most detritivores such as the crawfish. Note: The crawfish eat the microbially enriched detritus but digest only the living layer of microbes on the surface. Remember, as the detritus is broken up, more microbes grow on it. Furthermore, surface area to volume ratio increases.

If one examines plants in ponds closely, a film of living organisms can be seen below the water line. This animal and plant assemblage dominated by plant-algae is called epiphyton or awphics and, along with microbially enriched plant detritus, is an important source of basic sustenance for crawfish. Crawfish keep this material closely grazed. Ephyton may, in fact, be the major food source in newly filled ponds where the plant base—rice, alligator weed—is still living and no detritus has begun to form.

Green plants (including the algae in epiphyton) are essential components in the diets of healthy crawfish, which have a bright yellow hepatopancreas and well-pigmented shell. The color is derived from plant pigments called carotenoids. There has been much discussion concerning the absolute nutritional value of green plants in ponds; however, it is clear that if crawfish do not have access to such plants, they will not be healthy. This is certainly one value of alligator weed, which is common in ponds dominated by natural vegetation.

All crawfish ponds support a multitude of benthic and clinging creatures, which include insects and their larvae, worms, and mollusks (mostly snails), as well as planktonic creatures like water fleas, copepods, and ostracods. These provide essential animal nutrients not otherwise available in plant foods—especially important for immature crawfish.

**Natural Feeds and Crop Rotation**

Three basic feed “delivery” methods have been developed in the Louisiana crawfish industry. Dr. Martin Brunson has been a leader in crawfish forage research and much of the following commentary is based on his work in this important facet of crawfish farming. He categorizes these delivery systems as follows: (1) use of volunteer natural vegetation, (2) use of agricultural wastes and supplemental feeds, and (3) use of planted and cultivated forage crops.

**Natural Vegetation**

The oldest, simplest, and least expensive feed delivery method is the use of volunteer natural vegetation. Native plants are allowed to grow unchecked in the pond during the summer and then flooded in the autumn. Many plant species, both aquatic and upland, have been used in this manner, but aquatic plants are typically better suited to crawfish production. Native terrestrial or “dry land” plants are much less desirable and generally decompose so rapidly after autumn flooding that they affect production negatively: oxygen is depleted and forage does not last through the season.

Aquatic and semiaquatic plants thrive in crawfish ponds and persist longer under winter flooded conditions than do upland plants. Among the most commonly used native plants are alligator weed (Alternanthera philoxeroides), water primroses (Ludwigia spp.), and smartweeds (Polygonum spp.). Others, such as delta duckpotato (Sagittaria
\textit{platypylla}} and wild rice (\textit{Zizania aquatica}), have also been used. Various grasses and sedges, especially semi-aquatic species, are found throughout such ponds. Generally, crawfish production from ponds with native vegetation is lower than that achieved when a cultivated forage crop is used, but it is not necessarily because of inferior forage. In many instances, the intensity of management in such ponds is lower than that in planted ponds.

The detritus base in wood ponds includes soft-stemmed vegetation as well as leaves, the amount depending on how open the pond is. Leaves with low levels of tannins and lignins, like maple, are preferred as food by crawfish and other detritivores. Oak leaves take much longer to decompose although they seem to provide a good surface on which epiphyton can grow.

In the typical situation, one or more of these native plants is allowed to grow voluntarily in the pond during the summer and fall. In some cases, limited cultivation or fertilization is used to stimulate growth. At the autumn flooding, the farmer has a readily available forage base for crawfish production, and because many of these plants are aquatic or semi-aquatic, they continue to thrive until freezing temperatures arrive.

Using native aquatic vegetation has several major disadvantages. First, since these are volunteer plants, it is not certain that an adequate stand and suitable biomass for crawfish forage will be obtained. Cultural practices for these plants are not well developed, thus contributing to greater uncertainty in stand establishment. Secondly, many native plants are considered to be weed species and, as such, are undesirable in agricultural fields where other crops, especially rice, will be grown in later years. Finally, unless a pond has a large crawfish population, alligator weed can grow so quickly in the spring that it can stop water flow and sometimes interfere with harvesting.

Agricultural Wastes

Many by-products and waste products from agricultural activity have been evaluated as crawfish feed. Among the materials tested were sugarcane (\textit{Saccharum officinarum}), sugarcane bagasse, sugarcane filter cake, chicken manure, sweet potato (\textit{Ipomoea batatas}) trimmings and vines, rye hay (\textit{Secale cereale}), soybean stubble and hay (\textit{Glycine max}), rice hay (\textit{Oryza sativa}), and bahia grass hay (\textit{Paspalum notatum}). Although several of these supported crawfish growth, only the hays were found to have practical potential for large-scale commercial crawfish ponds. Hays such as rice and bahia grass can be used to supplement food supplies in ponds late in the crawfish season (spring) when the primary vegetation in the pond becomes limited or depleted. The addition of 300-500 pounds per acre of hay provides vegetative matter that enters the detrital food chain, thus providing suitable crawfish food. This practice is common, and although its efficiency is not thoroughly documented, positive results have often been reported.

Planted Forage Crops

The most efficient and dependable method of providing crawfish forage is through the use of a cultivated crop. Using a crop species has several advantages. The crawfish farmer controls the type of forage that will be available, instead of relying upon volunteer vegetation. An adequate stand of vegetation is assured, and concern about subsequent problems from unchecked weed growth is eliminated. In many cases, the farmer can realize a cash crop from the forage plants while supplying fodder for crawfish.

Several commercial plants have been evaluated as crawfish forage, including rice, Japanese millet (\textit{Echinochloa frumentacea}), sugarcane, and soybeans. The most promising is rice. Crawfish have been incidentally harvested from rice fields for decades, and rice has proven superior, both to other planted forages and to natural vegetation, for crawfish production. With 300,000 to 600,000 acres of rice in Louisiana, the potential for integrating rice and crawfish is great. Cultivation timing for rice fits nicely into the crawfish production cycle. Additionally, because rice is a semi-aquatic plant, it persists longer during the autumn and winter months than would other species that are less well adapted to wet conditions.

Recent studies indicate that certain varieties of rice are better suited than others for crawfish forage. Most of the rice-crawfish studies before 1984 used the rice varieties “Labelle” and “Saturn,” which have been popular in Louisiana. With such forage parameters under winter flood, and nutritional quality, other varieties appear superior to these for crawfish systems.

There are a number of varieties that not only provide adequate crawfish forage during the autumn and winter, but persist through the winter, thus providing crawfish with fodder at a time when other forage crops have been depleted. Recommended long-grain varieties include Labelle and Lemont for use in double-cropping and Starbonnet, Newbonnet, or Bellevue for crawfish monoculture.
An excellent medium grain for both double-cropping and monoculture is Mars, and Nortai is a good short grain for both types of culture.

There are basically two approaches to rice-crawfish culture. In the first, both rice and crawfish are raised as cash crops. Rice is planted in early spring and harvested for grain in late summer. The rice stubble is left standing and rattoon growth (green regrowth) is encouraged. The field is reflooded in early autumn and crawfish subsist on the decaying rice stubble and green regrowth. In the second approach, rice is planted solely for crawfish culture, with no concern for grain production. In this strategy, rice is planted in mid to late summer and the grain, if produced, is not cut. The entire rice plant then remains to provide crawfish forage. This method is most often used by landowners participating in governmental “set-aside” programs that mandate later planting dates, or by farmers who extend their crawfish harvest seasons into early summer, thereby necessitating the late planting of rice.

Although crawfish have been harvested from rice fields for many years, intensive commercial rice-field crawfish culture has only recently been established. Thus, production techniques are not highly refined and many questions are as yet unanswered. For example, some of the pesticides used on rice are highly toxic to crawfish. Consequently, the double-crop farmer assumes that he must choose whether to emphasize rice or crawfish. To maximize crawfish production, the use of rice chemicals is limited, and many times grain production ultimately suffers. Cultural and management practices for rice and crawfish must be developed to aid the full production of both crops.

Rice is currently the most frequently recommended forage, but it is not the ideal choice used alone. In many respects, the ideal forage may be a combination of rice and natural vegetation such as alligator weed.

Other agronomic crops may have potential as crawfish forage and for double-cropping with crawfish. One group of plants recently identified is the sorghums (Sorghum spp.). Grain sorghum, or milo (Sorghum bicolor), acreage in Louisiana has increased more than twenty-fold since 1979, and preliminary studies reveal that it might be a viable and desirable alternative to rice for double cropping with crawfish. Another sorghum that appears to have great potential is a sorghum-sudangrass hybrid. Most commonly used as silage or hay, this plant exhibits prolific growth and regrowth, producing during the summer several tons of dry biomass, which may later be used as crawfish forage.

Both sorghums are drought-resistant and might provide the farmer with the necessary “dry land” crop in his normal cropping system rotation. In rice producing areas, farmers typically rotate their rice fields into another crop (traditionally soybeans) every second or third year. Soybeans have little potential as crawfish forage, but the substitution of a sorghum provides the opportunity for production of a crawfish crop during the “off year.” A field used for crop-crawfish rotation is typically drained in late May or early June and planted with soybeans after the crawfish crop is harvested. However, it is not reflooded in the autumn after the soybean crop is harvested as it would be otherwise had rice been grown over the preceding summer. This is because there is normally not enough vegetation remaining in the field to sustain a good crawfish crop.

In the rice-crawfish-soybean rotation, it is possible to produce three cash crops in two calendar years, an idea that gave rise to the “3 in 2” multicropping concept. However, with the substitution of sorghum for soybean the potential exists for a “4 in 2” system, in which multicropping is fully developed and maximum productivity of soil, water, and energy resources can be realized.

Management practices for various crawfish-vegetation plans follow:

**Rice-Crawfish-Rice-Rotation**

<table>
<thead>
<tr>
<th>Month</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>March/April</td>
<td>Prepare ground and plant rice.</td>
</tr>
<tr>
<td>June</td>
<td>At permanent flood (rice 8-10 inches high), stock 50-60 pounds of adult crawfish per acre.</td>
</tr>
<tr>
<td>August</td>
<td>Drain pond over one week and harvest rice.</td>
</tr>
<tr>
<td>October</td>
<td>Reflood field.</td>
</tr>
<tr>
<td>November to March/April</td>
<td>Harvest crawfish.</td>
</tr>
<tr>
<td>March/April</td>
<td>Replant rice.</td>
</tr>
</tbody>
</table>

NOTE: This rotation has been done for years but consideration must be given to the pesticides used in rice culture and pond circulation patterns through rice fields. Dates in north Louisiana will be one month later for planting rice.
Rice-Crawfish-Soybeans Rotation

March/April  Prepare ground and plant rice.

June     At permanent flood (rice 8-10 inches high) stock 50-80 pounds of adult crawfish per acre.

August  Drain pond over one week and harvest rice.

October  Reflood field.

November to May  Harvest crawfish.

Late May/June  Plant soybeans.

March/April  Repeat with rice.

NOTE: This rotation has worked well in areas where land is switched to another crop every other year. It allows three full seasons for three crops and does not cut short the crawfish season. Use of pesticides is an important consideration in this rotation. If a sorghum is substituted for soybeans, then the field is reflooded in October and there will be no need to restock the pond with crawfish unless there has been a loss of stock over the previous summer.

Rice—Set-Aside

April/May  Flood field and stock 50-80 pounds of adult crawfish per acre.

May/June  Slowly drain pond over three weeks.

August  Plant rice and lightly flood or flush rice. Check ASCS (Agricultural Stabilization and Conservation Service) office for first planting date.

October  Reflood pond.

January to May  Harvest crawfish.

May  Slowly drain pond. Stocking not normally necessary, as surviving crawfish are usually adequate to produce young for next season.

NOTE: This rotation is for farmers in the extant set-aside program, which allows them to use idle land for crawfish. Regulations are subject to change, so farmers must check with their local ASCS offices to assure that they are in compliance with current regulations.

Permanent Crawfish Ponds

April/May  Stock 50-80 pounds of adult crawfish per acre.

May/June  Slowly drain pond over three to four weeks.

June/August  Plant rice at 60-70 pounds per acre. Mars is the variety recommended for Louisiana.

October  Reflood pond.

November to May  Harvest crawfish.

May  Slowly drain pond. Stocking not normally necessary, as surviving crawfish are usually adequate to produce young for next season.

NOTE: Most farmers prefer this rotation because they can set up the pond properly once, keep traps and pumps in one location, and need not restock the pond. Sorghums are being substituted for rice as a forage. Check with your local Extension Service office for current recommendations on forage crops for your area.

Artificial Feeds

Laboratory and pool studies have demonstrated that crawfish readily consume fish and crustacean feeds. The cost of artificial feeds is such that those designed specifically for crawfish have only recently been developed. They are so new, in fact, that precise recommendations and economics for pond use have not been refined. The basic problem is simple. There is, as yet, no way to predict the actual numbers of crawfish present in a pond because known numbers are not stocked as is the case in most forms of aquaculture. Crawfish ponds are “self stocking” and “stock” themselves over a period of several months. Furthermore, it is almost impossible to observe feeding activity, as is the case with fish systems, in which floating feeds are used. Even when crawfish densities can be
predicted, feeding has not led to significant gains in the weight of individual crawfish in very dense populations where density-dependent factors interfere with growth.

Protein is the most expensive part of an artificial animal feed. It appears that in tanks and pools red and white crawfishes require 25-30 percent protein in artificial feeds, of which 15-20 percent must be of animal origin. In one laboratory study, the fastest growth and protein deposition in red crawfish were observed when they were given a protein:energy ratio of 120 milligrams of protein per kilocalorie, in a diet containing 30 percent crude protein and 2.5 kilocalories per gram of dietary energy. Both red and white crawfishes are very efficient at utilizing plant proteins and carbohydrates in feeds. Lipids (fats) should probably not exceed about 6 percent of any artificial feed. In confined systems, crawfish on artificial feeds become very pale after several molts. If they are to retain normal pigmentation, their diets must be supplemented with a source of carotenoid pigment such as fresh, succulent plant material (elodea, alligator weed). In general, feeding rates of about 3 percent of estimated body weight per day when water temperatures exceed 68-70°F produce good growth in tanks and pools.

Supplemental feeds in crawfish ponds may be effective with protein levels of 15-20 percent. This is because there is much natural food in ponds. However, there is not enough experience with supplemental feeds in ponds to make any recommendations.

Use of Fertilizers

Crawfish pond production is based on the presence of a luxuriant growth of vegetation. Good management dictates that the pond soil should be fertilized in keeping with recommendations from the local extension service for growing the cover crop being employed in that pond. Naturally, a complete soil analysis should be performed on the soil before a new pond is built, and periodic checks should be made once the pond is in production.

A key element in crawfish culture is calcium, as 25 to 30 percent of crawfish shells are calcium. Sustained harvest of 500-1000 pounds of crawfish per acre per year over several seasons will obviously reduce calcium levels in the pond. A good rule of thumb is that if the soil tests show that calcium in the soil is adequate for growing a crop such as cabbage, which requires calcium-rich soil, the application of calcium (lime) is not needed. If the soil is deficient, lime should be applied as needed.

Application of chemical fertilizers to flooded ponds does not seem to benefit the crawfish production. No recommendations are available on the subject at this time. Organic fertilizers (manures) probably help, as the organic matter is eaten directly by the animals that crawfish eat (and the crawfish, too), increasing their food supply. There are certain to be aesthetic objections to such a practice. However, this is a common aquaculture practice in other countries. This area is one that requires further research that may lead to increased production and thereby benefit farmers.

POND CRAWFISH POPULATION DYNAMICS

This section will address the following topics: stocking, care of broad crawfish, burrowing activity, growth and survival, movements in and around ponds, yield, stunting, monitoring populations, and predicting yields.

A general statement about crawfish ponds as they are now managed is needed here. Ponds are managed by establishing sustaining populations. In areas with no resident red swamp or white river crawfishes, it may take several years before good populations are established. In such areas, first year production is usually several hundred pounds per acre of very large crawfish. Production can reach 1000 pounds or more per acre of smaller but very nice crawfish in the second or third year. In areas with resident crawfish populations, production is usually high in the first year but size is moderate.

Farmers report more frequently now poor production after a year of producing 1000-2000 pounds per acre. This seems to be associated with many small crawfish. That is, reproductive success of surviving brood stock was so great that high densities inhibit growth. Density should be reduced to enhance growth rates but prices for the small crawfish are so low that the farmers do not harvest them, compounding the problem. We do not stock known numbers of crawfish in our ponds the way catfish and trout farmers do. Until we can control numbers and match them to pond conditions and production goals, crawfish management will be an art, not a science. Planning economics on yields over 600 pounds per acre is not advisable.

The development of a computer simulation model of crawfish pond population dynamics by Dr. Robert P. Romaine of Louisiana State University is a major first step in effective crawfish pond management. It is particularly ironic that the model
depends heavily on basic red swamp crawfish biology data reported in the 1950s and 1960s by Professor Tetsuya Suko of Saitama University in Japan, a land that considers the red swamp crawfish to be a pest!

**Stocking**

**Species to Stock.** We recommend stocking only red crawfish because we do not have enough data about white crawfish to make recommendations. In addition, the red swamp crawfish is the preferred food species in Louisiana.

**Stocking Rates.** Current recommendations for crawfish ponds are as follows.

<table>
<thead>
<tr>
<th>Situation</th>
<th>lbs/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native crawfish in immediate area surrounding pond</td>
<td>20-25</td>
</tr>
<tr>
<td>Ponds with good cover, low or no crawfish in immediate area surrounding pond</td>
<td>20-25</td>
</tr>
<tr>
<td>Ponds with good cover</td>
<td>40-45</td>
</tr>
<tr>
<td>Ponds with sparse cover</td>
<td>45-65</td>
</tr>
<tr>
<td>Ponds with little or no cover</td>
<td>60-100</td>
</tr>
</tbody>
</table>

Crawfish yields of 1000 to 1500 pounds per acre per year are considered to be attainable in well-managed ponds. A little constructive computation reveals that 8 pounds of female crawfish are all that are needed to produce that sort of crop. The average crawfish used for stocking is 3 to 4 inches long. A female of that size can produce about 300 young. About 60 percent of these can be expected to survive to be harvested in a good pond. Considering that 20,000 crawfish at a weight of 20 per pound must be harvested to obtain a yield of 1000 pounds per acre, 144 females are required per acre. At 20 per pound, the total weight of required females is slightly more than 7 pounds. As the male-female ratio is normally 1 to 1, stocking 20 pounds per acre should be adequate for any pond. Some crawfish must be left in the pond to produce young for the next year.

Average production in Louisiana is 500-600 pounds per acre. Mortality rates of both brood crawfish and young crawfish are, obviously, quite high.

In controlled hatchery systems, the Wrights note the following results with various ratios of males to females. When there is a greater number of males to females, females are damaged and female mortality is high. A greater number of females to males results in low egg production. The best ratio is 1:1.

The red crawfish is native to many of the low-lying areas of Louisiana and east Texas where crawfish ponds are concentrated. They have absolutely no respect for levees and enter (or leave) these ponds throughout the year. As a result, "unstocked" ponds have generated substantial yields. However, building a pond without stocking at least a nominal amount of broodstock, regardless of native populations in the area, is foolish—with one exception. If a pond is built early enough in the year so that it is filled with water intentionally or naturally before March, it may develop a surprisingly dense crawfish population from crawfish already present in low-lying areas within the pond or from invaders from outside the pond. Thus, a pond should be checked for the presence of crawfish before it is stocked. Catches of one-half pound or more per trap indicate that the pond has been self-stocked and no stocking is necessary. Traps should be used to sample new ponds as it is easy for the layman to confuse small species of crawfish with young red crawfish if a net or seine is used for sampling. Failure to differentiate between species present could result in a poorly yielding pond the following year.

The white river crawfishes occupy most of the same range as *P. clarkii*. It is not surprising, then, to find them in ponds stocked almost entirely with red crawfish. New ponds where red crawfish introductions were not very successful in the initial year are often "saved" by strong production from white river crawfish that inhabited the area prior to pond construction. Subsequently an equilibrium is reached between the two species, with red crawfish almost always dominating the system, as previously discussed in the ecology section.

The key is survival of the broodstock. With reduced amounts of cover, their chances for survival are reduced drastically. Production less than 1000 pounds per acre per year can be a result of low reproduction in ponds, assuming that harvesting is intensive and poor water quality or fish do not kill young-of-the-year crawfish. As production can approach 2000 pounds per acre per year in extremely well-managed ponds, the need for improving the survival of broodstock seems to be warranted.

Another reason for poor production is too many crawfish. That is, growth is density dependent, and when there are too many young, none grow very well. So, how many are too many? This depends on the amount of forage, vertical substrate in the pond, water quality, and harvesting activity. Unfortunately, scientists have not yet worked ou
the relationships between densities and these factors. Production has reached 4000 pounds per acre. At 20 crawfish per pound, density would be around 80,000 per acre. However, this is probably the upper limit with lower densities needed to insure production of 20 per pound for larger crawfish. The use of baffle levees in crawfish ponds may lead to overpopulation because of increased burrowing sites.

Crawfish take 12 to 48 hours to dig a hole that is deep enough to protect them from predators. Observations of crawfish ponds and natural areas have shown that wherever there is cover (vegetation such as water hyacinth and alligator weed mats, existing holes or depressions, or relatively flat objects such as a board, piece of tin, boat, or log), crawfish will burrow successfully. We believe that farmers could facilitate the burrowing process and thereby improve production by starting holes with a pole around the edge of the pond and placing some form of inexpensive cover such as heavy cardboard or old boards on them. The usefulness of these procedures in established ponds is debatable. If water quality is good and there are no fish problems, they would probably be useful in established ponds where production is not good, especially those with little cover when they are drained.

When crawfish are moved, their gill chambers must remain moist. Crawfish can have moist air in the chambers, but if the gills dry, the crawfish will dehydrate. Moist packing material, like newspaper, sponge rubber, and shavings, and/or periodic showers of water must be employed.

There is much doubt about the effects of shipping on brood crawfish. As the Wrights point out elsewhere, the natural environment of crawfish is water, and they are under stress when out of it, especially when jammed into an onion sack. The Wrights recommend that brood crawfish be shipped in water, either in plastic bags filled with oxygen or in regular fish-hauling tanks. Otherwise, females under stress often reabsorb their developing eggs. Without conclusive research, one can only speculate on the proper shipping rates. However, those figures used for catfish, which have a similar physiology, are probably appropriate.

Purged catfish are shipped in 65-70°F water at rates of about 1-2 pounds per gallon of water in tank trucks with agitation aeration systems or compressed oxygen systems over 24 hours. Small catfish are shipped in plastic, oxygen-filled bags at rates of 3-4 pounds of fish and 16 pounds of water (about 2 gallons) for 24 hours. It is best to use two bags, 6 mil thick, one inside the other.

No person should, however, contemplate substantial shipments of crawfish anywhere without making experimental “dry runs” first. Crawfish physiology changes according to the time of year, and a shipping method that works in December may be fatal in May.

The system for shipping stocking crawfish described initially is probably effective in most production areas simply because distances and times are short. Yet we really do not know how effective they are because native crawfish often invade new ponds from surrounding areas. Our experience in restocking crawfish caught the same day suggests mortality rates of about 50 percent even where every effort was made to insure their survival. Further research is certainly needed to establish the most effective and least expensive methods of shipping brood crawfish.

**Care of Brood Crawfish**

Many ponds are stocked with crawfish from the Atchafalaya basin, as they are relatively inexpensive and readily available in the late spring. Such crawfish have come from moving water systems and often walk away from a pond. We recommend that pond crawfish be stocked in preference to Atchafalaya basin crawfish. There is no justification to the belief that they will improve the genetics of existing pond crawfish.

Crawfish that will be stocked in ponds should be stocked within several hours of capture. They should not be refrigerated but they should be kept shaded and moved early in the morning, late in the afternoon, or at night. They should experience as little stress as possible. Cooling to about 50 to 60°F for long distance shipments is advisable, but the crawfish should be warmed slowly before stocking. It is also better to stock crawfish in the center of the pond, to discourage their crawling out of the pond.

If crawfish have been out of the water for a long time, their gill chambers may be full of air. They will float when put into deep water and may be unable to reestablish water flow over the gills. If this is the case, they must be allowed to walk into the pond so that they can refill their gill chambers.

**Burrowing Activity**

An observant pond manager will note some burrowing activity throughout the crawfish season. There are minor peaks of burrowing in October after flooding and again in December. Activity becomes especially apparent during April when many crawfish from that year’s crop begin to mature. It becomes even more intense as the time for
pond draining approaches. Actual burrowing as ponds are drained does not, however, appear to be especially successful, as most ponds have very little cover in them at that time. Established ponds have many existing burrows, which are occupied when the ponds are drained.

There are few observations on crawfish burrowing behavior in pond bottoms away from shore. In areas devoid of any cover, crawfish tend to dig short, simple burrows to which they retreat when danger threatens. It is not clear whether they return to specific burrows or those that happen to be convenient. In areas with abundant cover, it appears that the crawfish secrete themselves beneath the cover rather than excavate burrows; however, more data are needed before the subject can be fully understood.

It is rare to find many burrowers on pond bottoms proper. The crawfish prefer to burrow in levees. When ponds are drained, the bottoms are slurry of anoxic potentially toxic muck. It is basically too soft to make anything but a shallow hole, and the crawfish must constantly rise to the surface to obtain atmospheric oxygen. Thus, the crawfish is constantly exposed to predators until water tables fall well below the surface, a period of 10-15 days. Often, the combined stresses of anoxic water and high temperatures kill the crawfish that escape predators.

For the red swamp crawfish, burrowing is critical not only to the survival of natural populations but also to successful culture in earthen ponds. Few published reports discuss this critical phase of this species' biology in cultural situations; however, Billy Craft (state biologist, Soil Conservation Service, Alexandria, La.) has conducted several unpublished studies of the burrowing behavior of this species in crawfish ponds. A summary of his findings follows.

Craft studied two ponds during a dry summer when the water table had declined to nine feet below the surface by the time the ponds were reflushed in late September. Thirty-three burrows were excavated, but only one crawfish was found to continue burrowing to follow the declining water table. Except for that one, none of the other crawfish were found below a depth of five feet. Eighty percent were found at a depth of about three feet.

Craft's study was done to determine whether crawfish need free water to survive the summer. He found free water in only one burrow when the burrows were excavated in late September, though all had 100 percent humidity from the soil moisture. While the crawfish fared well in their burrows, none bore eggs, so the water requirement for egg laying and egg development is still an unknown factor. Then, too, the ability of juvenile crawfish to burrow deeply enough to reach saturated soil is still not known.

It is the general consensus that ponds with clay soils do not need supplemental wetting during dry summers; however, silty clay soils should be soaked if normal rains do not fall. Caution must be taken to ensure that any water, whether from rainfall or irrigation, soak in quickly. If it is allowed to stand, the crawfish will be forced from their burrows into shallow waters that are hot enough during the summer to be lethal.

October and December burrowing is done by adult females that had not spawned prior to pond flooding. In addition, some of those burrowing in December also represent fast-growing young-of-the-year that have just matured and maturing holdover juveniles. These are especially important because they contribute to the second and third waves of recruitment of young-of-the-year crawfish to the pond. Harvesting during November is not advisable if females show considerable egg development and if burrowing activity is noticeable.

Burrowing is most apparent along pond levees. Burrows are least likely to be found in the pond floor proper. Burrows are almost always in association with some cover. Large ponds have much less levee space per unit of pond bottom than do smaller ponds. It may be advisable to engineer large ponds with additional levees—either above the water or low, submerged levees. Those submerged levees will appear quickly when the pond is drained but before the pond bottom is exposed. Crawfish will have additional area to burrow away from the regular pond levee. Such inner levees are generally found in rice field ponds. They are actually contour levees that are used to maintain the four to six inches of water necessary to cultivate rice. These are submerged when the rice ponds are flooded for crawfish culture.

The construction of extra levees was a recommendation made as early as the 1930s by Perry Viosca, but its value has yet to be proven by research. Note: It is still not clear as to how many levees are too many. That is, if there are too many burrows, density of young crawfish may be so high that the crawfish stunt.

**Growth and Mortality**

**Recruitment.** The red crawfish can produce up to two generations a year in Louisiana. Their
are several groups of crawfish in a pond. Each group is referred to as an age class. These age classes include holdover adults from the preceding season, holdover juveniles from the preceding season, and young-of-the-year crawfish. Spawning does not take place at one time so there are several age classes of young-of-the-year crawfish. The appearance of the young-of-the-year crawfish is called recruitment. The various age classes of young-of-the-year appear in sequence so many population biologists refer to them as waves of recruitment. The number of age classes, number in each age class, survival, and food availability will determine overall pond yield.

In productive crawfish ponds there are at least five age classes during the season. The first two are the holdover crawfish referred to above. The remainder are young-of-the-year crawfish. The first age class of young-of-the-year enters the pond when it is flooded in September-October. The others enter the pond in October-November and December-January. Spring recruitment is seen in most ponds in March or April. Some sporadic, low-intensity crawfish recruitment will take place in all months.

New ponds should lack holdover juveniles unless native crawfish, red or white, were already present in the pond area when it was built. Reproductive failure, coupled with absence of native crawfish, usually means very poor crawfish production in the first year. It is probably wise to restock such a pond lightly if substantial numbers of crawfish do not appear and crowd the pond at the end of the season.

Early (November-January) harvest is generally low and is usually made up of the holdover crawfish. Early pond flooding combined with warm temperatures can result in rapid growth of the first age class of young-of-the-year crawfish such that they will become harvestable in November or December. In general, however, the various age classes of young-of-the-year crawfish do not add significantly to the harvest until late January or February in warm years and March in cold years. Although catch in traps is low in the fall, prices more than justify the effort necessary to harvest them.

There is invariably a gap between the catch of holdover crawfish and the young-of-the-year age classes. The gap is basically dependent upon temperatures. It is shorter in mild winters than cold ones. The gap is especially pronounced should the age class(es) be eliminated by poor water quality (low dissolved oxygen) or predaceous fish.

In the October-December period, the harvesting of holdover females that have not spawned can present a serious problem. It can eliminate a theoretical production of 9 pounds of crawfish (3,000 young per female X 60 percent survival = 180 harvestable young crawfish 20 per pound = 9 pounds of crawfish) per female. In general, it is now recommended that if more than 10 percent (1 in 10) of the females in the early catch have well developed tan or brown eggs (see reproduction section), then harvesting should be discontinued.

Survival/Mortality. As crawfish in an age class grow older, some will die. Death can result from natural causes such as predators, diseases, molting stress, low oxygen levels, and climatic conditions or it can result from human activity through fishing. In well-managed crawfish ponds where fish are excluded or controlled and water quality is good, at least 50 to 60 percent of each young-of-the-year age class that reaches 1 inch in length will survive to reach a harvestable size. Survival to 1 inch can be highly variable and may be as low as 5 percent. Large fish populations or low oxygen levels can destroy almost all crawfish in a pond before they reach a harvestable size.

Experience has shown that well-managed, open crawfish ponds yield harvests of 1,000 to 1,500 pounds per acre of crawfish year after year, regardless of the presence or absence of wading birds, predaceous insects, and spiders (see life history section). They will invariably fail, however, if large numbers of fish such as green sunfish, bullheads (pollywogs), and bowfin (chouique) are present in the pond. Elimination of predators other than fish might improve yields.

The wading birds are protected by law, and no permits are issued to kill them while they are feeding in crawfish ponds. One can, however, readily keep them away from a pond by frightening them. This is a tedious job and does not appear to be warranted. Certainly, protective cover in burrowing areas is advisable in new ponds or established ponds with little or no cover and a history of poor production.

What does one do if excessive numbers of predaceous fish are present in a pond in the fall? Regrettably, one can only speculate about the effectiveness of various options. These can include complete draining and reflooding, partial draining and poisoning of the fish, and marginal poisoning with fish toxicants to kill the fish along the shore where they usually concentrate. Cost-benefit ratio is just not known. It is easy enough to calculate the costs of toxicants, labor, water, and pumping, but
the increase in yield is impossible to predict. For example, if the fish are small enough, generous crawfish crops can still be harvested because the fish are too small to harm the majority of the young-of-the-year crawfish; however, if the fish are bigger and the initial yields of young crawfish die for various reasons, a pond may not even produce a harvestable crop. The close monitoring of the crawfish pond is necessary to provide appropriate management information as quickly as possible.

Fish are usually killed by completely draining ponds or draining them as much as possible and poisoning the remaining water with a fish poison such as antibiotic B or rotenone. This normally is done during the summer. A word of caution is in order here. Even if a pond can be completely drained, water will remain in some low areas. These should be poisoned, because green sunfish, bullheads, and bowfin stranded in these pools can survive by finding crawfish holes or root holes and remaining in them until the ponds are reflooded in the fall.

Screen systems should be attached to inlets if surface waters are used, and baffles or screens are needed on the drain to prevent fish from entering ponds.

The principal carnivorous creatures in most aquatic ecosystems are the fishes. These are largely eliminated in crawfish ponds. As a result, the populations of predaceous insects explode. Three groups are of concern to crawfish pond managers. These are the hemipterans (true bugs), the coleopterans (beetles), and the odonates (dragonflies). The hemipterans and beetles must breathe air while the nymphal stages of dragonflies are truly aquatic and have gills. All hemipterans are very carnivorous but only the water scorpions (Ranatra spp.) and the giant predaceous water bugs (Bolbostoma spp. and Lethocerus spp.) are large enough (2-3 in.) to attack most crawfish.

The small (0.25-0.50 in) backswimmers such as Notonecta spp. are highly predaceous on small aquatic animals. The hemipterans all have a piercing beak that they use to inject proteolytic enzymes (digestive juices) that kill and digest their prey. The fluid is then sucked from their prey through their beaks (Figs. 64, 65, 66).

Giant predaceous water beetles (2-3 inches) of the genus Cybister are dangerous to crawfish as both adults and larvae. The adults have crushing jaws and tear their prey apart. The larvae look like large worms with grotesque fangs. The hollow fangs inject proteolytic enzymes into prey (Figs. 67, 68).

Dragonfly nymphs, especially the large (2-3 inches) Anax spp. nymphs, readily eat smaller crawfish. Their mouth parts are specially modified to include an extendable, toothed mask. This mask can reach in front of the nymphs about one-third of the length of their bodies. Prey is grasped and drawn back to the mouth where mandibles crush and tear it apart (Fig. 69).

Fig. 64. Water scorpion, Ranatra sp.

Fig. 65. Giant predaceous water bugs, Lethocerus sp. (adult), Lethocerus sp. (juvenile).
Fig. 66. Backswimmers, *Notonecta* sp.

Fig. 67. Giant predaceous water beetle, *Cybiater* sp.

Fig. 68. Giant predaceous water beetle larva, *Cybiater* sp.

Fig. 69. Dragonfly nymphs, *Anax junius* (right) and *Pachydiplax longipennis* (left).

Fig. 70. Fisher spider, *Dolomedes* sp.
Besides predaceous insects, the large (2 inches) aquatic fisher spiders (Dolomedes spp.) capture and eat crawfish. They too have piercing fangs that inject proteolytic enzymes into their prey. These spiders are at home both above and below the surface of a crawfish pond (Fig. 70).

Most of the mortality of young crawfish in crawfish ponds, other than that caused by bad water, is undoubtedly caused by predaceous insects and spiders. Methods for controlling these predators have not yet been developed. Fish culturists use a mixture of old crankcase oil and diesel fuel (50:50) to kill air-breathing arthropod predators. Roughly one gallon per acre suffices to clog air-breathing tubes. Crawfish ponds, however, have so much vegetation in them for much of the year that the oil slick is useless. Poisons such as Baytex used to kill insects in fish ponds also kill crawfish. Prawn culturists have found that stocking mosquito fish, Gambusia affinis, will help in controlling insect predators in their ponds. This may prove useful in crawfish ponds, but in confined situations mosquito fish will eat third instar crawfish just released, roughly 0.5-inch long.

The Wrights find that mortality between the third instar stage and the one-inch stage is 90 to 95 percent in ponds. They culture third instar red crawfish in tanks for roughly 30 days. These are released into ponds at a size of about 1.5 inches. Mortality is less than 10 percent at that time.

Once trapping begins most mortality of harvestable crawfish is caused by their harvest. Survival of an age class once it becomes large enough to harvest is less than 10 percent in a heavily harvested pond.

As the red crawfish becomes established in new regions, new predators will appear. A recent report from Zambia notes that a local variety of carnivorous iguana (a large lizard) finds young red crawfish very palatable. They are also actively eaten by a carnivorous variety of tilapia fish native to Africa. Otters, Lutra spp., relish crawfish and have been reported a problem in such diverse places as Louisiana, Spain, and Zambia.

Movements In and Around Ponds

Red crawfish are capable of extensive migrations (see ecology section). This can account for excellent crawfish production in ponds that were never stocked; however, this is normally seen only in ponds in areas with well-established natural crawfish populations.

Movements of crawfish within ponds are not well known. Mark/recapture experiments have involved small ponds less than five acres in size and have shown that such areas may be traversed by adult crawfish in less than 12 hours. Most pond populations seem to be very stable with a relatively small percentage leaving the pond in a normal season. Red crawfish are more active when light is subdued. They are most active at night and are more active on cloudy days than clear days. They are much more reclusive in clear water than murky, turbid water.

Very little is known about the existence of home ranges in red crawfish. Dr. Alan Covich of the University of Oklahoma, Stillwater, has placed radiotransmitters on large adult red crawfish and tracked them in 1/10-acre ponds. He found that they moved at night and that they apparently used several submerged burrows for cover during their nocturnal wanderings. This suggests that these adults had a home range. This seems to be the case with adults in Louisiana ponds in fall and winter. However, it appears that, at least in the spring, when the bulk of the crawfish are maturing, no home ranges exist in Louisiana ponds. This is an important consideration in pond management and specific studies will be needed to determine precisely what is happening.

Yield

Production information has been slowly generated during the past few years. The Louisiana state average has consistently been 500-600 pounds per acre. Well-managed open ponds consistently produce 800-1500 pounds per acre per year. Yields up to 2000 pounds per acre per year are reported with some consistency. Within the open pond category, rice field ponds that are drained in March to accommodate rice production produce 300-500 pounds per acre per year. Those kept flooded into late April or early May can be as productive as open ponds. Wooded ponds and open marsh ponds rarely yield more than 300 pounds per acre per year. Even well-managed wooded ponds suffer from major dissolved oxygen deficiencies, have lower temperatures, and probably produce lesser amounts of edible detritus for the crawfish. Marsh ponds generally have very poor water quality.

Maximum reported production was 4,000 pounds per acre produced in a one-acre pond managed by Archie Warinner. Mr. Warinner practiced nontraditional management, employing an extensive water circulation and aeration system and supplementing natural reproduction in the pond by adding females bearing eggs or recently hatched young. However, yields up to 3,500 pounds per acre
have been generated in uncirculated, traditional ponds, suggesting that there is much to learn, yet, about pond management.

There is no reason open ponds cannot produce 4,000 or more pounds per acre with supplemental stocking of young crawfish, supplemental feeding, and circulating/aerating water on a massive scale. These practices, however, are not yet economical in Louisiana at this time.

**Stunting**

The red crawfish can reach maturity and stop growing at sizes as small as 2 to 2 3/8 inches. This is below the minimum commercial size of 3 inches and the preferred size of 3 1/2 inches or larger. Stunting will take place in ponds if the crawfish are not heavily harvested. Both social and nutritional factors lead to stunting. The only solution is to harvest the crawfish intensively. Stunting can be detected by checking males for the Form I condition (see the section on the reproductive system). If most of the males are small and in the Form I condition, stunting is a problem (Fig. 71).

Another sign of impending stunting is the presence of many small 2 to 2 3/4 inch immature male crawfish with extensive growths of algae and assorted plants and animals on their shells. These are not growing rapidly and will probably stunt unless conditions are improved. Research has shown that supplemental feeding will prevent stunting of such crawfish at subcommercial sizes, but the economic feasibility of such feeding has not yet been demonstrated.

One theoretical approach to stunting problems is to kill as many of the crawfish as possible in late April or May by applying a toxicant or by draining the pond very rapidly. This practice is thought to reduce the number of crawfish in the pond so that those remaining will grow larger in the next season and fewer young will be produced, also reducing competition. We must emphasize that though this appears to have been effective in some ponds with chronic stunting problems, replicated studies have not yet been conducted to verify the applicability of this practice. A strong argument against this is that prices have been highest in the fall and winter regardless of crawfish size. Because

![Fig. 71. Mature, Form I male red crawfish.](image-url)
the greatest income is generally earned during this period, the reduction in numbers of holdover crawfish could seriously reduce profits.

An alternative approach to killing stunted crawfish is to move them into an unstocked pond before they mature and stop growing. This has proved to be an economically viable activity when premium prices are paid for large crawfish. Stocking rates of 400 to 500 pounds per acre in April or May have realized yields of 1200 to 1300 pounds per acre in 6-12 weeks.

Near the end of the crawfish season, stunting may take place in ponds dominated by annual vegetation or rice. This material will have either been decomposed by natural processes or will have been eaten by the crawfish. At such times food becomes a limiting factor; crawfish can no longer get out of each other’s way by climbing stalks of vegetation; and waters are warming rapidly. The result is that most of the remaining crawfish will mature at small sizes. Again, supplemental feeding may ultimately prove useful in correcting this problem.

**Monitoring Ponds and Predicting Yields**

A pond must be monitored to ascertain the status of the crawfish. They cannot be observed like row crops so they must be captured with dip nets or traps and measured. Predicting yield on the basis of information generated from pond monitoring is not an exact science, but monitoring can indicate whether there is a crop and how big it is. The accompanying figure shows how to measure crawfish in millimeters (Fig. 72).

**Collection of Crawfish**

**Nets and Traps.** Small crawfish, less than 50 mm (2 inches) long, should be sampled with small mesh—1/8-inch mesh or smaller dip nets. A net with the following dimensions is adequate: handle length, 3.5 feet; net frame, 1.5 feet wide by 1 foot high; net depth 1 foot or more. The net frame should be heavy-duty or reinforced at the joint with the handle. As crawfish approach 50 mm (2 inches) in size they become difficult to catch with a dip net. At this time a small mesh trap, 1/4- or 1/2-inch mesh, is helpful. Plastic-coated five-eighths-mesh crawfish wire is available commercially. It is much easier to handle than hardware cloth and is adequate for sampling (Fig. 73).

**Frequency of Sampling.** A pond should be sampled at least once every two weeks beginning shortly after it is almost completely flooded in the fall. Sampling once a week would be preferable, but the effort is probably not justified. A good pond manager should visit his pond daily and occasionally go around the pond at night with a head lamp.

**Sampling Effort.** One should try to obtain at least 50 crawfish with a dip net (100 would be preferable, but it is not always easy to catch 100 with a dip net) and at least 100 crawfish with small mesh traps.

Sampling ponds is tedious work. It can also be unpleasant if one has to use a machete to get to the water’s edge. Problems involved with high grasses around ponds include cuts from briars, wasp stings, and snake bites. In addition, young crawfish prefer
recently flooded, fine grasses to gather in. These are shaded out if pond banks are not cut.

When young crawfish are abundant, a hundred or more can be caught in several dips. At other times, no more than 30 crawfish of all sizes can be caught in an hour. Consistency should be observed, that is, with a dip every 30 to 40 paces around the edge of the entire pond. The net should be extended away from the bank and raked quickly back to the bank while the net frame is kept against the bottom. The number of dips made and the number of crawfish caught should be noted. Densities of crawfish can be calculated by dividing number of crawfish caught by the area sampled (area that the net covers times the number of dips made). There is generally no need to keep more than 100 crawfish when monitoring the pond with a dip net. But if and when 100 are caught, they should be kept for measuring later. Other crawfish can be released after they have been counted.

The need to sample the entire pond cannot be overemphasized. We have noted that in some ponds where small crawfish were present in about one half of the pond, there were few present in the remainder of the pond. Production was high, however, because the crawfish dispersed into the rest of the pond as they grew.

Most small crawfish congregate around the edge of the pond. However, if there is no cover there, they move offshore until they find it. This fact should be kept in mind when one is monitoring a pond. If it occurs, it will be necessary to dip in cover away from the shore.

Dipping for crawfish can be very difficult in early season if pond banks are grown up. First, it is difficult to get to the water, and second, it is hard to drag a dip net through the heavy vegetation. One may have to dip several times in one area to get a sample. Keeping levees mowed is very helpful.

One should try to maintain one or two small mesh traps per surface acre. More would be preferable, but they are expensive.

**Determination of Age Classes.** At this time, it is necessary to measure individual crawfish to determine age classes. To facilitate measurement, one can make a simple measuring board by gluing a flat, 6-inch (150 mm) plastic ruler on a flat 12 x 4-inch board, buttig it. It is easier to measure in millimeters, but millimeters may be converted to inches by dividing by 25.4. Dip net and trap samples should be kept separate from each other (Fig. 74).

The crawfish should be measured from the tip of the head (rostrum) to the tip of the tail by placing it ventral side (belly) down on the measuring board. Each measurement should be recorded and the number indicated in each size class (5-9 mm, 10-14 mm, 15-19 mm, 20-24 mm, 25-29 mm, 30-34 mm, 35-39 mm, 40-44 mm, etc.) on a separate record sheet (see Appendix example problem). When the total number of crawfish measured is obtained, one can determine the percentage of crawfish in each size class by dividing the number in each class by the total number of all crawfish measured, and multiplying by 100. The result is the percentage of all crawfish represented by that particular size class (Fig. 75).

When the percentages represented by each size class have been computed, age classes can be identified. There should be at least two or more groups of figures that stand out from those around them. For example, one might have:
The numbers 15 percent and 25 percent stand out clearly from those around them. Such numbers are termed modes. Each mode normally represents a specific age class of crawfish. Age class data should be recorded each time the pond is monitored for comparison during the season. Some members of an age class will be larger or smaller than the majority of the members of that age class. Modes may also overlap, especially in the spring when different age classes reach maturity and cease growth at about the same size.

As a monitoring program continues, the location of these modes will shift from the left to the right on the record sheet for that pond as the crawfish grow. Young-of-the-year appear to the left side of the record sheet as new age classes appear. (During very cold weather, growth may stop, and modes will stay constant for a time.) Dip net sample modes will normally get smaller as they approach 50-70 mm (2 to 2 3/4 inches). There are two reasons for this: first, crawfish become harder to catch as they grow, and second, a number will die naturally, reducing their total numbers. Such age classes should appear in the small mesh traps.

The same procedure should be followed with the measurements (data) from the small mesh trap samples. Small mesh traps should be used as soon as the dip net monitoring begins. See Appendix B for assistance in learning how to determine age classes from field data.

**Determination of General Magnitude of Crop (Potential Yield).** Table 17 will assist in monitoring a crawfish pond and predicting yield. It is based on work in open ponds (with and without rice) from one-quarter acre to 60 acres in size. If very few crawfish are caught through the fall and into the winter with a dip net (an average of one crawfish for every two dips), yield will be poor, probably less than 300 pounds per acre if that much. The presence of three age classes of young-of-the-year crawfish and sustained catch of about one small crawfish per dip into and following the colder months (mid-December to mid-February) indicates that yield should exceed 500 pounds per acre. It can approach 1000 pounds per acre if survival is good and average catch per dip is more than one crawfish per dip. A good rule of thumb for determining survival is to keep track of the average size of crawfish caught by dip net. Average size should increase gradually to about 50 to 65 mm (2 to 2 1/2 inches) by mid-February to early March. This indicates that crawfish are growing well and survival is good. The first age classes of young-of-the-year crawfish should be
Table 17. Seasonal monitoring of Louisiana crawfish ponds to predict yield

<table>
<thead>
<tr>
<th>Seasonal Small Mesh Dip Net Catch</th>
<th>Identifiable Age Classes of Young Crawfish</th>
<th>Production Schedule</th>
<th>Probability of Stunting</th>
<th>Potential Production Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct./Mid Dec./Late Dec./Mid Feb.</td>
<td>High to Spotty</td>
<td>High 5-6</td>
<td>Commercial catches (0.5-1 lb/trap) in Dec.; high catches in late March.</td>
<td>High &gt;700 lbs</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td>1-3</td>
<td>Commercial catches in November may be high, but low in spring.</td>
<td>High 100-300 lbs</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>Moderate 3-5</td>
<td>Commercial catches in Jan.; highest catches begin in late March—early April.</td>
<td>Low 700-1000 lbs</td>
</tr>
<tr>
<td>Moderate</td>
<td>Spotty</td>
<td>Moderate 2-4</td>
<td>Commercial catches in April.</td>
<td>Moderate 100-300 lbs</td>
</tr>
<tr>
<td>Low</td>
<td>Spotty</td>
<td>Moderate to High</td>
<td>Cannot be easily determined</td>
<td>Production probably too low to warrant harvesting.</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Dip net catch—high, over five per dip; medium, one to five per dip, and low, less than one per dip. Catch per dip is very subjective. In areas with heavy cover, several dips must be made to catch crawfish, though one dip would be sufficient in areas with short, soft-stemmed grasses on a gentle slope.

*Pond good candidate for supplemental stocking of small crawfish (40-70 per pound) if economics are favorable.

75-100 mm (3-4 inches) but the addition of younger and smaller age classes reduces the average size.

To determine the average size of the crawfish in dip net samples, add all measurements and divide by the total number of measurements (see Appendix B).

When the number of young crawfish stays one or more per dip, but average size varies and does not approach 50-65 mm (2 to 2 1/2 inches) through the fall and winter, survival is low. Either fish are killing and eating the young crawfish (fish will be caught in small mesh traps) or a problem such as low dissolved oxygen is causing high mortality.

One early sign that stunting may be a problem is the consistent catch of three or more small crawfish per dip during the fall. Average size will increase through the fall, winter, and early spring, but much more gradually than does in a pond where stunting is not a problem.

One should become especially concerned if young-of-the-year crawfish are not abundant by mid-November, and should keep checking for reproduction, as early recruitment may have died from poor water quality. But make no extensive plans for sales if young-of-the-year are still absent in late December.

It is important to sample the entire pond. Some ponds have few small crawfish present in about one half of the pond but have abundant supplies in the other half. Yield is high because the crawfish dispersed into the rest of the pond as they grew.

Elimination of an age class for any reason will have an adverse influence on yield. If a pond would be expected to yield about 1000 pounds per acre from three young-of-the-year age classes plus holdover crawfish, and the first young-of-the-year age class is lost, one might logically assume that yield will be cut by about 300 pounds. But this is not always the case because survival in the other age classes may increase in the absence of the first age class and compensate for the loss. Certainly, however, elimination of the first and second age class will serve to delay the period of onset of sustained catch per unit effort (see below). It is one thing to have a potential yield of 1000 pounds per...
acre, but it is an entirely different matter when it comes to actually harvesting that yield. A farmer may lose his maximum yield as a result of the inability to harvest the crop. Reasons for this include lack of labor (not available or too costly), lack of bait, and lack of market (a serious problem in April and May if a large wild crop drives the price down). Failure to harvest intensively invariably leads to a stunting problem.

As mentioned above, catch during December, January, and February is generally low—less than one pound per trap per night. The first age class of young-of-the-year crawfish becomes large enough to harvest, sometime between mid-February and late March, and catch exceeds more than one pound per trap per night and total daily harvest from the entire pond reaches a peak and remains relatively stable until the season ends. Since small mesh traps catch crawfish in the 2- to 3-inch size category, use of such traps will permit one to follow growth of crawfish to harvestable size. Modes for each age class will shift to the right size of the record sheet from one sampling period to the next. The amount of shift will give the growth rate for every sampling period. For example, if the first age class of young-of-the-year is about 50 mm (2 inches) long on January 15 and is 62.5 mm (2 1/2 inches) long on January 30, the growth rate is 6.25 mm (1/4 inch) per week. Thus, they would be expected to reach 77.5 mm (3 inches) in size by February 15.

If dip net catch is consistently very low into the spring, trapping may not be really successful until middle or late April. Trapping then becomes very successful and crawfish are almost always 4 1/4 inches, or larger. Overall yields are normally not over 300 pounds per acre. An explanation for this phenomenon is not readily apparent.

A problem that is encountered with small mesh traps is that small crawfish will often avoid them in mid-spring if they are full of large crawfish. In fact, if regular trapping does not reduce numbers of harvestable crawfish fast enough, younger age classes will grow to harvestable size before they actually enter traps. However, if catch in the regular traps falls off and catch of small crawfish in small mesh traps is poor, one can be relatively sure that further yields will be low. Conversely, if catch in regular traps falls off but many small crawfish are caught in the small mesh traps, yields will be good.

Other Pond Monitoring Methods. Dip net samples do not adequately sample crawfish over 2 inches in length. Conventional seining is effective in open water, but emergent vegetation makes this difficult in most ponds. One way to solve this problem is to add a heavy chain to a seine's lead line. This will knock down soft-stemmed vegetation and provide a more representative sample of the pond's crawfish population. It is also an effective way of obtaining modest numbers of soft-shelled and premolt crawfish. Seines are useless in ponds with thick-stemmed vegetation and extensive algae mats. In addition, seines require two operators.

Some specialists report success in sampling ponds by dragging a small-mesh dip net through the pond from a harvesting boat. Such a net should have a heavy-duty handle and frame, and great care should be exercised to avoid stumps and other fixed objects, lest the operator be thrown from the boat.

It is possible to make a sorting table from different meshes of hardware cloth at different levels. The crawfish are dumped on the upper, coarsest mesh. They subsequently sort themselves, with the smaller ones falling downward, until a lower mesh retains them. There is some disagreement about the number of meshes needed to separate the crawfish into legitimate age classes, but this is definitely a labor-saving technique.

Crawfish and Waterfowl Management

The vegetation grown in crawfish ponds produces seeds, corms, and tubers that are relished by waterfowl. Ponds in which rice was intentionally cultivated for harvest or crawfish fodder are especially attractive to waterfowl. Shallow water and the proximity of natural feeding and nesting areas add to the lure of crawfish ponds. Thus, one can expect crawfish ponds to generate waterfowl hunting and they do, providing owners with recreation and additional income from those willing to lease hunting rights.

There are some problems with crawfish-waterfowl management. Waterfowl are generally most abundant in ponds after sunset and before dawn, feeding and roosting in the ponds during the night, before and after legal shooting hours. The least disturbance tends to drive them from the crawfish ponds during the day. Thus, extensive crawfish harvesting substantially curtails waterfowl hunting in crawfish ponds. The most successful waterfowl hunting invariably occurs during cold, stormy weather and anyone hunting at a pond should be flexible enough to take advantage of weather changes. Also, most waterfowl prefer to land in open areas, and these should be available. Finally, shallow water levels, about 12 inches, are
required for the more sought-after puddle ducks like mallard, pintail, teal, and widgeon. If there is much slope in a pond, substantial areas may have little or no water over them during the late fall-early winter waterfowl season.

Marsh-type impoundments managed strictly for waterfowl can produce crawfish crops. These systems are drained in the summer to permit the growth of various waterfowl feeds and filled during the fall, winter, and spring. Generally, crawfish production has been low, 100 to 300 pounds per acre. The major problem has been one of water quality. Waterfowl impoundments are usually so large that pumps are ineffective in circulating water to improve water quality. Also, vegetation biomass is generally great and this complicates oxygen problems, especially if ponds are filled before the weather cools in the fall. There is no doubt that ducks, especially diving ducks, and coots eat crawfish. There is probably little real damage as compared with that caused by low oxygen levels; however, definitive research is necessary to assess the severity of this potential problem.

Green tree reservoirs are swamp areas that are drained in the spring and filled during the waterfowl season. Trees like water oaks produce mast (acorns), which is actively sought by puddle ducks. Theoretically, there is no apparent difference between green tree reservoirs and wooded, swamp-type crawfish ponds. However, green tree reservoirs are usually drained in March, two to three months before swamp crawfish ponds are drained. This is done to prevent stress and damage to the desirable mast-producing trees in the reservoirs but is contrary to good crawfish pond management. Research needs to be conducted on the effects of extended flooding on mast-producing trees in green tree reservoirs before crawfish cultivation can be advocated in them.

POLYCULTURE: CRAWFISH AND FISH

Normally one should eliminate fish from crawfish ponds since most will eat crawfish; however, one can produce a crawfish crop in some fish ponds. To do this, fish that cannot eat crawfish must be stocked. Such fish are either the small ones of such species as catfish, bass, and sunfish or ones that normally do not eat crawfish—minnows and some tilapias. Or crawfish and fish can be separated physically. There are several options for this. Fish can be raised in cages. Crawfish can be raised in sump areas or waste control ponds below, above, or between fish ponds. Finally, if there is a fairly extensive section of shallows in a pond that can be flooded at the appropriate time by water level manipulation, fair crawfish populations will develop as long as there is a good cover crop of grasses and emergent weeds growing in the area while it is dry. The vegetation serves as food and cover for the crawfish.

One polyculture scheme that worked well in Louisiana involved the use of crawfish, buffalo fish, paddlefish, and catfish. The ponds were treated as if they were regular crawfish ponds with early fall flooding. Crawfish were harvested during the winter and spring. During the spring, buffalo fish and paddlefish, neither of which eats crawfish, were stocked loose in the ponds and channel catfish were stocked in cages. When most of the crawfish had been harvested and those remaining had burrowed in late spring, the catfish were released into the pond. In addition to 1000 pounds of crawfish per acre, about 3000 lbs of fish were harvested per acre in the early fall of the next year. Although the ponds were not reflooded until December, there was a fair degree of crawfish recruitment. Growth was poor because there was almost no vegetation in the ponds to serve as food and substrate. Yield of crawfish was less than 225 pounds per acre.

It is clear from the above that second year crawfish yield with such a polyculture scheme is poor unless feed is added to ponds and, if necessary, young crawfish are stocked to supplement natural reproduction. It was suggested that the ponds be allowed to remain fallow but flooded during the second crawfish season and if necessary stocked with adult crawfish in late spring and followed by routine pond draining and pond flooding the following fall. Fish would not be stocked again until the following spring.

In one study, 5- to 7-inch fingerling channel catfish were stocked directly into small experimental crawfish ponds in late September at rates up to 5000 per acre. Crawfish production was as high as 1000 pounds per acre and was adversely affected only in ponds that were contaminated with green sunfish. Catfish growth was poor; the production was around 500 pounds per acre, but this was attributed to poor water quality and low winter growing temperatures. The catfish were only one year old when harvested in late May and had reached the so-called stocker size suitable for growth to one pound in four to eight weeks.

Crawfish production up to 800 pounds per acre has been generated during the summer in small ponds stocked with freshwater prawns, Macrobrachium rosenbergii. These ponds had
well-established crawfish populations but were fallow and dry for most of the winter and spring. They were drained completely, refilled, and stocked with post larval prawns (1/2-inch) in May. Most of the crawfish were harvested from mid-June to mid-July. The crawfish generally disappeared when, in early August, the prawns reached a size large enough to kill them. Similar predatory relationships, in which large prawns eliminated crawfish, have also been observed in tropical Hawaii.

Tilapias (Sarotherodon spp.) grow well in shallow ponds such as those used to cultivate crawfish. This is a possible summer crop in areas of the United States where these exotic fishes may be cultivated, though no tilapia is legal in Louisiana. One report from Zambia suggests that crawfish may, in fact, interfere with tilapia spawning by disrupting activities in nests. If this is true, crawfish should be most useful in controlling the overpopulation of tilapia and the resultant stunting, the most common management problem in tilapia culture. Tilapias do not normally prey on crawfish.

**ARTIFICIAL SPAWNING OF RED CRAWFISH**

At this time, setting up hatcheries and stocking small red swamp crawfish in ponds is not practical because it costs too much to be competitive with natural reproduction in crawfish ponds. However, the production of young crawfish on demand will undoubtedly become important in crawfish farming in future years, especially as high-value products like soft-shelled crawfish make it feasible to manage ponds intensively.

A method for producing young red swamp crawfish for laboratory use during most months of the year has been developed by Dr. Joe B. Black of Louisiana College in Pineville. It is relatively simple. Mr. and Mrs. John Wright of the Newberry Crayfish Hatchery in Santa Barbara, California, developed a somewhat similar but large-scale method to produce small crawfish. Mr. Donald Gooch modified Dr. Black’s method while he was director of the Crawfish Center at the University of Southwestern Louisiana to permit more cost-effective production of small crawfish for early autumn. These methods are discussed as follows.

**Black Method**

Adult breeding specimens are maintained in individual glass stacking bowls, 8 x 3 inches (obtainable from almost any biological supply company). No aeration is needed if the water is not too deep and is not fouled by overfeeding. A substrate of pea gravel covers the bottoms of the bowls and water levels are kept at about 1 1/2 inches, or just enough to cover the crawfish. Water is changed every seven to ten days. In most cases, chlorinated tap water can be used, but it is best to age it a day or so.

Feeding is simple and cheap. Though they eat almost anything organic, crawfish are basically scavengers and detritus feeders. Green aquatic plants such as alligator weed or elodea, which is preferable, are added to the bowls to provide food and oxygen. Rotted leaves from a compost pile are added and seem to provide the greatest bulk of the food consumed. Though maple is a good choice, any type of hardwood leaf can be used. Dr. Black uses water oak extensively. If dry, the leaves should be soaked first. Three times weekly a small portion of high protein feed such as the new crawfish feeds or dry cat or dog food is added for each crawfish. Do not feed them more pellets than they will eat in 15-30 minutes.

The crawfish are kept indoors at an average temperature of 73 to 79°F. No attempt is made to vary the amount of light to which the crawfish are exposed, about 12 to 14 hours of light per day, but lights are used at night only for emergencies.

A mature, Form 1 male crawfish (enlarged claws and hooks on the bases of the walking legs) is added to a bowl containing a single, mature female crawfish (claws somewhat enlarged and distinct groove in the sperm receptacle). Breeding is more likely to be successful under these conditions than if the female is placed into a bowl with a male. After successful mating, the sperm receptacle of the female contains a clear gelatinous sperm plug. The entire mating process usually lasts about 15 to 25 minutes, after which the male should be removed and returned to his own bowl. Records should be kept, as males may be sterile or the same female may be bred to several different males if paternity is not a concern.

It is possible to obtain an estimate of the time that eggs will be laid by observing the female’s glair glands. These are structures on the bottom of the tail fan and around the bases of the abdominal appendages (swimmerets). They are not normally distinct but as the time for egg laying approaches, the glair glands enlarge and become white patches. These are especially apparent on the tail fan. The glair glands produce a mucus-like material that protects the eggs as they are laid. One can also look directly at the eggs by raising the top of the carapace carefully while depressing the abdomen. A strong beam of light is very useful for this purpose.
Dark brown eggs filling the body cavity, along with enlarged, white glair glands indicate that egg laying is about to take place.

Two months after mating (average time, four to six weeks), the female will produce a clutch of 100 to 400 eggs, the number depending to some degree on the size and age of the female. The eggs are dark gray to black, if fertile; orange, if infertile. These are cemented onto the abdominal appendages (swimmerets) of the mother for another couple of weeks. When most of the young have been released from the mother, she should be transferred to another bowl to prevent cannibalism. The young can be retained in the brood bowls. Some cannibalism will occur, with young feeding on newly molted brothers and sisters, but this can be held to a minimum either by providing cover for the molting young or by distributing them among several containers.

The female usually molts a few days after the young become independent and starts feeding aggressively. During this stage the female is not receptive to the male and cannot be induced to mate; indeed, a smaller male left overnight with the female will often be eaten. After a couple of months, the female will molt again and can be mated once more for a subsequent brood; however, a male should not be placed with a newly molted, soft-shelled female. Allow two to three days for the exoskeleton to harden. Females maintained as just described will regularly produce two and occasionally three clutches of eggs yearly.

Replacements for the older breeding stock are selected from the larger and more aggressive young in each hatching and placed in individual bowls. These are usually ready for breeding within three to four months. It is especially important to start with young crawfish and raise them in the bowls (or other containers) in which they will spend most of their lives. The crawfish grow up to three inches in the small bowls used by Dr. Black, though they could grow larger in a larger bowl. Trying to confine, grow, breed, and spawn larger crawfish in these bowls is usually not successful because the animals are not accustomed to such confinement.

The nursery containers used by the Wrights are gallon-sized plastic bottles such as those used for bleach. A round hole is cut in the top for access and the females are deposited there in about two inches of water. Incubation takes two to three weeks at 72°F. The crawfish are normally not fed, and water is changed every three to four days. The young crawfish are removed when they can swim freely and are placed in shallow (six inches deep) troughs for about 30 days until they reach an inch in length. Stocking densities are about 20-30 per square foot. Water is slowly trickled into the containers to replace evaporation losses and the young are fed cut fish, cracked corn, baby food, and vegetables. Survival is 80-90 percent, well above the estimated 10-20 percent in ponds.

Gooch Method

Adult females are collected from ponds in mid to late spring, having already been bred. They are placed individually into six-inch lengths of PVC pipe, four inches in diameter, which are arranged vertically in a shallow trough containing one to two inches of water. The tops must be covered. Trough size should be such that the pipes fit tightly and will not move readily. There will be some mortality over the first two to three weeks of confinement. Dead females need to be removed and replaced. Water should be changed if it fouls, but there should be no feeding and aeration is not required. Of course, water level must be held at the one- to two-inch level. These troughs are kept in a cool (70-72°F), relatively dark place. The majority of the females will lay their eggs during the period from mid-September through mid-November, with most laying during October. See Fig. 76 for a modification.

Wright Method

Adult breeders are held in shallow troughs five inches deep at densities of one to two per square foot and a sex ratio of one male to one female. They are not grown in the tanks but are fed. After females lay eggs, they are removed from the breeding tank for “incubation” in nursery containers. This should not be done until the eggs have firmly set on the female’s swimmerets, about 72 hours.

Fig. 76. Albert Gaudé demonstrates modifications of the Gooch red swamp crawfish hatchery system. Photo: J. Hurley.
of this method. [Note: Pipe sections may also be placed in cafeteria trays and stacked several high.]

Off-Season Production and Other Species

To produce young red swamp crawfish in large numbers at any time other than mid-autumn, one would have either to raise his own broodstock out of synchrony with the normal pond hatch or obtain adult crawfish from ponds. Young-of-the-year crawfish generally do not mature until the March-April period because colder winter temperatures slow growth. In contrast, they can mature in about two months in a warm hatchery so long as they have adequate growing space and food. Adult crawfish can sometimes be obtained in the December-January period from ponds; however, we must emphasize that no one has, to our knowledge, actually produced young by stocking such crawfish in a Gooch system. Theoretically, it should work, but we must await proof before we can advocate that approach.

The reproductive activities of many crawfish species are affected by temperatures and photoperiods. It is not clear yet how the manipulation of these factors affects red swamp crawfish, so it is not possible at present to make recommendations about off-season production of young.

The methods described above were developed using the red swamp crawfish and are effective with this species. Results with the white river crawfish (Procambarus clarkii) have not been as consistent, so we cannot make any recommendations for producing young of this species.

GENETICS

Studies of crawfish genetics have generally been neglected by the scientific community, though limited information is available about karyology, the number and morphology of chromosomes. The number of chromosomes in the red crawfish is approximately 188, compared with 46 for humans.

Inheritance of simple color patterns has been discussed in the biology section. Heterozygosity, the amount of genetic variation, has generally been reported to be low in crawfishes. Heterozygosity is important to selective breeding programs because it is easier to breed organisms selectively if heterozygosity is great. In one study comparing heterozygosity in red crawfish, Dr. Craig Busack found that there was little heterozygosity in red crawfish populations around the U.S. Dr. Busack also studied white crawfish populations from around the U.S. when all were considered to be P. a. acutus. He found considerable heterozygosity, by crawfish standards. This helped to justify the separation of this "species" into three species by Dr. Hobbs.

Dr. William Wolters of LSU and his students Mr. Joe Craig and Dr. Gregg Lutz have studied selective breeding in red crawfish, examining for growth, body size, and processing traits. They concluded that it should be possible to genetically improve growth and dressout percentage. Drs. Wolters and Lutz also addressed the topic of negative selection as a consequence of current pond management practices. That is, the selective trapping of the largest, fastest growing crawfish could lead to negative selection for growth. However, they concluded that current harvesting practices in commercial ponds pose little threat of negative selection on harvested ponds.

MANAGEMENT PROCEDURES IN LOUISIANA AND ELSEWHERE

Basic management procedures in Louisiana are summarized in the sections on natural feeds and crop rotation and Tables 18 and 19. Elsewhere, winter crawfish growth is so slowed in middle south latitudes (Arkansas through central California) that low latitude (southern Louisiana and southeastern Texas) management schemes specifying rice in the warm months and crawfish in the cool months are not feasible. When pesticide use is minimal in middle latitude rice fields, significant quantities of crawfish accumulate in drainage canals when waters are drained before rice harvest in the late summer. These crawfish have only recently been exploited commercially but on a very limited scale. This is essentially the same way that red crawfish are "managed" in Spain.

OFF-SEASON CRAWFISH PRODUCTION IN THE SOUTH

Until recently, there was no real reason to produce crawfish during the warm summer months when ponds are normally dry in the south. Now, premium prices are paid for crawfish during the summer months in some areas, and there are markets for bait-sized crawfish grown in the summer. Finally, producers of soft-shelled crawfish are interested in obtaining hard-shelled crawfish during the summer to permit year-round production of soft-shelled crawfish. Crawfish, primarily red
Table 18. Louisiana crawfish pond management procedures.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Approximate Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction and flooding (new pond)</td>
<td>By 15 May</td>
</tr>
<tr>
<td>Stocking (new pond)</td>
<td>15 April - 30 May</td>
</tr>
<tr>
<td>Draining</td>
<td>Draining may begin as early as 15 May but should not begin until at least 2 weeks after stocking in new ponds.</td>
</tr>
<tr>
<td>Fish control</td>
<td>15 June - 15 August</td>
</tr>
<tr>
<td>Improvement and vegetation control of planting</td>
<td>As soon as possible after bulk of pond is drained.</td>
</tr>
<tr>
<td>Pumping/circulation</td>
<td>Two weeks after pond is filled, circulate water until water temperature falls below 65°F. Exchange water on a weekly basis (more often, if possible). Circulate again in the spring, if necessary.</td>
</tr>
<tr>
<td>Harvest</td>
<td>Old pond 25 November–mid June, continuously during mild winter, intermittently during severe winter in November, check to make sure that no more than 10% of females have mature eggs. New pond 20 December–mid June if hatch successful.</td>
</tr>
</tbody>
</table>

Louisiana Off-Season Crawfish Production Cycle

- **November–December**: Stock brook crawfish, drain pond, plant forage (wheat/rye grass)
- **December–April**: Grow forage.
- **April–May**: Fill ponds with water 24 to 36 inches. Natural recruitment of young crawfish.
- **June–October**: Harvest crawfish.

*Average yield in one test was 850 pounds per acre with the range being 360 to 1,200 pounds of crawfish per acre.

South Carolina Off-Season Crawfish Production Cycle

- **February**: Fill pond with water to a depth of 36 inches. Natural crawfish recruitment (no supplemental stocking).
- **February–September**: Feed crawfish supplemental hay and alligator weed.
- **June–Harvest crawfish  September**
- **October–November**: Drain pond and repeat cycle.

*Average yield in one study was 1,000 pounds per acre.

Texas Off-Season Crawfish Production Cycle

- **March**: Plant rice as crawfish forage.
- **March-May**: Raise water levels as rice grows. Stock 100-300 pounds of crawfish per acre.
- **July–Harvest crawfish  September**
- **October–March**: Drain pond or keep pond filled for autumn, winter, and spring production.

*Ponds have been stocked with very small crawfish at sizes above 50 per pound. Production can reach 1,500 pounds per acre.

**PRODUCTION OF CRAWFISH FOR FISH BAIT**

Crawfish are important foods for many species of sport fishes, and thus are very popular fish baits. Manufacturers of fishing lures have produced...
Table 19. Life cycle of a Louisiana crawfish pond.

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Indicates that a process is occurring at a reduced rate.

*New ponds.

Old ponds. 25 Nov. (if less than 10% of females with well developed eggs); new ponds. 20 Dec.

numeros lures that mimic live crawfish to capitalize on this biological phenomenon. Both hard and soft-shelled crawfish may be used, although soft-shelled crawfish are superior baits and command much higher prices. Unpeeled tails make excellent baits for larger fishes like catfish and freshwater and saltwater drums. Peeled tails are equally attractive to sunfish, perch, and carp.

Over 100,000,000 pounds of crawfish are harvested annually in the United States and the red swamp crawfish accounts for at least 80 percent of this total. Therefore, by sheer volume, it has the potential for overwhelming bait markets. Most of this total is grown in ponds or harvested from natural waters in Louisiana during the November-May period. Markets for bait crawfish in the heavily populated midwest and northeast have been restricted to summer months when local crawfishes are abundant. So far, no distribution systems have been developed for the bountiful supply of Louisiana crawfish to permit capitalization on winter and spring fishing seasons in these regions.

Products

Bait crawfish buyers usually speak in terms of numbers per pound (count) or pounds per thousand crawfish. Preferred sizes for live hard crawfish for fish bait are 50 to 200 per pound depending on the target fish species. These crawfish are abundant but usually rejected by crawfish processors for food because of their small size. Depending on target fish species, the whole crawfish, the unpeeled tail, or the peeled tail could be used for bait. Inquiries about frozen crawfish for bait have been received for over a decade in Louisiana but no processors have seriously pursued such a market outlet.

One unique crawfish bait form is preserved in formalin. Very small crawfish, 1 1/4 to 2 inches
long, are preserved in 5 percent formalin. This is accomplished by placing live crawfish in a solution of one part of 37 percent formalin (full strength) plus 19 parts of water for about a week, washing them in fresh water, and flavoring them with an attractant like oil of anise. The absolute market potential for such a product is not clear when one considers how many successful soft-bodied artificial crawfish lures are now widely available.

Harvesting

Crawfish are harvested with baited traps or some form of dip net, seine, or trawl. Advanced premolt crawfish which are about to shed their shells (less than three days to molting) will usually not enter baited traps. Therefore, trapping is the best method for obtaining premolt crawfish that will not be subject to molt stress when handled and moved to market. However, thin-shelled postmolt crawfish readily enter traps seeking food after shedding their shells. Rapidly growing crawfish, regardless of species and size, molt on a 10 to 20 day basis. Therefore, it is wise to know an individual population's molt cycle when planning harvesting and shipping schedules.

Smaller crawfish are more active during the day than larger crawfish. Therefore, day-time trapping produces higher proportions of small crawfish than night-time or overnight trapping. Trap mesh size also affects size of crawfish caught. Large crawfish often keep small crawfish out of a trap even if they cannot get into it themselves. If this is a problem, the larger crawfish need to be captured and removed from a pond.
Nets are not selective when it comes to harvesting crawfish. Anything in a net's path is caught. Therefore, one may catch significant numbers of fragile early postmolt, advanced premolt, and soft-shelled crawfish as well as intermolt, hard crawfish. This requires sorting which is not widely practiced in the crawfish industry. Both soft-shelled and late premolt crawfish may be frozen and sold later for bait. These bait forms are not as popular as live animals but are generally much more effective than hard crawfish. The angler can easily remove the old, brittle shell from a late premolt crawfish, live or thawed, and it will be almost as effective as a soft-shelled crawfish. Premolt crawfish can also be kept alive in a bait bucket as one would keep minnows and they will often molt during the fishing trip.

The same concerns about molt cycles in planning the trap-harvesting of bait crawfish must be considered in net harvesting of bait crawfish. Using some form of bait to “chum” an area can reduce the numbers of soft-shelled and late premolt crawfish that are caught. Harvesting at night can usually produce higher numbers of large crawfish, as they tend to be more active than during the day. Some crawfish producers in the midwest tie pieces of bait onto a 20- to 30-foot seine and then lay it in the water along the pond bank with the lead line out the deep end. Many crawfish can then be caught by quickly lifting the two ends after a “set” of 15 to 30 minutes.

Handling and Shipping of Bait Crawfish

Crawfish need to be purged for 24 to 48 hours to allow for the elimination of wastes from their digestive systems. Nonmoltling crawfish, as a rule, can be held at a density of about 50 per square foot either submerged with aeration or partially submerged (water 1/2 to 1 inch deep). The water has to be exchanged several times during the first 24 hours to remove wastes and to prevent accumulations of pathogenic bacteria and toxic levels of ammonia. If the crawfish can raise their heads (cephalothoraxes) to the surface in a shallow system, they can use atmospheric air and survive; however, they much prefer to be kept in water with oxygen levels above 3.0 parts per million.

No hard and fast rules can be provided for holding submerged crawfish. Warm water fishes can be held at several pounds per cubic foot of water with heavy aeration after they have been purged. However, crawfish must have vertical partitions in the water column in a deep tank (most holding tanks are about three feet deep) because they cannot suspend themselves in the water column as fish do. Crawfish have no swim bladders and cannot “float.”

Obvious premolt, soft-shelled, and tender postmolt crawfish have to be separated from the firm, intermolt hard-shelled crawfish. If this is not done, mortality will be great. These vulnerable crawfish are excellent fish baits but require special handling. Intermolt crawfish can be shipped by air in water-saturated, sealed boxes. Abrupt temperature changes must be avoided and temperature should be in the 60° to 70° F range. Packing material (sphagnum moss, shredded newspaper, etc.) should be saturated with water, but water must not accumulate on the bottom of the container, especially around crawfish on the bottom. Crawfish should be packed one layer at a time (one crawfish deep) with partitions between layers to prevent the crawfish from being crushed.

Crawfish can be shipped in oxygen inflated plastic bags (heavy gauge) with wet packing material to minimize weight and jostling. Again, they should be purged before shipping.

Some bait dealers haul live hard-shelled bait crawfish in plastic grape bags (boxes). These are equipped with wooden “shoulders” so they can be stacked without crushing the crawfish.

Shipping times should be as short as possible although tests have shown that properly packaged, purged hard red swamp crawfish can easily survive 72 hours without major mortality so long as they are in water-saturated air (100 percent humidity). Check with private carriers (including the bus lines) and the U.S. Postal Service for the best rates.

Live soft-shelled crawfish can be shipped as hard-shelled crawfish but they must be chilled, 40° to 45° F. This stops the hardening process. They have to be layered in packing material, one layer thick, to minimize shipping damage. Though they will hold for several days under such conditions, they need to be moved and sold quickly.

SOFT-SHELLED CRAWFISH

Small soft-shelled crawfish (50 to 100 per pound) have long been produced in the northern states for fishbait. Crawfish about to shed their shells are caught with seines in small ponds and held in tanks or troughs for 12-48 hours until they molt. They are then refrigerated and sent to market.
The production of larger soft-shelled crawfish for the gourmet food market began several years ago in Louisiana and surrounding states. Sizes have ranged from 15 to 35 per pound, with the average being about 25 per pound. Most of these crawfish are produced by catching immature crawfish in traps, confining them in shallow trays, feeding them, and, just before they molt, placing them into molting trays. Recommended stocking rate is one pound per square foot at temperatures around 80°F. Recirculating systems are used to conserve water and heat and to maximize efficiency.

Although imminent molt (late premolt) crawfish are periodically abundant in crawfish ponds, no system has been developed that permits their easy capture in ponds for transfer to molting containers. There is generally too much vegetation in ponds to permit conventional seining. However, several machines with trawl devices have been developed for harvesting crawfish (see harvesting section) and should soon have a major impact on the soft-shelled crawfish industry. A discussion of the molting process is presented in the biology section of this text.

Detailed information about soft-shelled crawfish production is available from a number of texts listed in the bibliography at the end of this book. Note that production systems were developed with the red crawfish as the target organism. Although white crawfish molt readily in confinement, they do not molt as rapidly as red crawfish when confined in the intermolt stage and fed at high densities in shallow trays.

OTHER SPECIES OF AMERICAN CRAWFISH SUITABLE FOR CULTIVATION

Crawfish are now grown in earthen ponds by establishing self-perpetuating populations. This effectively limits crawfish culture to a few species, including P. clarkii and the white crawfishes (P. a. acutus, P. zonangulus, and the undescribed species) in much of the United States and Orconectes immuns in the midwestern and northeastern U.S. Orconectes im-munis is very similar to red and white crawfish in life cycle and adaptability to earthen ponds with alternate wet-dry periods. But it rarely exceeds 2 1/2 inches in length and is cultured almost exclusively for fish bait.

Several species of Procambarus perpetuate in earthen ponds and can probably be cultured. These include Procambarus fallax and Procambarus troglodytes on the lower east coast; Procambarus alleni in Florida; Procambarus hayi in the central south; and Procambarus simulans in the lower and central south. P. troglodytes is very similar to P. clarkii and is hard to distinguish from it, but taxonomists insist that it is a separate species. All of the Procambarus species mentioned except P. alleni reach sizes over four inches.

In the central U.S., three Orconectes species, Orconectes rusticus, Orconectes viridis, and Orconectes nais, grow well in fish culture ponds that are dried each year in the winter as a sanitation practice. These species probably warrant further attention if demands for crawfish rise, but O. rusticus, at least, was all but eliminated from one set of Ohio ponds by P. clarkii. Thus, in Stocking crawfish, care must be exercised to identify the species.

Should hatchery production and stocking become economically viable, Pacifastacus leniusculus, the northwestern U.S. signal crawfish, can be cultured, particularly in cooler waters—55 to 70°F. In fact, they are cultured and stocked in Europe where high prices make it profitable to do so.

There are over 350 species of crawfish in North America. It is doubtful that P. clarkii and the white crawfishes are the only ones suitable for culture. However, P. clarkii has been the most widely publicized and introduced species. Introductions in areas where this species is not native have been made without any real effort to screen native species for suitability for culture. Ecologists and taxonomists speak disparagingly about this because introduced species have eliminated native species. Yet one would never think twice about moving cattle, sheep, and goats about the world, even though native herbivores might be suitable for domestication. Regrettably, time and funds for screening species are rarely, if ever, available, so that prospective farmers are limited to those species that have been successful elsewhere.

Those concerned about introductions and finding suitable crawfish for culture need to identify species already growing in area fish hatchery ponds. They have already been able to adapt to pond life and it might prove profitable to culture them in favor of nonnative species. However, identification is crucial, as P. clarkii has become well established in Indiana and Ohio fish hatchery ponds after being introduced with minnows from other states.
AUSTRALIAN CRAWFISH

Australian crawfish belong to the family Parastacidae and over 100 species have been identified. Sizes range from less than one-half ounce to over six pounds. The five largest crawfish include: Astacopsis gouldi (to 7 1/2 pounds), Cherax teniumanus (to 3 pounds), Cherax destructor (to 1/2 pound), Eucastacus armatus (to 5 1/2 pounds), and Euastacus australasiensis (to 1 1/2 pounds). The Australian government has been interested in promoting crawfish culture and has investigated marron C. teniumanus and yabby C. destructor for culture potential. More recently, the Queensland marron, or Queensland red claw, C. quadricarinatus, intermediate in size between marron and yabby, has drawn considerable interest in Australian aquaculture circles. The other species, although large, have a small abdomen compared with the head and are slow growing. None is currently considered suitable for culture. The largest, Astacopsis gouldi, is a cool-water stream dweller and is unsuited for aquaculture in earthen ponds.

C. destructor is very similar to P. clarkii in its habitat requirements and readily adapts to earthen ponds. C. teniumanus is naturally found in permanent streams but has promise as a candidate for culture in earthen ponds. One main difference between culturing the Cherax species and culturing P. clarkii is that the Australians often produce the young crawfish outside the pond and stock known numbers at rates up to 15 per square yard. However, adults may also be stocked to establish sustaining populations. The Australians also “feed” their crawfish with chicken mash, alfalfa pellets, hay, and other agricultural by-products. Rates up to two pounds per square yard have generated good results. Production has exceeded 2000 pounds per acre in one four- to five-month growing season, but size is roughly two to three ounces—this compared with P. clarkii sizes of one ounce.

Many people have inquired about the feasibility of importing various Australian crawfish to the United States. There are several major reasons why this is not a sound idea. Biologically, we do not know what effect they will have on American ecosystems. They could become as serious a “pest” as P. clarkii has become on the West Coast. Also, all of the Australian crawfish are believed to be highly susceptible to the crawfish plague (see disease section), which is known to exist throughout the United States. American crawfish tolerate the plague but a well-established crawfish farm stocked with Australian crawfish might be ruined in a few days.

There are also legal considerations. For example, the Australian government restricts the export of several species of crawfish. In general, most states require that one obtain a permit before importing any nonnative aquatic species, even P. clarkii, and failure to do so is a violation of federal law. Penalties can be very stiff and can involve prison sentences. Certainly, anyone contemplating the culture of any Australian crawfish would be well advised to secure reliable counsel such as someone with the local cooperative extension service.

CRAWFISH ASSOCIATIONS

The International Association of Astacology (crawfish biology) publishes an international newsletter, a directory of astacologists, and its periodic symposium proceedings. Its official domicile is the University of Southwestern Louisiana, Lafayette, Louisiana 70504.

Several states have crawfish associations of various types. These include Louisiana, Texas, Arkansas, South Carolina, North Carolina, and Maryland at this writing. Local Cooperative Extension Service offices can assist in locating addresses. The Louisiana Crawfish Farmers’ Association is, by far, the largest of these associations, and publishes a quarterly magazine entitled Crawfish Tales. The LCFA’s current address is P.O. Box 9656, New Iberia, Louisiana 70562.

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