

LOUISIANA CRAWFISH PRODUCTION MANUAL



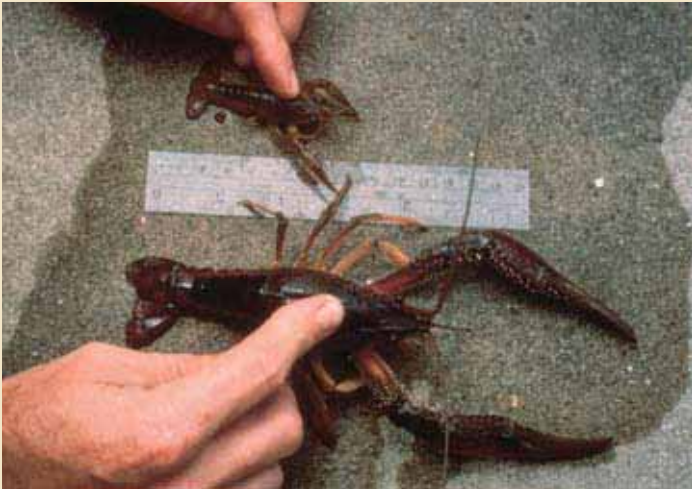


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Figure I.1. Although they are outwardly similar at first glance, a number of characteristics distinguish the red swamp (left) and white river crawfish (right).

Whether from managed ponds or wild habitats, Louisiana's crawfish harvests are composed of two species – the red swamp crawfish (scientific name: *Procambarus clarkii*) and to a lesser extent the white river crawfish (scientific name: *Procambarus zonangulus*) (Figure I.1). Although scientists in other parts of the world use the term “crayfish” for these and all related species, in this manual we refer to these two species as “crawfish” to reflect not just their common names, but also the widespread use of the word by producers, marketers and consumers in Louisiana and elsewhere in the United States.

Louisiana's crawfish farming industry has grown to include more than 1,200 farms occupying more than 120,000 acres. Production from wild habitats, mainly the Atchafalaya River basin, varies from year to year. Total production for the 2004-2005 season was more than 82 million pounds, with almost 74 million pounds from farms and more than 8 million pounds harvested from natural habitats by approximately 1,100 fishermen. The farm-gate and dockside value of the 2004-2005 harvest exceeded \$45 million.

Crawfish ponds have no standard size, but most are between 10 and 40 acres, and most producers manage 150 or fewer acres (Figure 1.2). Occasionally, a single pond may include more than 1,000 acres, especially in bottomland areas where water levels are manipulated in natural habitats for crawfish production (Figure 1.3).

Formulated feeds are not used to produce crawfish. Instead, rice, sorghum-sudangrass or natural vegetation is grown in the summer (when ponds are drained) to serve as the base of a natural food chain for crawfish. Crawfish ponds are not stocked



Figure I.2. Although there is no “standard” crawfish pond, a successful pond must be built on flat land that will hold water and support a forage crop for the crawfish.



Figure I.3. In some parts of Louisiana, semi-natural habitats are impounded to allow for crawfish production through control of natural hydrological cycles.

with hatchery-reared young as in other forms of aquaculture. Farmers rely on reproduction by unharvested crawfish from the previous year or on mature crawfish that are stocked to produce young naturally.

Educational and technical assistance in all aspects of crawfish production and marketing is provided by the LSU AgCenter through the Louisiana Cooperative Extension Service in every parish. Help is available through individual consultation, on-farm visits, production meetings and publications (Figure 1.4). Anyone considering going into crawfish farming should review current financial budgets available from the LSU AgCenter and discuss the feasibility of their projects or business plans with an extension professional who can identify the best available data for making decisions as to how to proceed. Louisiana Cooperative Extension Service agents and specialists are the best source of information on the feasibility of farming crawfish in your area.

History

Crawfish have been consumed for centuries by American Indians and in many parts of Europe. Commercial sales of crawfish in Louisiana began in the late 1800s. At that time, crawfish were harvested from natural waters throughout the southern region of the state. The first record of a commercial crawfish harvest in the United States was in 1880. That year, a harvest of 23,400 pounds was recorded, with a value of \$2,140. By 1908, a U.S. Census

Profitability Varies

The profitability of crawfish farming changes from year to year because of the variable supply of wild and farm-raised crawfish, and resulting fluctuations in wholesale and retail prices. As a result of the unpredictable yields from pond to pond and year to year, few people make their living only from farming crawfish. Overall production on a crawfish farm depends greatly on whether the crawfish are grown in rotation with rice or in permanent crawfish ponds and on the size and management level of those ponds. Breakeven prices vary greatly from farm to farm and in different regions of the state.



Figure 1.4. Field faculty and state specialists with the LSU AgCenter are available to visit producers throughout the state.

report listed Louisiana's crawfish production at 88,000 pounds, with a value of \$3,600.

In the years following the Great Depression, crawfish sold for as little as 4 cents per pound. During this period, with the development of improved transportation and cold storage, crawfish markets within Louisiana shifted from local consumption in rural areas to higher-volume markets in cities such as Baton Rouge and New Orleans. During this same period, the introduction of wire mesh crawfish traps provided fishermen a much more efficient method of harvest (Figure 1.5).

In 1950, the Louisiana Legislature funded the Wildlife and Fisheries Commission to study the life history of crawfish in small ponds. By this time, the practice of re-flooding rice fields after grain harvest was occasionally practiced to produce crawfish for family consumption. This practice of crawfish "farming" eventually spread to closed-in woodlands and marshland as well.

Up until this time, most of the crawfish available for people to consume had come from wild harvests in natural habitats. Although crawfish were abundant some years because of high water levels in the Atchafalaya Basin and other natural wetland



Figure 1.5. Even though the first crawfish traps were fairly simple designs, they enabled the industry to increase supply rapidly. Over the past two decades the construction and efficiency of commercial traps has improved tremendously.

How are Crawfish Classified?

Over the centuries, biologists have devised classification systems to represent groupings of animals and to better define where individual species fit within those groupings. With time, these systems have become more and more complicated, but this in turn provides more information about the relationships between species and groups of species. According to the most commonly accepted classification system, the red swamp crawfish and white river crawfish can be described as follows:

Kingdom: Animalia (animals)

Phylum: Arthropoda (crustaceans, insects, spiders, scorpions, etc.)

Subphylum: Crustacea (crustaceans)

Class: Malacostraca (crabs, pill bugs — rollie-pollies, krill, and related species and groups)

Order: Decapoda (meaning ten legs: lobsters, shrimp, crabs, crayfishes — also called crawfishes, and relatives)

Sub-Order: Pleocyemata

Superfamily: Astacoidea (all crayfishes)

Family: Cambaridae (cambarid crayfishes — one of three major groups of crayfish)

Subfamily: Cambarinae (a group of North American crayfish species, with more than 300 members)

Genus: *Procambarus*

Subgenus: *Scapulicambarus* (for red swamp crawfish), *Ortmanicus* (for white river crawfish)

Species: *clarkii* (for red swamp crawfish), *zonangulus* (for white river crawfish, which was previously called *acutus* for many years)

Scientists often refer to animals and plants by their genus and species classifications. Thus, the red swamp crawfish is referred to as *Procambarus clarkii* and the white river crawfish is *Procambarus zonangulus*.

areas, in other years crawfish were scarce and difficult to come by. This variation in supply made it difficult for markets to grow, but once crawfish farming began, more consistent supplies were possible.

By the mid-1960s, the amount of land devoted to crawfish farming had increased to approximately 10,000 acres of managed ponds. At this point, an industry based on peeling crawfish became established, and the new markets for crawfish meat allowed both crawfish farming and wild harvests to increase even more (Figure 1.6). Acreage continued to increase in Louisiana, from approximately 44,000 acres in the mid-1970s to current levels of roughly 120,000 acres.

Small harvests of farmed crawfish for human consumption occur in other states, such as Texas, Arkansas, Mississippi, Alabama and the Carolinas, but Louisiana is by far the largest producer of crawfish in the United States. Official estimates are not available, but industry experts estimate that Louisiana usually accounts for 90 percent to 95 percent of the total U.S. production from year to year. The vast majority of crawfish aquaculture in the United States is focused on production for human consumption, but some pond-cultured crawfish are sold for fish bait or marketed as aquarium or scientific specimens.

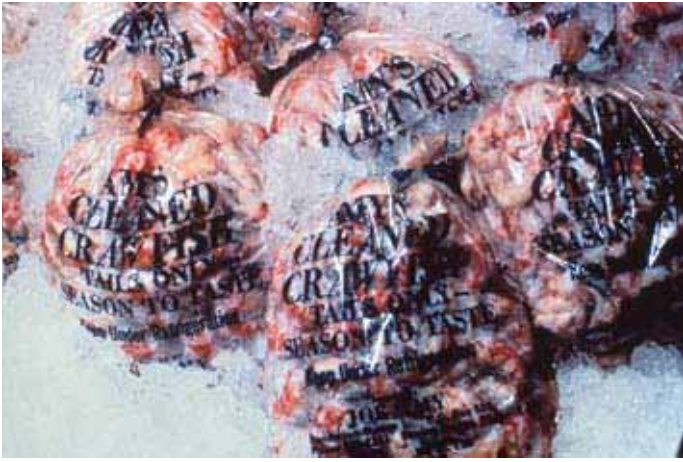


Figure 1.6. The earliest efforts at commercializing markets for crawfish tail meat involved simple methods, but allowed for marketing of fresh product to a wide consumer base.

As the crawfish farming industry began to expand during the 1950s and early 1960s, a number of people felt that for economic growth and benefits to take place, harvests would have to become even more predictable from year to year. Predictability, however, would require research to develop recommended production practices. In 1964, researchers in Louisiana State University's School of Forestry and Wildlife Management began conducting research on crawfish biology and improved methods for pond production.

Initial research focused on how best to manage crawfish ponds to provide a productive habitat, including what type of vegetation to plant, when to plant it, when to flood the ponds, how many crawfish to stock, how to discourage natural predators such as insects and wild fish and other basic topics (Figure 1.7). As time went on and the industry continued to grow, research focused on solving more problems, such as improving trap designs, developing formulated baits that would not have to be refrigerated or frozen, managing the amount and quality of water used in producing crawfish, evaluating the possibility for genetic improvement of crawfish, looking at new ways to process crawfish, developing new products made with crawfish meat and many other topics.

A large portion of Louisiana's crawfish aquaculture, in excess of 50 percent, is practiced in conjunction with rice production. Crawfish farming fits well into many existing farm operations by using marginal agricultural lands, crop rotations, and permanent farm labor and equipment during off-peak farming periods. Crawfish can be produced either in permanent rotation with a rice crop year after year in the same location or in a field rotation with rice and occasionally some other crop, with restocking of crawfish each rotational cycle. As the economics of rice production in Louisiana have weakened over recent decades, many rice producers have turned to crawfish as an accessory crop that can be integrated into their existing farming operations.

Additional Sources of Information

Additional information on crawfish aquaculture and the crawfish industry, including news articles, crawfish statistics, fact sheets and newsletters that do not appear in this production manual can be found on the LSU AgCenter's Web site. Several fact sheets on crawfish farming and other very informative

fact sheets on aquaculture in the southern United States can be found on the Southern Regional Aquaculture Center's Web site. To locate this Web site, type in "Southern Regional Aquaculture Center Fact Sheets" in the search command of your favorite Internet search engine. Personnel in your local LSU AgCenter extension office can assist you in obtaining the most current information available on crawfish farming or other aspects of agricultural production associated with crawfish farming.

Natural Fishery

Historically, significant harvests of wild crawfish have occurred in Louisiana. This production moves through the same market channels as farmed crawfish, affecting prices received by farmers. In recent years, however, many of the traditional areas of wild harvest have failed to produce large volumes of crawfish. To what extent this reduction in wild harvest might reflect long-term trends in water management, climate and habitat alteration remains uncertain. Since 2000, less than 20 percent of Louisiana's harvests on average have come from the wild fishery.



Figure 1.7. Crawfish research has been conducted for many years by the LSU AgCenter in a number of administrative units, including the Aquaculture Research Station and the Rice Research Station.

Chapter 2. Crawfish Biology

Procambarus clarkii (red swamp crawfish) and *P. zonangulus* (white river crawfish), the two species of commercial importance found in Louisiana crawfish ponds, have similar ecological requirements. As a result, it is not uncommon to find both species in the same pond. Both species are associated with natural cycles of flooding and drying common to much of Louisiana, and both construct burrows, in which they survive and reproduce during temporary dry periods. There are some differences between the two species, but care must be taken when reviewing information about the white river crawfish (see “How Are Crawfish Classified?” in chapter 1) because early references may refer to this species as *P. acutus acutus*, or *P. zonangulus*.

The red swamp crawfish produces more, but smaller, eggs than the white river crawfish, and it is capable of spawning year-round in the South. It appears to do better in more nutrient rich-waters than those of the white river crawfish. White river crawfish are seasonal spawners, usually spawning only in the autumn in the southern United States. Feeding rates have been found to be greater for the red swamp crawfish at temperatures in excess of 86 F, indicating a possible competitive advantage at higher temperatures. In contrast, the white river crawfish may grow faster at lower temperatures, and it typically reaches a slightly greater maximum size. Usually the red swamp crawfish are found in greater abundance in waters with lower dissolved oxygen (DO) content.

In general, both species are adapted to the conditions found in commercial crawfish ponds, and both respond well to the low input systems of production used in Louisiana. The abundance

of one species or the other may vary among and within culture ponds over time, but the red swamp crawfish most often dominates and is the most desired species in the marketplace. White river crawfish are most often found in greatest numbers in ponds that are used to culture crawfish year after year.

How these two species interact in crawfish ponds is not fully understood, but one hypothesis is that the red swamp crawfish tends to dominate in more ponds because of greater reproductive potential and a more prolonged reproductive season. No major difference in growth rate and survival between the two species has been observed under typical culture conditions. Some researchers suggest that later pond flooding dates (late October to November) may favor the white river crawfish because of its tendency to spawn later and its slightly larger hatchlings. These factors would provide an advantage over red swamp crawfish young that hatched at the same time. Recent research suggests that whichever species successfully produces large numbers of babies first during autumn months will predominate in the pond for the rest of the season. Much information is lacking, however, regarding interactions of these two species.

These two species are often similar in appearance, especially at a young age. They can be easily identified, however, by experienced persons. Despite efforts to exclude white river crawfish from many farms, both species will thrive under routine culture practices, and they often coexist in production ponds. No evidence exists of natural hybrids between these two species. Several books provide an excellent overview of the anatomy and biology of these and other crawfish species.

Red Swamp Crawfish



- *Procambarus clarkii*
- 70% – 80 % of annual catch in Louisiana
- Two halves of the carapace (head) meet to form a thin line
- Almost always have a blue-gray pigmented line on the underside of the tail
- Less elongated and more flattened claws than white river crawfish when mature
- Darker walking legs than white river crawfish
- Red pigment on adult bodies (except for rare color variations) – not always so with juveniles
- Lay eggs any time but mostly during fall and winter months
- Produce up to twice as many eggs as white river crawfish
- Thrive in systems flooded early in the fall
- Hatchlings smaller than white river crawfish
- Prefer swampy habitats
- Most young appear from September through December but can be found in all months
- Usually mature from April through June
- Native range is northeastern Mexico and the south central United States
- Commercially valued in Louisiana
- Introduced to many countries

White River Crawfish



- *Procambarus zonangulus*
- 20%-30% of annual catch in Louisiana
- Space called an “areola” separates each half of the carapace (head)
- No pigmented line on the underside of the tail as adult or juvenile
- More elongated and cylindrical claws than red swamp crawfish when mature
- Lighter walking legs than red swamp crawfish
- Never has red pigment on its body – sometimes adults can look pink
- Lay eggs only during mid- to late fall in Louisiana
- Produce fewer and larger eggs than red swamp crawfish
- Thrive in systems flooded in late fall
- Hatchlings larger than red swamp crawfish
- Prefer flooded wetlands with flowing, well-oxygenated water
- Usually mature from April through June
- All young appear from September through December in Louisiana
- Commercially valued in Louisiana
- Native range is Alabama, Louisiana, Mississippi and Texas
- Endemic only to the United States

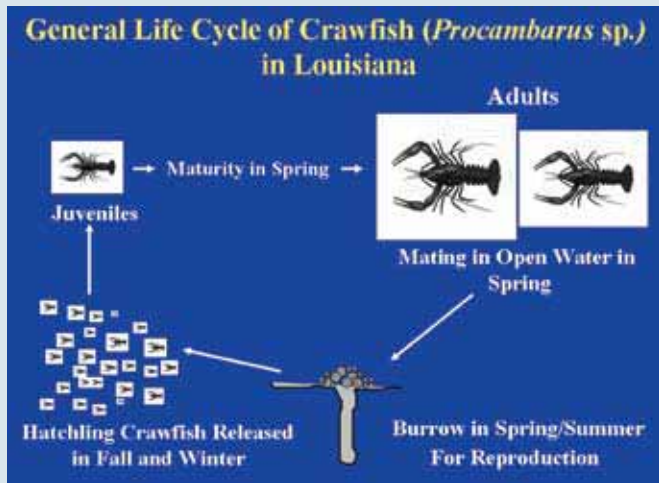


Figure 2.1. A diagram of the crawfish life cycle.

Life Cycles

Based on their distribution in North America, the red swamp and white river crawfish are classified as “temperate” species; that is, they will tolerate cold winter conditions. Both species, however, possess a number of traits that are usually associated with animals that live in warm waters. These species are short-lived (2 years or less), have high juvenile survival and can alternate between reproductively active and inactive forms. Moreover, *P. clarkii* is capable of spawning year-round in the southern United States, and some females can reproduce more than once per year.

These crawfishes have life cycles that are well-adapted to farm production strategies (Figure 2.1). Mature animals mate in open water where sperm is stored in a special receptacle, after which the female retreats to a burrow to eventually spawn. Burrowing activity can occur at any time but is most prevalent in late spring/early summer in Louisiana. Although spawning can take place in open water, the burrow provides protection while the fertilized eggs or young are attached to the underside of their mother’s tail (Figure 2.2). Females carrying eggs or hatchlings are highly susceptible to predators, because they cannot use their normal tail-flipping escape response.



Figure 2.2. Crawfish eggs are typically laid and fertilized in the burrow where they become attached to the swimmerets on the underside of the female’s tail.



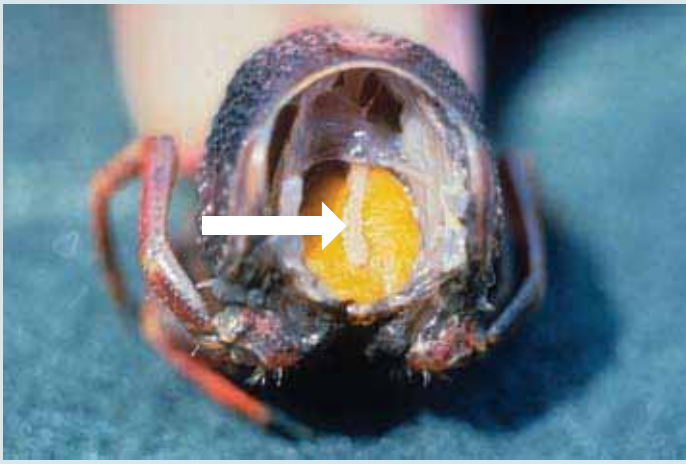
Figure 2.3. Crawfish burrows appear near the waterline in ponds when mature crawfish begin burrowing for reproduction. Burrows may or may not have the typical “chimney” associated with the entrance.

Crawfish of all ages and sizes, whether mature or immature and male or female, will dig or retreat to burrows to survive periods of dewatering. Crawfish ponds are usually drained during the summer months to allow for planting and growth of vegetation. Prior to draining, some mature crawfish burrow near the waterline (Figure 2.3). As the water level drops, additional crawfish burrows appear lower on the levee and are sometimes found on the pond bottom; however, the burrows on the pond floor often contain a high percentage of non-reproductive crawfish, such as males and immature juveniles.

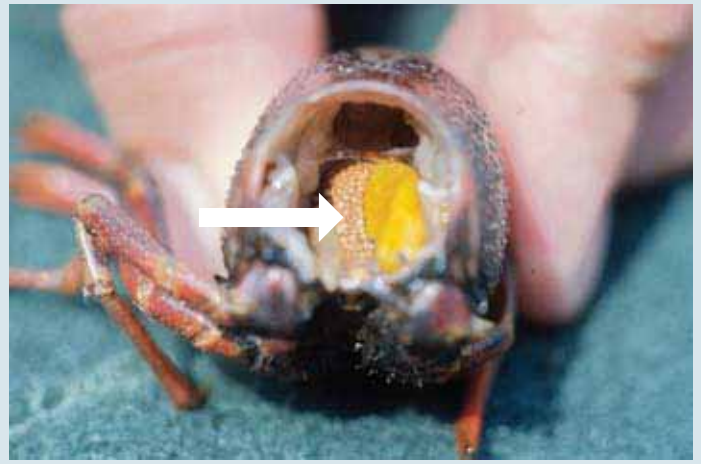
Ovarian (egg) development in mature females is temperature dependent, usually beginning prior to burrowing and reaching completion within the burrow. Developing eggs within the ovary become rounded, increase in size, and change from a light color to dark as they mature (Figure 2.4). At maturity, the large black eggs are shed from between the walking legs, are fertilized externally and are then attached to the swimmerets on the underside of the tail with an adhesive substance called glair. Although crawfish can survive in high humidity within the burrow, some standing water is necessary for successful reproduction. The number of eggs laid varies with female size and condition, but large red swamp or white river crawfish females can have more than 500 eggs.

The hatching period depends on temperature and usually takes about 3 weeks. Hatched crawfish are attached to the female’s swimmerets through two molting phases, after which they resemble an adult crawfish and begin to feed. Hatchlings instinctively remain with the female for several weeks after their second molt although they are no longer attached. It is critical that the female and her young leave the burrow within a reasonable time because little food is available in burrows. When conditions force the crawfish to remain in the burrow, increased mortality can occur.

Pond flooding or heavy rainfall is usually necessary to encourage female crawfish to emerge from their burrows. Females emerge with their young (or sometimes with eggs) attached to their tails (Figure 2.5), and advanced hatchlings are quickly separated from their mother as she moves about in the open water. Because reproduction is somewhat synchronized in pond-reared crawfish, ponds are routinely flooded in autumn to coincide with the main period of reproduction. White river crawfish are autumn and winter spawners, but red swamp crawfish reproduction may occur at any time. Peak reproduction of



White eggs



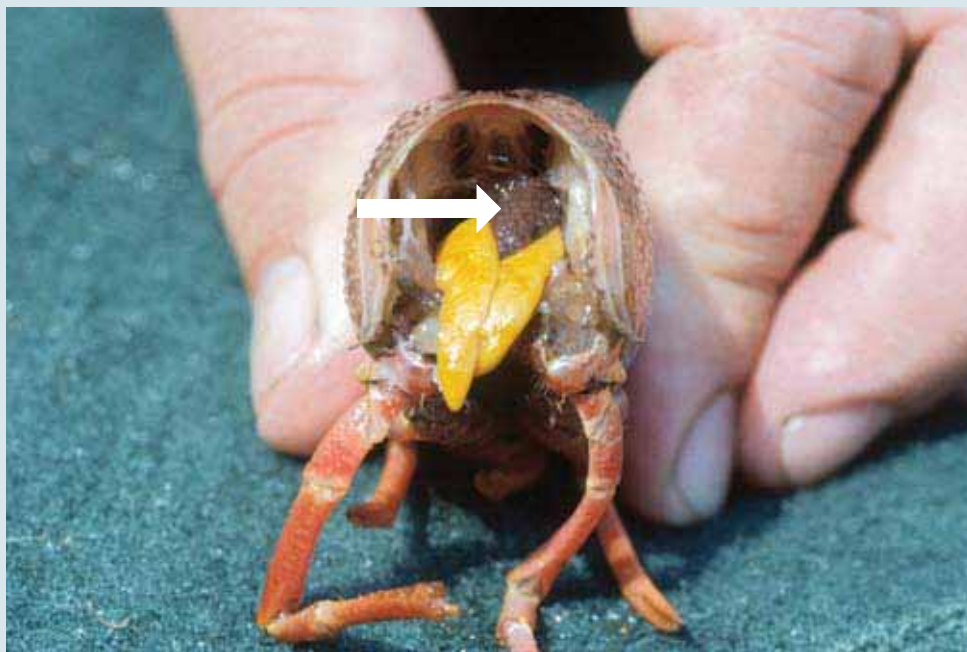
Tan eggs



Yellow eggs



Brown eggs



Black eggs

Figure 2.4. Eggs in various stages.



Figure 2.5. Female with hatchlings attached to swimmerets beneath the abdomen.

red swamp crawfish, however, usually occurs in autumn, with minor pulses (or “waves”) of hatchlings entering the population later. Extended reproduction and differential growth typically result in a population of mixed sizes in most ponds.

As with all crustaceans, a crawfish must molt or shed its hard exoskeleton to increase in size. Frequent molting and rapid growth occur in production ponds when conditions are suitable. Growth rate is affected by a number of variables, including water temperature, population density, oxygen levels, food quality and quantity, and to a lesser extent by genetic influences. Harvest size is typically reached 3 to 5 months after hatching for fall recruits, but it can be attained in as little as 7 to 9 weeks under optimum conditions.

When males and females molt to a reproductively active stage, growth ceases. Sexually mature individuals exhibit distinct characteristics, including darker coloration, enlarged claws, and hardened sexual structures. Mature males also develop prominent hooks at the base of the third and fourth pair of walking legs. The appearance of mature crawfish in the population usually increases as temperatures rise during late spring. Females will mate (often several times) after molting to a mature form and then begin the process of constructing burrows at the water’s edge on levees.

Burrow Ecology

Several studies have provided more detail of crawfish burrows, but, in brief, crawfish cultured in Louisiana dig simple (unbranched), nearly vertical burrows, usually 40 inches or less in depth (Figure 2.6). Burrows serve as refuges from predators and provide moist or humid environments necessary for crawfish to survive through dry periods. Louisiana crawfish have evolved over millions of years to reproduce within the protection of their burrows. Most burrows are built at night and may require several days to complete. Crawfish burrows are usually dug by a single individual, and the burrow diameter is determined by the size of the crawfish. The burrow extends downward into a chamber slightly larger than the diameter of the tunnel.

Water levels in burrows vary with the moisture conditions in the soil. Free water at the bottom of the burrow is more often

associated with “trapped” water than the actual water table of the soil. Walls of the burrow and terminal chambers are extensively worked by the crawfish, possibly to ensure good seals. The terminal chamber normally contains wet slush when water is not present, which serves as a humidifier. The entrance of the completed burrow is eventually closed with a mud plug (Figure 2.7), sometimes having a chimney or stack of the soil removed during excavation. Burrow entrances at the water’s edge are often associated with natural cover, such as vegetation or woody debris. Over the course of the summer, weathering and covering by vegetation may make the burrow entrance undetectable.

Burrows usually contain a single female, or sometimes a male and female together, but occasionally they may contain additional crawfish. Successful survival and reproduction within the burrow depends on many factors, such as the severity and length of the dry period, characteristics of the burrow (such as depth, soil type and moisture) and health of the animal. Immature crawfish and crawfish forced to burrow by rapidly dropping water levels may construct shallow burrows that will not have sufficient moisture for survival during lengthy dry periods or drought. Soil types with limited clay content or soil with very high clay content that cracks when dry also may limit crawfish survival while in burrows.

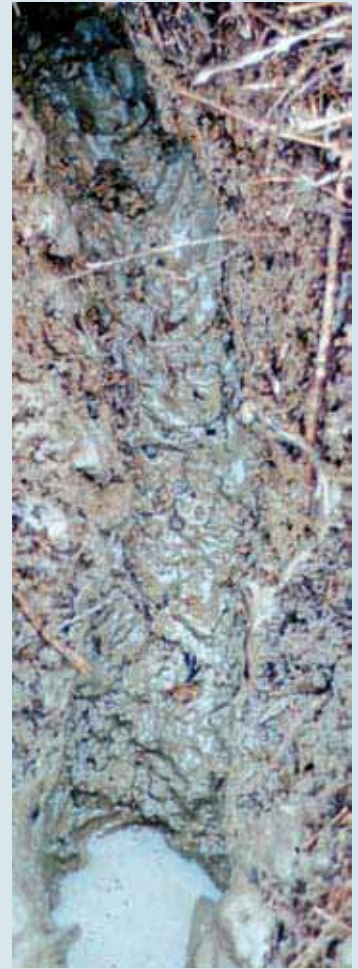


Figure 2.6. An exposed crawfish burrow showing depth and construction.



Figure 2.7. Active crawfish burrows will eventually become sealed with a mud plug or cap. With time and weather, and covering of vegetation, the burrow entrance may become inconspicuous.

Once sealed in, crawfish are confined to the burrow until the hard plug that seals the entrance is sufficiently softened by external moisture from flooding or rainfall. Pond flooding, especially when associated with heavy rainfall, facilitates and encourages the emergence of crawfish from burrows.

Crawfish Population Structure

The appearance of new hatchlings in a pond is referred to as “recruitment,” and these crawfish usually constitute the bulk of the annual harvest, even when significant numbers of holdover juvenile crawfish are present after flooding. Pond crawfish populations usually include (1) holdover adults from the preceding production season or stocking, (2) holdover juveniles from the preceding season and (3) the current young-of-the-year (YOY) recruits.

The number of age classes and numbers within age classes comprise the overall crawfish density. Crawfish density and population structure have a great impact on overall pond yields and size of crawfish at harvest. The highest densities and most complex population structures usually occur where crawfish have been grown in the same location for several consecutive seasons. In new ponds and ponds held out of production for a year or longer, crawfish density is often lower and the number of age classes is fewer. In these situations, crawfish are often larger and more uniform in size; however, overall yields may be considerably lower.



Population Dynamics

Unlike most aquaculture ventures, where known numbers and sizes of juveniles are stocked, crawfish aquaculture in Louisiana relies on natural recruitment (reproduction) from mature animals (either stocked or already present) to populate the pond. Population density depends largely on broodstock survival, successful reproduction and survival of offspring. Density is mainly influenced by environmental conditions over which producers may have little or no control. Additionally, improper management after autumn flood-up, including low oxygen levels, abundance of predators or pesticide exposure can negatively impact crawfish populations and subsequent production even when broodstock survival and reproduction are high.

Because of this lack of influence and control over population levels, population density and structure is probably the most elusive aspect of crawfish production. Extended reproduction periods and the presence of carryover crawfish from



Figure 2.8. Soft, freshly molted crawfish (top) and its cast exoskeleton (bottom).

previous season often result in several size or age groups of crawfish being present in a pond at any given time. These various size/age groups are what make up the population structure.

Although “natural recruitment” in crawfish farming has many advantages, a significant disadvantage is that crawfish producers have little means of accurately controlling or even determining population density and subsequent yield. Available sampling methods are crude and currently include dip net sweeps and use of “test” traps. These methods are highly variable and subject to many sources of bias or error. Producers generally do not have a good assessment of their populations until harvesting is well underway in late spring, after pond temperatures have increased substantially.

Molting

As with all crustaceans, a crawfish must molt or shed its hard external shell (“exoskeleton”) to increase in size (Figure 2.8); hence, the growth process involves periodic molting interspersed with inter-molt periods. Approximately 11 molts are necessary for young crawfish to reach maturity. A molt cycle is recognized as having five major stages, but it should be understood that the process is actually continuous. The inter-molt phase is the period in which the exoskeleton is fully formed and hardened. During this phase, crawfish feed actively and increase their tissue and energy reserves. Preparation for molting takes place in the pre-molt stage. This includes the formation of the new, underlying (soft) exoskeleton while a re-absorption of the calcium from the old shell occurs. During the late pre-molt period, crawfish cease feeding and seek shelter or cover.

Molting is usually accomplished in minutes. The brittle exoskeleton splits between the carapace (head) and abdomen (tail) on the back side, and the crawfish usually withdraws by tail flipping. During the “soft” phase that follows, the soft exoskeleton expands to its new, larger dimensions. Hardening (calcification) of the new exoskeleton takes place during the post-molt period, which can be divided into two phases. Initial hardening occurs when calcium stores within the body are transported to the new exoskeleton. Calcium is stored in the body both in soft tissue and for a short period in two hard “stomach stones” or gastroliths (Figure 2.9) located in the head, on each side of the stomach. These stones disappear during the initial hardening period after molting. The second phase of hardening is by absorption of calcium from the water. As crawfish resume feeding, further hardening of the new shell occurs.

Molting is hormonally controlled, occurring more frequently in younger, actively growing animals than in older ones. The



Figure 2.9. Gastroliths are found in the “head” portion of molting crayfish and are associated with temporary calcium stores.

increase in crayfish size during molting, and the length of time between molts, can vary greatly and are affected by factors such as water temperature, water quality, food quality and quantity, population density, oxygen levels and to a lesser extent by genetic influences. Under optimum conditions, crayfish can increase up to 15 percent in length and 40 percent in weight in a single molt.

In culture ponds, frequent molting and rapid growth occur during spring because of warming waters and adequate food sources. The appearance of mature crayfish increases as the season progresses. Rapid increases in temperature (above 80 F) may stimulate onset of maturity at smaller sizes, especially under conditions of overcrowding and food shortages. “Stunting,” the condition whereby crayfish mature at an undesirably small size, is a problem in many ponds.

Nutrition

Crayfish have been classified as herbivores (vegetation eaters), detritivores (consumers of decomposing organic matter), omnivores (consumers of both plant and animal matter) and, more recently, obligate carnivores, which means that they “require” some animal matter in the diet for optimal growth and health.

Crayfish have been known to ingest living and decomposing plant matter, seeds, algae, epiphytic organisms, microorganisms and an assortment of larger invertebrates such as insects and snails. They also will feed on small fish when possible. These food sources vary considerably in the quantity and quality in which they are found in the aquatic habitat. Living plants, often the most abundant food resource in crayfish ponds and natural habitats, are thought to contribute little to the direct nourishment of crayfish. Starchy seeds are sometimes consumed and may provide needed energy, but intact fibrous plant matter is mostly consumed when other food sources are in short supply. Aside from furnishing a few essential nutrients, living plant matter provides limited energy and nutrition to growing crayfish.

Decomposing plant material, with its associated microorganisms (collectively referred to as detritus) is consumed to a much greater degree and has a higher food value. The ability of crayfish to use detritus as a mainstay food item, however, appears to be very limited. Fortunately, in a typical crayfish pond environment numerous animals besides crayfish rely on the microbe-rich detritus as their main food source. Mollusks, insects, worms, small crustaceans and some small vertebrates depend on detritus (Figure 2.10) and, when consumed by



Figure 2.10. A myriad of invertebrates in crayfish ponds, fed by decomposing plant fragments (top), furnish crayfish with the high quality nourishment needed to sustain maximum growth.

crayfish, these animals furnish high-quality nutrition. Scientists have realized that for crayfish to grow at their maximum rate, they must feed to a greater extent on these high-protein, energy-rich food sources.

Sufficient evidence has been established to indicate that although crayfish must consume high-protein, high-energy sources to achieve optimum growth, they can sustain themselves for some time by eating intact and decomposing plant sources and even bottom sediments containing organic debris.

Supplemental feeds are not routinely provided to crayfish aquaculture ponds. Commercial culture of crayfish relies on a self-sustaining system for providing nourishment to crayfish, as occurs in natural habitats where crayfish are abundant. An established (or at least encouraged) vegetative forage crop provides the basis of a complex food web (Figure 2.11) that ultimately fuels production of crayfish with harvests that typically average 400-600 pounds per acre and can often exceed 1,000 pounds per acre.

Plant fragments from the decomposing vegetation provide the “fuel” that drives a detrital-based production system, with crayfish at the top of the food web. As a result, the main means of providing nutrition to crayfish in aquaculture is through establishing and managing a forage crop. Ideally, once ponds are flooded in the fall, a constant and continuous supply of plant fragments fuels the food web from which crayfish derive their nutrition. (Also see chapter 5.)



Figure 2.11. A simplified diagram of the nutrient pathways of the food chain in crayfish ponds, with the forage crop serving as the principal fuel and crayfish at the top of the food chain.

Chapter 3. Crawfish Production Systems

Commercial culture of Louisiana crawfish relies on earthen ponds, with production methods that are much less intensive than those found in other forms of aquaculture. The methods used for crawfish aquaculture is little more than limited control of the environmental conditions under which these animals evolved.

Red swamp and white river crawfish are naturally adapted to habitats with seasonal flooding and drying, where the dry period usually occurs from summer into autumn. The life cycle of crawfish is well suited to fluctuating periods of flooding and dewatering. In their natural, river or swamp habitats, sustained periods of river overflow permit crawfish to feed, grow and mature. Temporary dewatering, in both natural habitats and crawfish ponds, promotes aeration of bottom sediments, reduces abundance of aquatic predators and allows for establishment of vegetation that serves as cover for crawfish and the source of important food resources when water returns. Crawfish survive the dry intervals by digging or retreating to burrows where they can avoid predators, acquire moisture necessary for survival and reproduce in safety.

Current farming practices are based on the annual water cycles and conditions to which these crawfish have become adapted over millions of years. Flooding and draining of crawfish ponds mimic the natural flooding and drying cycle in Louisiana's Atchafalaya River basin. The control achieved under farming conditions provides optimal timing of these events and allows crawfish producers to positively influence water quality, food resources and other factors within their ponds. As with natural ecosystems, crawfish aquaculture relies on natural reproduction. No hatcheries or nurseries are required. Crawfish in forage-based culture ponds, as in the wild, depend on a naturally available food web for nourishment. Supplemental feeding is not a common practice; it has not yet been shown to predictably increase yields or size of crawfish at harvest.

Crawfish are grown in shallow earthen ponds 8 to 24 inches deep. Relatively flat, easily drained land, with suitable levees, is required for production, harvesting and management of vegetation (Figure 3.1). Crawfish are cultured in areas where the soil has sufficient clay to hold water and accommodate bur-



Figure 3.1. Successful crawfish production requires flat soils with sufficient clay content. Lands suitable for rice or sugarcane production are often also well-suited for crawfish.



Figure 3.2. Specialized equipment and supplies are essential for commercial success.

row construction. Water requirements for crawfish production are similar to those for other freshwater aquaculture ventures, with the possible exception of water quantity. Ponds are flooded in the fall and drained in the spring, and because of the oxygen demand from decaying vegetation, additional water exchanges are sometimes necessary.

Equipment requirements for culturing crawfish include irrigation systems, harvesting equipment (boats, traps, sacking tables, etc.) and agricultural implements to establish the forage crop and maintain levees (Figure 3.2). Access to sufficient labor and alternative marketing outlets are essential for successful commercial operations.

Although crawfish aquaculture ponds are sometimes categorized by pond type or dominant vegetation, a better strategy is perhaps to categorize ponds by two basic production strategies. (See summary of production strategies in Table 3.1) One strategy is monocropping, or monoculture, in which crawfish are the sole crop harvested, and production typically occurs in the same physical location for several production cycles or even longer.

A second strategy is the crop rotation system, in which rice, and sometimes soybeans or other crops, are raised in rotation with the crawfish. In these systems, crawfish are either rotated with rice in the same physical location year after year, or crawfish are cultured in different locations each year to conform to normal field rotations of the other crops.

Although these two major management strategies have many similarities, different production goals dictate different management concerns.

Monocropping Systems

Crawfish monoculture or "single-crop" systems is the production method of choice for many small farms or where marginal lands are available and unsuited for other crops. Permanent ponds, or sites devoted to at least several consecutive production cycles, are typically used for this strategy. Pond size and production input for this approach range from large (greater than 300 acres) impounded wetlands with little management to small (less than 15 acres) intensively managed systems. The main advantage of a monocropping strategy is that producers

Table 3.1. Summary of Major Crawfish Production Strategies With Common Practices by Month.

Months	Crawfish Monoculture	Crop Rotational Systems	
		Rice-Crawfish-Rice	Rice-Crawfish-Fallow or (Rice-Crawfish-Soybean)
Jul - Aug	Forage crop planted or natural vegetation allowed to grow	Rice crop harvested in August and stubble managed for regrowth	Rice crop harvested and stubble managed for regrowth
Sep - Oct	Pond flooded and water quality monitored and managed	Pond flooded in October and water quality monitored and managed	Pond flooded in October and water quality monitored and managed
Nov - Dec	Harvest when catch can be economically justified	Harvest when catch can be economically justified	Water quality monitored and managed
Jan - Feb	Crawfish harvested 2-4 days per week according to catch and markets	Crawfish harvested 2-4 days per week according to catch and markets	Crawfish harvested 2-4 days per week according to catch and markets
Mar - Apr	Crawfish harvested 3-5 days per week according to catch and markets	Crawfish harvested 3-5 days per week until late April, then pond drained and readied for planting	Crawfish harvested 3-5 days per week according to catch and markets
May - Jun	Crawfish harvested until catch is no longer justified; then pond drained	Rice planted in May and rice crop managed for grain production	Pond drained and soybeans planted or harvest proceeds as long as catch is feasible; pond then drained and left fallow
July - ...	Repeat cycle	Repeat cycle	Harvest soybeans in October, plant rice in March/April, stock crawfish in May, repeat cycle

can manage for maximum crawfish production without the various concerns associated with other crops, such as pesticide exposure, seasonal limitations and other constraints associated with crop rotation.

Crawfish yields in monocropping systems typically range from less than 200 lb/ac in large, low input ponds to more than 1,200 lb/ac with intensive management. Some ponds have yielded in excess of 2,500 lb/ac. In many “permanent” crawfish ponds, yields tend to increase annually up to three or four years of consecutive production.

Additionally, smaller ponds usually have higher yields than larger ponds, especially when marketing smaller, lower-value crawfish is not a problem. Earlier and more intense harvesting is often justified in older, permanent ponds because of the dense populations and increased numbers of holdover crawfish. This practice is economically important because earlier harvests are almost always associated with higher prices.



Figure 3.3. When crawfish densities become too great, growth slows or ceases even in the presence of abundant forage and good water quality.

Although the monoculture approach offers several advantages, it also has disadvantages. These often include: (1) the need to construct dedicated ponds, whereas with rice/crawfish rotational cropping, the established rice field serves the purpose; (2) land, overhead and operating costs must be amortized over one crop only; and (3) crawfish overcrowding frequently occurs after several annual cycles, particularly in smaller ponds; therefore, yields become composed of small (stunted), low-priced crawfish that are difficult to market (Figure 3.3).

Production schedules vary within and between geographical regions, but permanent monocropping ponds generally follow the schedule presented in Table 3.1. Since crawfish populations are self-sustaining, stocking is usually needed only in new ponds, when a pond has been idle for a year or more or after extensive levee renovation. Subsequent crawfish crops rely on holdover broodstock from a previous cycle. Ponds are stocked from 40 lb/ac to 80 lb/ac of adult red swamp crawfish sometime between early April and early July (Figure 3.4). Stocking dates and rates are usually dictated by the availability and cost of mature crawfish.

Ponds are thoroughly drained, ideally beginning no sooner than two to three weeks after stocking. Cultivated or volunteer vegetation is established in pond bottoms during the summer when ponds are dewatered. The vegetative crop serves as the main nutritional input for the following crawfish season. Rice is the standard cultivated crop, and emphasis is on forage (stem and leaf) production. Grain, if present, is not harvested in crawfish monocropping systems. After reflooding in autumn, producers monitor the crawfish population with baited traps and initiate harvesting when catch and marketing conditions justify the labor and expense. Harvesting continues (often in intermittent intervals) until ponds are drained the following summer, and the cycle is repeated.



Figure 3.4. Stocking a rice field pond with crawfish broodstock.

Crop Rotational Systems

Crawfish may be cultured in two basic crop rotation systems. One is rice-crawfish-rice, and the other is rice-crawfish-fallow/soybean. In both strategies, crawfish culture follows the rice harvest, and the forage crop used for growing crawfish is the crop residue and re-growth of the rice stubble after grain harvest. Advantages of these rotational strategies include efficient use of land, labor and farm equipment. Moreover, some fixed costs and the cost of rice establishment can be amortized over two crops instead of just one.

Rice-crawfish-rice

This approach takes advantage of the seasonality of each crop to obtain two crops in one year. Rice is grown and harvested during the summer, and crawfish are grown during autumn, winter and early spring in the same field each year. (See Table 3.1). As with monocropping systems, crawfish are only stocked initially. They are introduced directly into the rice crop about 4 to 7 weeks post-planting. Following grain harvest, the residual rice crop is usually fertilized with a nitrogen-based fertilizer and irrigated, if necessary, to achieve a ratoon crop (regrowth) of forage (Figure 3.5). Subsequent to the fall “flood-up,” management practices are similar to those of a monocropping system with the exception of a shortened growing and harvesting season to accommodate the establishment of the next rice crop.

A major disadvantage with this rotational strategy is that usually neither crop can be managed to yield maximum production. Rice yields in the South are maximized when rice is planted in early spring. Draining the crawfish pond prematurely to accommodate rice establishment decreases total crawfish

yield. Pesticide use is another major management consideration, and it is a particular constraint with this production strategy. Crawfish and rice yields vary and depend on management emphasis. Those systems managed mainly for crawfish can expect crawfish yields similar to well-managed monocropping systems but at the expense of rice yield and vice versa.

Rice-crawfish-fallow (or rice-crawfish-soybean)

The second major rotational strategy employs crawfish in a rotational system of rice and sometimes soybeans. The major difference in this rotation strategy is that rice is not typically cultivated in the same field during consecutive years, to aid in the control of rice diseases and weeds for maximum rice yield. As with a rice-crawfish-rice rotation, however, crawfish culture follows rice cultivation; therefore, crawfish production does not occur in the same physical location from one year to the next. (See Table 3.1). Under this method, if soybeans or another crop is incorporated, three crops per field can be realized in two years. Depending on a variety of factors, some producers may elect to plant a different crop (hay, pasture or grain sorghum) or simply leave the field fallow instead of planting soybeans after the crawfish season ends.

The field rotational approach requires sufficient land resources to allow staggered crops in different fields within a farm, and it is the preferred cropping system for larger commercial rice farmers. This cropping strategy comprises much of the acreage used to grow crawfish in Louisiana. It has several advantages over rotation within the same field. Each crop can be better managed, and the crawfish production season can be extended. For example, in lieu of draining crawfish ponds in early spring to plant rice, crawfish harvest can continue until late spring or early summer when the pond is drained to plant soybeans (or other crops), or longer if plans are to leave the field fallow. Furthermore, by rotating physical locations each year, overpopulation of crawfish is rarely a problem, and crawfish size often is larger because of lower population densities.

Crawfish yields under this management approach are not commonly as high as with monocropping systems, but with proper management, yields can routinely exceed 900 lb/ac. Some disadvantages of this rotational strategy relative to crawfish production in permanent or semi-permanent ponds are: (1) the need to restock every year, (2) routine low-population densities and (3) frequently, a late-season harvest when prices are in decline and marketing is more difficult because of abundant supplies.



Figure 3.5. In many situations, crawfish can be produced on the same land as a rice crop, although usually with somewhat lower yields.

Chapter 4. Pond Location, Design and Construction

Pond location, design and construction are the most important physical factors for successful crawfish production. Proper design and construction give the crawfish farmer better control over flooding, drainage, forage management, water circulation and harvesting. Although management practices can be easily changed from year to year, trying to change ponds that were poorly designed and improperly constructed can be expensive. Seek advice from your local LSU AgCenter extension agent and area United States Department of Agriculture (USDA) Natural Resources Conservation Service engineer prior to beginning construction.

Location

Crawfish ponds should be located in flat, open areas, and the soils should have sufficient amounts of clay. Adequate water sources should be available. Clay loams, sandy clay loam and silty clay loams are satisfactory soil types. A clay soil is necessary to hold water and to maintain the integrity of crawfish burrows. Generally, soils that can be rolled into a ball have enough clay for crawfish culture. Elevations must be sufficiently high to allow the pond bottom to remain above water levels in the surrounding drainage ditches and canals (Figure 4.1).



Figure 4.1. Sufficient elevation to allow for good drainage is required for crawfish pond management.

For rice-field ponds, sites are usually limited to existing rice fields. Even so, consideration of which fields will be placed in crawfish production is important. Because of the labor intensive operations of crawfish farming, many rice farmers typically commit only 10 percent to 50 percent of their total rice acreage to crawfish. Often the best producing rice fields are not selected for rotation with crawfish. It is important to select rice fields with adequate all-weather access because crawfish harvesting and pond management are daily activities and often occur during wet weather. Fields selected for crawfish production should have accessible and economical water supplies because the water requirements for crawfish farming are higher than for rice production.

Field size and layout may be an important consideration when producing crawfish on rice acreage. Trapping lanes are more efficient when long and straight, and levee crossings should be kept to a minimum. Limited access for vandals and thieves may be an important consideration. Consideration of the positioning of fields destined for crawfish production may

also be important from a pesticide perspective. Positioning of crawfish ponds between producing agronomic fields, or downwind from a field where aerial application of an insecticide is planned is not prudent.

Design and Construction

A number of considerations should be taken into account when constructing permanent crawfish ponds. Many of these also apply to rice fields that are intended for crawfish production. Perimeter levees should have a core trench cleared of debris to prevent water seepage. The minimum perimeter levee base should be 9 feet wide to prevent leakage from the burrowing activities of the crawfish. A levee system 3 feet high is adequate to contain the minimum 8 to 12 inches of water necessary to cultivate crawfish. The land should have no more than a 6-inch fall between perimeter levees. Otherwise, the area should be leveled or divided into two or more ponds. Ponds with steep elevations and resulting depth variations hinder forage establishment, restrict water management techniques and reduce harvesting efficiency.

Wide and deep interior ditches inside crawfish ponds, which are usually adjacent to large perimeter or large baffle levees, should be avoided where possible. These deep areas provide a pathway of least resistance for water flow that can reduce circulation in other areas of the pond, potentially causing poor quality and reduced catch in areas away from the ditches. Additionally, interior ditches are difficult to drain, and they may serve as a refuge for predatory fish after ponds are drained. Interior or baffle levees are constructed to guide water through the pond for proper aeration and to help maintain proper water quality (Figure 4.2).



Figure 4.2. Baffle levees are often comparable to typical rice field contour levees. The key is to direct the flow of water through the pond to avoid “dead” areas with little or no oxygen.

Baffle levees are built about 6 feet wide at the base. They should extend a minimum of 6 inches above the expected water level for the pond. If the part of the baffle levees above the water line is not substantial enough, settling and erosion will cause the levees to breach in one or two years. Baffle levees should be spaced 150 to 300 feet apart to facilitate water circulation. Core trenches in the baffle levees are not necessary. A recirculation canal outside the perimeter levee and a re-lift pump will aid in water circulation and minimize water discharge (Figures 4.3 and 4.4). Ponds designed to recirculate water are important in areas where the quality of the surface water supply fluctuates or where well water must be pumped from great depths at great cost. (See chapter 6, "Water Quality.")

Drains should be matched with the pond size, pumping capacity and projected rainfall (Figure 4.5). Two 10-inch drains are sufficient to drain a 20-acre pond. Ponds must allow vehicle access in wet and dry conditions and allow efficient use of harvesting equipment.

Most often, crawfish ponds in a rice-crawfish rotational system use established rice fields where the field lay out and irrigation systems are fixed. Some modifications of the field may be necessary, however, for best results with crawfish. Small levees that are adequate for rice production in shallow waters (less than 5 to 6 inches deep) are not adequate for crawfish production where water levels are usually maintained at 8 to 16 inches. Larger levees are especially critical for the perimeter, which hold in water. Whereas rice production requires a water holding period of 8 to 10 weeks, crawfish ponds are usually flooded for 7 to 10 months. Settling, erosion, burrowing rodents and crawfish burrowing can take their toll on small levees. Therefore, rice fields destined for crawfish production usually require much taller and wider levees. It should be noted though that levee construction/reconstruction should occur before introduction of crawfish broodstock because levee renovation after crawfish have burrowed can reduce broodstock survival and reproduction.

Levees can also act to keep flood waters out of a crawfish



Figure 4.3. Many crawfish ponds can be adapted to allow for circulation using one or more re-lift pumps.

pond at times. Breached levees from flood waters can disperse crawfish out of the pond and introduce unwanted fish into the pond. With electronic laser leveling, some rice fields have become very large with few or no interior levees. If too large, these fields may possess a ratio of linear levee to total pond area that is too large for optimal reproduction, because crawfish use the levees as burrowing sites. Conversely, the presence of too many interior levees potentially provides excess reproduc-



Figure 4.4. When ponds are extremely level, recirculation can be accomplished using commercially available or shop-built paddlewheel aerators.



Figure 4.5. Drains must have sufficient capacity to lower ponds over a short period of time.

tive burrowing area and can lead to overpopulation and stunted crawfish. The optimal levee-to-pond area ratio has not been determined and varies with geographic location and other conditions.

Rice-field water irrigation is usually designed to achieve efficient water output with little concern for maximizing oxygen content of the water. Therefore, it is recommended that water discharge outlets on irrigation wells be modified to include aeration screens to maximize oxygen input to provide for the highest quality of water in fields where crawfish are to be grown.

Best Management Practices for Crawfish Pond Construction

A set of best management practices (BMPs) for crawfish production has been developed in cooperation with the USDA Natural Resources Conservation Service (NRCS). (See summary in Table 4.1) These practices seek to minimize erosion, reduce the amount of contaminants (nutrients and pesticides) in effluent discharges and maximize the benefit to wildlife.

Table 4.1. Summary of United States Department of Agriculture National Resource Conservation Service (NRCS) Best Management Practices for Crawfish Pond Design and Construction.

Conservation Practice	NRCS Code	Comments
Access road	560	Necessary for daily transportation to crawfish ponds for water management, forage management, harvesting and marketing crawfish. May impede natural runoff. May contribute to siltation if not properly vegetated. May reduce wetland habitat.
Brush management	314	May be required to plant forage and to develop harvesting lanes. Physical removal may cause temporary turbidity problems. Labeled use of herbicides would not have a significant environmental impact.
Channel vegetation	322	Turbidity caused by unvegetated channels may contribute to sedimentation problems. Vegetated channels help turbidity problems and improve water quality pumped into ponds.
Crop residue use	344	Natural vegetation may be allowed to grow before preparing for forage production to reduce erosion during interim of draining and planting forage. Provides habitat for wildlife. Cover improves soil moisture and should improve conditions for crawfish in burrows.
Filter strips	393	Provide a means of reducing sediment in inflow and discharge water where practical. May reduce soil erosion.
Fish pond management	399	Crawfish ponds used to produce crawfish commercially. Depth and forage production differ from typical fish ponds. Provides positive impact on the environment. Provides habitat for many forms of wildlife, such as wading birds, waterfowl and many furbearers.
Irrigated field ditch	388	Another effective irrigation tool that promotes good water management and conservation. Provides pathway for water from source to ponds.
Irrigation water management	449	Planned irrigation, flooding and draining to manage forage and crawfish.
Wells	643	Well water recommended over surface water.
Wetland development	657	Flooded crawfish ponds greatly benefit and improve the quality of the water entering and exiting the field in most cases. Crawfish ponds and production have a positive impact on the environment.
Wildlife wetland	644	Crawfish ponds provide more than 120,000 acres of manmade wildlife wetland habitat that greatly benefits waterfowl, wading birds, gallinules, shorebirds, furbearers, reptiles, amphibians and numerous invertebrate animals that benefit other species of wildlife.

Chapter 5. Forages and Forage Management

Crawfish farming practices are based on annual hydrological cycles and conditions, to which the crawfish have become adapted – namely, seasonal flooding and drying, with the dry period usually occurring during the summer. Pond inundation, or flooding, begins the chain of events that establishes the environment from which crawfish obtain most of their nutrients. As indicated in Chapter 2 under nutrition, crawfish are not routinely fed pelleted rations. Rather, the production strategies in Louisiana and other southern states rely on a forage-based system for providing nourishment to growing crawfish. (Also see supplemental feeding in Chapter 9.)

A forage-based production system benefits crawfish indirectly by supporting a complex ecological community of invertebrates, which the crawfish then consume as high quality food sources. The invertebrate community that is so important to crawfish relies on a continual influx of plant fragments that are in turn consumed by bacteria and other microorganisms. Put simply, the forage crop serves as the fuel for a food web, with crawfish at the top of the food web.

Careful Management of Forages

Because commercial crawfish production requires high crawfish densities, and because flooding duration is long (7-10 months), the forage-based food chain becomes highly used and requires careful management for maximum crawfish yields without supplemental feed. High crawfish yields without supplemental feed require ample quantities of aquatic invertebrates in the pond, fueled by a constant supply of plant fragments.

depletion of the food resource and can cause low oxygen conditions. Too little vegetative detritus can result in actual food shortages for the organisms that crawfish rely on as high quality food items and, therefore, food shortages for crawfish.

Crawfish farming, as practiced in Louisiana, requires a forage crop that provides plant matter to the underwater food web consistently throughout the growing season. In general, voluntary stands of vegetation perform this task poorly. Terrestrial grasses make for a poor crop because much of the stand is killed upon flooding, negatively affecting water quality and providing short-lived detrital resources (Figure 5.1). Because of the adaptations of rooted aquatic and semi-aquatic plants such as alligatorweed (*Alternanthera philoxeroides*) (Figure 5.2), smartweed (*Polygonium* spp.) and others, fragmentation is usually inconsistent and often seasonal. Much of the vegetative biomass of hardy aquatic plants normally remains alive and above water and is unavailable to the food web except for seasonal events such as killing frosts, which often make it available in excess quantities and at times (winter) when it can be least utilized.



Figure 5.1. Terrestrial vegetation that is killed upon flooding breaks down quickly, causes water quality problems and provides little fuel for the natural food web that supports crawfish harvests.

Despite the inadequacies of individual plant species in a volunteer stand, the right mixtures of native plants can have a complementary effect and do occasionally produce acceptable crawfish yields. With voluntary stands of vegetation, however, the appropriate mixture of species is very difficult to obtain on a consistent basis. Furthermore, some native plants tend to become so thick they impede harvesting efforts and/or efficiency. Pond warming during spring, and often water circulation, can be slowed by thick stands of plants. Moreover, many voluntary species are considered noxious weeds and are undesirable in fields where agronomic crops will be grown during subsequent years.

Planted agronomic crops routinely have been the most effective forage resources for crawfish ponds. They are effective partly because these plants exhibit the desired characteristics under the long-term flooded condition of a crawfish pond and partly because adequate stands of vegetation are achievable and predictable when recommended management practices are followed.



Figure 5.2. Naturally occurring aquatic plants such as alligatorweed can provide for some crawfish production, but they generally cannot generate the yields realized with rice or sorghum sudangrass.

October



November



December



January



February



March



April



May



June



Figure 5.3. The growth and decay characteristics of rice make it suitable for use as a forage in crawfish ponds.

Other Benefits from the Forage Crop

Apart from supporting natural food production, native and cultivated plants can benefit crawfish ponds in other ways.

(1) Forages provide refuge and hiding places for crawfish to escape predators and help to minimize cannibalism.

(2) Standing plants provide vertical substrate that allows crawfish to escape the bottom, utilize the water column and reach the pond surface during periods of low oxygen.

(3) Forages also provide substrate, or attachment surfaces, for epiphytic organisms and invertebrates that comprise part of the crawfish's diet.

Rice (*Oryza sativa*) has become the standard forage crop for the industry (Figure 5.3). Because of its semi-aquatic nature, rice tends to persist well in flooded crawfish ponds, yet it furnishes plant fragments to the detrital pool in a consistent manner. Sorghum-sudangrass hybrid (*Sorghum bicolor* x *S. sudanense*) is also used successfully (Figure 5.4). Millets (browntop, Japanese, proso and pearl cultivars), grain sorghum and soybean stubble also have been examined as possible forage crops, but all

these plants demonstrate limited potential for crawfish production when compared to rice or sorghum-sudangrass.

Agronomic plant type and management considerations for maximum yield in crawfish ponds depend on the type of culture system used for growing crawfish. Although basic cultural requirements and practices for producing crawfish are similar regardless of management approach, different production goals dictate different management concerns. This consideration particularly applies to the forage crop and its management. Information regarding recommended practices for planting and management of forage crops can be found in publications such as the Louisiana Rice Production Handbook (Pub. 2321) or by contacting your local LSU AgCenter extension agent.

Monocropping Systems

In crawfish monocropping systems, choice of plant species/variety and time of planting are the most important considerations regarding forage management. (Also see Management Considerations in Chapter 7.) Aside from relying on voluntary



Figure 5.4. Sorghum-sudangrass, when managed properly, can be a suitable alternative to rice as a forage crop in crawfish ponds.

vegetation, choices for maximum benefit are limited mainly to rice or sorghum-sudangrass hybrid, and the choice usually depends on personal preference and logistical considerations. Rice is the most widely used of the two, and variety selection is primarily based on forage characteristics rather than grain traits. Unless waterfowl hunting is part of the overall management goal, grain production in the crawfish forage crop is not desirable.

Until 2004, rice variety selection for use in crawfish ponds had been limited to those varieties developed for grain production. Rice breeders have consistently developed rice varieties for grain production that have high grain-to-forage ratios, are shorter in plant height and are earlier maturing – characteristics that, although desirable for high-yielding grain crops, are less desirable in a crawfish forage crop. Desirable traits for rice used in crawfish ponds include high forage biomass production, low-temperature tolerance, longer maturity cycle, high resistance to lodging, slow senescence (breakdown) rate, disease resistance and propensity for plant re-growth in spring.

In 2004, the LSU AgCenter released the first rice cultivar developed specifically for use in crawfish monocropping systems. “Ecrevisse” was the culmination of years of screening and evaluation of rice genotypes originating around the world, and selection of one line that was further improved (purified) under Louisiana’s growing conditions. This new variety exhibits much greater forage biomass production, better persistence under the extended flood conditions of a crawfish pond and has a greater propensity for post-winter regrowth than the commonly used domestic varieties (Figure 5.5). Because of the selection criteria used and the methods employed for further development of this variety, there was an inherent selectivity for disease resistance and adaptability to South Louisiana’s soil and environmental conditions. Therefore, until a better variety is found, this new variety should be the hands-down choice for establishing a rice forage crop in crawfish monoculture ponds in Louisiana. Ecrevisse is almost certainly limited to crawfish monocropping systems, however, because it is a short grain rice and exhibits poor milling traits, making it less desirable for use in grain markets.

Selection of rice varieties other than Ecrevisse for establishment in crawfish monocropping ponds is currently limited



Figure 5.5. Ecrevisse, the first rice variety specifically developed for crawfish production, as it appeared in late spring in a commercial crawfish pond when planted the previous summer.

to commercially available high grain-yielding varieties. Recommendations from commercially available varieties are scant because few comparative studies have been made regarding their suitability in crawfish ponds. New varieties are released and adapted so often that it is impractical to investigate thoroughly each one within the different regions where crawfish are grown. In general, those varieties that are well-adapted to local conditions, are taller, have a longer maturity cycle, tiller well, produce abundant forage biomass and senesce slowly are likely to be the best choices for planting in crawfish ponds. In theory, supported only by preliminary research, it may be beneficial to mix several varieties when planting in crawfish ponds. Differences in post-flood characteristics of different varieties, such as fragmentation rate, crop persistence and re-growth potential may provide detrital material to the pond on a more consistent and extended basis than a forage crop composed of only a single variety.

It has also been demonstrated that sorghum-sudangrass, commonly used by cattlemen for grazing and hay, is a well suited alternative forage crop for crawfish monocropping systems. It grows rapidly, can produce nearly twice the amount of forage biomass as rice, is very hardy and drought resistant and may prove more reliable in some cases than rice when a stand must be established in late summer. This crop, if managed properly, also exhibits good persistence in crawfish ponds with consistent fragmentation of material well into the season. One of the main benefits of sorghum-sudangrass over rice is that it does not require as much moisture for optimum growth. An adequate rice crop can rarely be achieved without some irrigation during the summer growing phase in Louisiana. Conversely, sorghum-sudangrass may need little or no irrigation and, in fact, cannot tolerate saturated soils for an extended period while in its early growth stages. Another potential benefit of sorghum-sudangrass over rice is that it has a later recommended planting date. Because of its rapid growth potential, when the optimal window for rice establishment has passed, forage stands can often still be established (or salvaged) by planting sorghum-sudangrass.

Regardless of which agronomic crop is chosen for use in crawfish monocropping systems, time of planting is extremely important. For best results, when waterfowl hunting is not a consideration, it is essential to plant early enough in the summer to achieve maximum vegetative growth, but not so early that the plant reaches full physiological maturity. A forage crop that matures or “fills grain” prior to the onset of winter tends to senesce more rapidly (Figure 5.6), often resulting in early depletion of the forage resource and subsequent stunting before the crawfish season’s end. In South Louisiana, the most appropriate planting time for rice for crawfish forage is during the first two weeks of August. For sorghum-sudangrass, optimum planting time is generally in the last two weeks of August.

Recommended Crawfish Forage Planting Times in Monocropping Systems

Rice - Optimum planting time for crawfish forage in southern Louisiana is the first two weeks of August

Sorghum-sudangrass - Optimum planting time in southern Louisiana is the last two weeks of August

Recommended planting dates tend to be earlier in more northerly areas. If a crawfish producer anticipates flooding early (prior to mid-October) or grazing or baling of the crop, earlier planting of sorghum-sudangrass should

be considered. When waterfowl management is an important component of the farming practice and seed formation in the crawfish forage crop is desired, species selection and/or planting dates may need to be altered. In most situations, however, it is difficult to manage for maximum benefits in the crawfish forage crop while managing for waterfowl hunting.

Adequate stand establishment is another important aspect of forage management. Even under the best of situations, early depletion of the forage resource can occur, especially with high populations of crawfish (Figure 5.7). Nevertheless, to ensure maximum benefit from the forage crop, starting with an ample stand of forage is essential. Regardless of plant type chosen, when dry-seeding forage for crawfish, good stands are easier to achieve in well-tilled seedbeds. Water seeding is also a common method for the commercial planting of rice; however, achieving proper stands can be difficult with this method during the sum-



Figure 5.6. Rice planted too early in crawfish monocropping systems, whereby the plant reaches maturity (fills grain), tends to become depleted prematurely as noted in this LSU AgCenter experiment (June planted rice on right, August planted rice on left).



Figure 5.7. A forage-depleted pond. This situation is often common by late winter and early spring.

mer heat. High water temperatures can impede germination or stifle survival of young seedlings.

Water (or moisture) management is an important consideration for both water- and dry-seeded fields. Rainfall after planting is the preferred means of obtaining and maintaining moisture, but in the absence of timely rains, irrigation may be needed. As with water seeding, standing puddles of water after planting can contribute to poor stands of forage in dry-seeded fields. Permanent, but shallow, floods usually can be established in rice forage crops when the rice plants are tall enough (2-4 weeks after planting) to withstand standing water. If the pond contains minimal amounts of terrestrial weeds that would not contribute to water quality problems when flooded, a shallow flood is desirable.

Dry-seeding Recommendations

For dry seeding of rice, 75 lb/ac to 90 lb/ac of seed are recommended for drill planting, and 90 lb/ac to 120 lb/ac of seed are recommended for dry broadcasting. Sorghum-sudangrass can be planted at 20 lb/ac to 25 lb/ac if drilled or 25 lb/ac to 30 lb/ac if dry broadcast in well-tilled seedbeds. Dry broadcast-seed of both rice and sorghum-sudangrass should be lightly covered (0.25 to 0.5 inch) with harrow or other similar equipment for best results. Depth of drill-planted seed depends largely on soil type and moisture content, and LSU AgCenter extension service recommendations should be followed for proper seeding depth.

Water levels can be slowly increased as the rice grows until full flood depth is reached in the fall. Establishment of the permanent flood in crawfish ponds planted with sorghum-sudangrass, however, should be delayed until the forage crop has stopped growing or the optimal flood-up date (typically October 15) is reached.

With any agronomic forage crop and with most soil types, some fertilization will likely be needed for optimum forage production. Normally, on lighter soils at least 40-60 units of nitrogen (N) and a lesser amount of phosphorus (P) and potassium (K) are usually required, but a soil test is recommended for determining exact needs. Other soil amendments, such as agricultural lime, are sometimes needed but depend on several factors, including forage crop, soil type and chemistry and water characteristics. They should be determined by soil (and sometimes water) testing. Soil and water samples can be ana-

lyzed by the LSU AgCenter's Soil Testing and Plant Analysis Laboratory for a nominal fee. Contact your local LSU AgCenter extension office for instructions on submitting soil and water samples for analysis.

Pesticide management in the forage crop should be dictated by needs on a pond-by-pond basis. In crawfish monocropping systems where grain production is not the desired outcome, chemical weed control should only be undertaken when weed type and density threatens the health of the forage crop. The presence of some weeds in the forage crop is not detrimental and may even be desirable if the weeds act in a complimentary nature to the forage crop. For example, limited amounts of alligatorweed, well dispersed in a pond, are often beneficial. As the rice crop diminishes during the later part of the season, alligatorweed usually thrives in the warming water, providing shelter, substrate and some food value to the pond.

Water-seeding Problems

If water seeding is attempted, seeding rate should be in the 90 to 120 lb/ac range, and efforts must be made to discharge the water within 1 or 2 days of planting and to avoid standing puddles of water within the field that can reach high temperatures. Another problem with water seeding comes when a producer seeds into water left standing from the previous crawfish season. Often, remaining crawfish can seriously hamper stand establishment by consuming the rice seed. Successful water seeding, especially during the heat of midsummer, can be difficult even for the most experienced producer with precision leveled fields.

Insects, especially fall army worms, and diseases also can affect forage crops. Very few pesticides, however, can be used in crawfish ponds. Pond flooding can be an effective alternative treatment for armyworms in rice but this strategy is usually not a suitable option in sorghum-sudangrass. Aside from the chemical label restrictions linked to pesticide use, concerns also

are associated with the exposure of crawfish to many chemical compounds. Although the crawfish are likely protected within the burrow from most legal pesticide applications on dry ground, extreme caution and knowledge should be exercised when making any pesticide application. The LSU AgCenter extension service or other knowledgeable professionals should be consulted when questions about pest problems arise.

Rotational Cropping Systems

Multicropping of rice and crawfish requires different forage management strategies than monocropping systems. Different crop types are not an option, because crawfish always follows a rice (for grain) crop. (Also see Management Considerations in Chapter 7). Rice variety selection is limited under this production strategy because of the grain production requirements. Rice varieties are generally chosen for their grain-yielding and milling characteristics rather than forage characteristics, which tend to be inconsistent with those traits needed for high density crawfish production. Under moderate densities of crawfish, however, many high grain-yielding rice varieties are sufficient. For maximum benefit under high population densities, rice variety selection in a multi-cropping strategy should also take into consideration the ratooning characteristics of the variety. Residual straw and stalks in harvested rice provide little

long-term benefits in terms of food resources. The bulk of the required forage base is derived mainly from ratoon or re-growth of the rice stubble after grain harvest.

Within the confines of best yielding (and milling) rice varieties, consideration should also be given to those varieties with a high propensity for ratoon forage production (Figure 5.8). Commercial rice varieties are constantly changing as new and improved lines are released; therefore, variety selection should be based on the best available information, which is usually obtained from LSU AgCenter extension personnel or publications such as “Rice Varieties and Management Tips” (Pub.2270), published annually by the LSU AgCenter Louisiana Cooperative Extension Service.

Management of the forage crop for crawfish under a rotational strategy is principally related to ensuring proper re-growth from the ratoon crop and minimizing the negative effects on water quality from breakdown of straw and debris from the grain harvest. As with crawfish monocropping systems, fertilization and irrigation is often needed to ensure maximum forage production. Because of previous applications of phosphorus and potassium in the main rice crop, subsequent applications may not be necessary, but often additional applications of nitrogen are required for maximum response and re-growth. Soil tests and/or advice from a professional should aid in determining exact nutrient amendments needed for each situation.

Rice stubble responds best to applications of fertilizer, followed by irrigation, shortly after grain harvest. Extended delays in supplying moisture to the stubble during dry conditions can result in poor re-growth. Also, periodic irrigation or, as with crawfish monocropping, maintaining a shallow flood may be warranted to ensure adequate moisture and uptake of nitrogen applications. Water quality will deteriorate quickly, however, with a constant flood due to high amounts of decomposing plant matter and must be improved before crawfish begin to emerge. Improved quality can be accomplished by water discharge or allowing for complete evaporation, followed

by refilling, often several times. Since most rotational cropping occurs in precision-leveled fields, the most efficient means of water and forage management prior to establishment of the permanent flood is to implement a shallow flood (2-4 inches deep) and allow for evaporation, with water replenishment before the soil becomes too dry.

To further minimize water quality concerns, the straw and debris left from grain harvesting operations can be baled and removed, burned or chopped (to speed degradation). Those practices should occur during or immediately following grain harvest and before applying fertilizer and water. Timely rain or irrigation is essential for proper re-growth and also aids in partial decomposition of dead plant material that can cause water quality problems upon flooding for crawfish. Nonetheless, timing of the permanent flood should be delayed in these systems until cool weather persists. This is usually early to mid-October or later in South Louisiana. As with crawfish monocropping systems, weed-free fields are not necessary for adequate crawfish yields, and caution should be exercised anytime pesticide applications are contemplated.

Post-Flood Management of the Forage Crop

Regardless of the production strategy employed or forage type used, few forage management options are available, or needed, following crawfish pond flood-up. For ease of harvesting, some producers choose to establish trapping lanes in the forage crop prior to flood-up. Lanes can be established by mowing, disking or dragging a heavy object in a path where boat “runs.” Other farmers elect to establish lanes, if needed, after flooding by repeated trips with a harvest boat. For best results, trapping lanes should be constructed so that traps rest squarely on the bottom to optimize catch efficiency.

Forage biomass persistence, especially with rice, can sometimes be improved by minimizing flood depths. In general, with the exception of some aquatic plants, the deeper the water depth is maintained in ponds, the more rapidly the forage crop will be depleted. Forages also can become depleted prematurely when crawfish biomass is high or when the crop matures and forms grain prior to winter. Grain formation, aside from coinciding with increased breakdown rates, often attracts birds that, in high numbers, may physically break down the forage crop prematurely.

Rice crops, especially immature stands, may have a tendency to resume growth when temperatures warm sufficiently in the spring, provided living stalks survive the winter and crawfish density is not exceedingly high. This new growth can be critical in providing additional food resources at a time when they are needed the most. To encourage spring re-growth, however, pond managers may need to lower the water level in turbid waters to expose viable nodes on the rice stalk to warmth and sunlight. Lowering water level is an important, but often overlooked, management strategy that increases food resources and can sometimes prevent stunting.



Figure 5.8. In a rotational cropping system, where rice varieties are chosen for their grain production, minor differences may be observed among varieties with regard to forage traits as shown in this experiment. Management practices, however, usually have a much greater influence on forage performance than variety selection.

Chapter 6. Stocking

Crawfish aquaculture relies on natural reproduction of resident or stocked adults to populate the ponds. Yields of harvestable animals within a season depend on broodstock survival, successful reproduction and survival of offspring. In established ponds, however, where production occurs in the same location each year, crawfish populations are usually self-sustaining with no need for supplemental stockings, short of some major catastrophe that interrupts the normal life cycle, such as a major die-off (from pesticides or other contaminants) prior to successful brooding. Once a pond is established, subsequent crawfish crops rely on holdover broodstock from a previous cycle. This reliance is possible because harvesting operations are inefficient, allowing significant “carry over” of unharvested individuals from year to year, even under the most intensive harvesting efforts.

Since crawfish populations tend to be self-sustaining, stocking is usually only needed in new ponds, when a pond has been idle for a season or longer or after extensive levee renovation or other events that disrupt the reproductive process in permanent ponds. Stocking of new ponds is usually necessary, unless it is known beforehand that sufficient numbers of crawfish of the right species are present to serve as broodstock. When a pond is idle for at least a season and remains dry for much of that time, crawfish broodstock mortality may increase and/or reproductive processes may be hampered to the point that restocking is needed.

Restocking is often needed following major levee renovation because the most productive broodstock are usually burrowed into the levees in open ponds, and earth moving will often destroy broodstock within their burrows or prevent re-emergence in the fall. Sometimes repair or renovation of existing levees is unavoidable, but if done on a large scale during the interval between crawfish burrowing in spring or early summer and reproduction during the fall, restocking will likely be needed. Unfortunately, restocking may not always be possible before the next production season. Severe drought conditions during the critical reproductive period (July to October in the South) also can impair reproduction.

Field rotational methods for crawfish aquaculture do not normally allow for crawfish populations to reach high densi-

ties. To ensure adequate numbers of broodstock in a pond that has been out of production for one or more seasons, rotational ponds are usually stocked annually. (Also see Chapter 3.) For the most part, population control is one of the most difficult aspects of crawfish production due to, in part, factors that are not under the producer’s control. Many factors associated with stocking practices, however, do fall under the control of a pond manager and can greatly influence production outcomes during the subsequent season. Research has indicated that broodstock survival and reproductive success following stocking can be highly variable, though many of the reasons are still unidentified.

Species and Size

Producers in Louisiana should stock only red swamp crawfish because of their high fecundity and preference in the marketplace. In areas with no marketing concerns over white river crawfish, some mixture of reds and whites is acceptable. Size of mature broodstock is of little concern because, although larger crawfish produce a higher number of young, fewer crawfish are purchased per pound of broodstock. Smaller crawfish produce fewer young on average, but more crawfish are purchased per pound. Therefore, total recruitment potential is similar regardless of the size of the broodstock used. Yet, smaller crawfish are sometimes sought because their price per pound is usually lower. Some anecdotal evidence suggests that small, mature broodstock may be hardier than very large adults, but this has yet to be verified.

Dates

New ponds in a monocropping system are usually stocked between April and July when broodstock sources contain a high percentage of sexually mature individuals with at least some advanced ovarian development. (See Chapter 3.) Cost of broodstock is sometimes an important variable when decisions to stock are made, with prices usually lowest near the end of the harvest season. Stocking should follow all major levee work, most notably when levees provide the only exposed ground in a flooded pond. Crop rotational systems that employ the field rotation approach are usually stocked in late May, in June or July, when rice plants are large enough to withstand the crawfish without damage and when most needs for harmful pesticide applications have passed – about 45 days post-planting.

Habitat

Crawfish broodstock are obtained from a variety of habitats (monoculture ponds, rotational ponds and the wild crawfish fishery) and from a wide array of conditions within each of those habitats. Research has not shown a strong link between habitats broodstock may be collected from (say, farmed versus wild) and their survival or reproductive success. It is likely, though, that the environmental conditions within habitats where breeding stock is obtained, such as water temperature, quality and quantity of nutritional resources, crowding and other factors are responsible for much of the variability in reproductive success. Suitable broodstock can be obtained from any type of pond or natural habitat as long as the crawfish are in good health and not under undue stress. Common stressors in any habitat are related to elevated temperatures, low oxygen, poor nutrition and overcrowding, including overcrowding inside traps prior to harvest.



Red swamp crawfish are preferred for aquaculture due to their high fecundity and preference in the marketplace.

Vegetative cover within the pond being stocked plays an important role in broodstock survival. Although daily nutritional needs are easily met after stocking (because of low densities of crawfish stocked), vegetative cover serves to protect stockers from predators and cannibalism and may serve to buffer the pond temperature. Many types of vegetation also provide access to the surface in times of low oxygen. Vegetation, or some other form of cover, along the water's edge also provides protection from predators while brood crawfish are constructing burrows. If levee surfaces are completely bare and devoid of cover, artificial cover, such as cardboard, plywood, clumps of hay or corrugated roofing material strategically placed along the perimeter near the water's edge will enhance successful burrowing.

Pond water temperature during and after stocking can also be a critical factor. Crawfish cannot tolerate water temperatures over 92 F to 95 F for long periods. Crawfish may seek deep or shaded areas of the pond, if available, to avoid the extreme temperature of midday, but if refuges are unavailable, crawfish will simply leave the pond or die. Increased water depth, vegetative cover and shade, or water exchanges are all options for buffering the effects of high water temperatures at stocking.

Handling

Proper handling of broodstock is also critical for best results. Care should be taken to limit the amount of time broodstock remain in the trap prior to harvest and in storage and transit after harvest. Lengthy exposure to elevated temperatures, direct sunlight or wind will kill or severely stress broodstock, as will rough handling or contamination with foreign substances such as fuel or chemicals (Figure 6.1). Crawfish should be kept clean, moist and at temperatures between 60 F and 80 F. These practices are best accomplished by shading (with tarps, burlap or other suitable materials) and wetting sacks of crawfish periodically. Broodstock should not be kept in refrigerated coolers or completely iced down. Limited use of ice, however, may be a suitable means of controlling temperature and moisture during transport. Harvesting or transporting crawfish broodstock at dawn, dusk or night is also a suitable means of reducing stress. Always exercise caution when handling the animals. Excessive or rough handling can lead to crushing or cracking of the delicate exoskeleton, raising mortality.

Conditions under which crawfish are introduced to the pond are also critical. Contrary to rumor, crawfish should



Figure 6.1. Crawfish intended for pond stocking must be protected from drying out and excessive heat, not to mention contamination with fuel or chemicals.



Figure 6.2. When stocking crawfish, always introduce them directly into the water.

always be emptied directly into the water and not onto dry ground adjacent to the water (Figure 6.2). Because crawfish are mobile, there is no need to equally disperse them over the entire pond or even around the entire perimeter, but some dispersal may be necessary in large fields. However, crawfish should be stocked into each section or segment of a divided pond. Best results are achieved when water temperatures do not differ greatly from the temperature of the crawfish themselves at the time of stocking. Therefore, stocking during the cooler hours of the day/night or during cloudy/rainy weather is one way to minimize this difference and maximize survival.

Rates

Stocking rates are based primarily on anecdotal evidence, pertinent factors affecting successful survival and burrowing and, to some extent, personal preference. Recommended stocking rates vary depending on the number of native crawfish present and the amount of cover around and within the pond. Amount and type of cover, such as vegetation in the pond and at the water's edge often will affect the number of crawfish surviving and successfully burrowing after stocking. Stocking rates of 50 lb/ac to 60 lb/ac are recommended for areas lacking native crawfish and with sufficient cover to protect stocked crawfish from predators (both in the pond and while burrowing).

Stocking rates may be decreased from these general recommendations when healthy populations of native crawfish are present. Similarly, they should be increased when conditions make for poor survival following stocking or when burrowing is hazardous due to predators or inclement weather. Although not well documented, it is possible that effective stocking rates may be lowered somewhat when stocking occurs in ponds with permanent levees that already have many old or existing burrows.

In very large ponds with flat bottoms and few interior levees, effective stocking rates may be limited by the amount of linear levee surface around the pond. When the ratio of pond surface area becomes exceedingly large compared to linear levee, available burrowing area at the water's edge may be limited, thereby necessitating lower stocking rates. Simply put, not enough levee is available for crawfish to burrow into.

Anticipated weather patterns after stocking also may influence desired stocking rates. Successful burrowing depends on critical moisture levels in the soil. Drought makes for poor

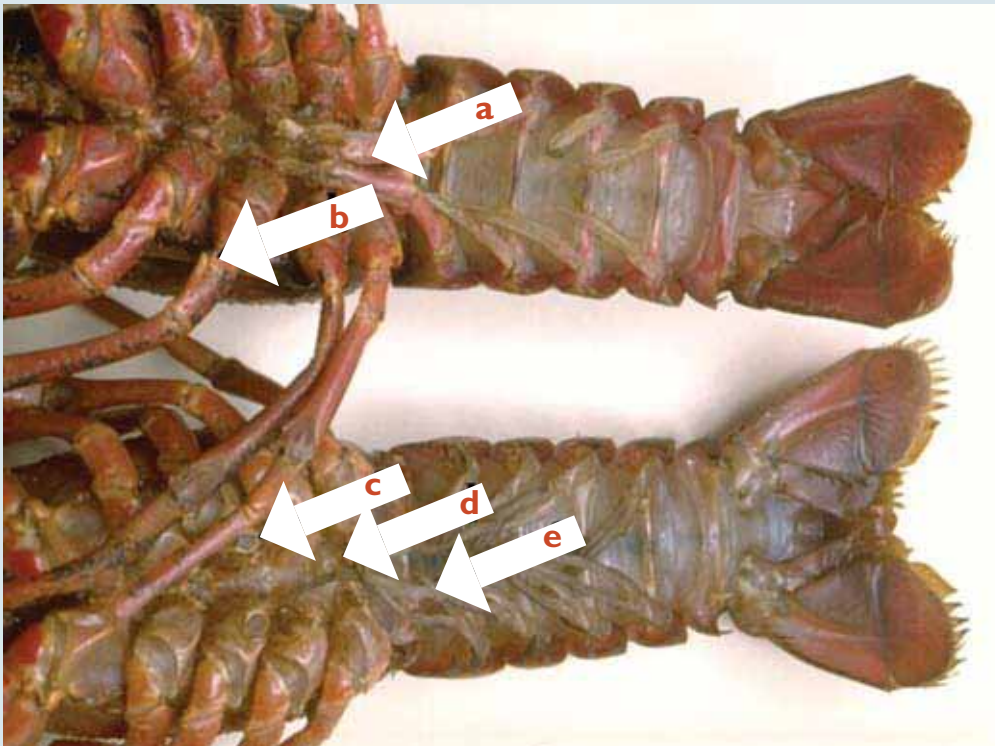


Figure 6.3. The sex of crawfish may be determined by the calcified, modified swimmerets (a) and prominent hooks at the base of the middle two pairs of walking legs (b) in mature males (top), and presence of oviduct openings (c), seminal receptacle (d) and lack of hard, calcified swimmerets (e) on females (bottom), when viewed from the underside.

burrowing by lowering water levels and drying out the levees. Frequent rainfall helps stabilize water levels and makes burrowing easier for the crawfish, possibly even allowing burrow excavation away from the water's edge. In short, stocking recommendations of 50 lb/ac to 60 lb/ac are only general recommendations – many producers elect to stock up to 80 lb/ac or more when post-stocking survival is unpredictable. Producers should weigh all of the factors in their given situation and adjust stocking rates accordingly.

Sex Ratio and Condition of Broodstock

The sex ratio and condition of crawfish broodstock both are important. At least 50 percent of the crawfish used as stockers should be females (Figure 6.3). The percentage of females can be higher, but percentage of males should not be higher than females. Healthy males can mate with more than one female. Quality crawfish broodstock also should have an outwardly healthy appearance and be highly active at normal temperatures.

Under typical stocking conditions, most of the broodstock should be sexually mature, especially if environmental conditions in the new ponds are poor (little food or shelter, poor water quality, high temperatures, etc.) or the pond must be drained soon after stocking. If pond conditions or water levels deteriorate soon after stocking, it is desirable that crawfish be able to begin burrowing shortly after introduction. The goal of broodstock management is for crawfish to start burrowing on their own (for reproductive purposes) when they have reached maturity and mated, rather than being forced to burrow for survival purposes because of pond drainage. Therefore, under less than ideal conditions, it is desirable to stock crawfish that are nearly all mature at the time of stocking.

Conversely, if new ponds have optimal temperatures and oxygen levels, contain sufficient cover to minimize predation and can maintain these conditions for an extended period after stocking, it may be desirable to stock with younger crawfish that are not closely synchronized in their state of maturity. Under favorable conditions, “pre-adult” crawfish can mature and mate in the new pond following stocking, and a mixture of younger and more mature crawfish at stocking might extend the effective spawning period over more months in the subsequent production season. An increased spawning period increases chances of successful reproduction and recruitment under unpredictable conditions before and after flooding, such as drought, hurricanes, delayed flood-up or other events that might interfere with normal recruitment. Nonetheless, for the most predictable results, at least half of the crawfish at stocking should be sexually mature.

In addition, when stocking occurs during summer, at least some portion of the mature females should show signs of ovarian development. Mature females possess yellowish to tan, or

even darker eggs (see Figure 2.4 in Chapter 2). The optimal percentages of crawfish with advanced ovarian development and the optimal stages of development at stocking have not been determined and probably vary from situation to situation.

As with any species, reproduction calls for nutritional needs beyond those required for body maintenance or even growth. Crawfish need to have enough stored energy reserves prior to burrowing not only for survival during the long burrow confinement, but also for the reproductive processes that occur in the burrow, where additional food resources are limited or nonexistent. Crawfish used for broodstock should possess adequate nutritional reserves prior to stocking or be able to acquire what is needed following stocking but prior to burrowing. Hence, aside from exhibiting signs of egg development, suitable stocker crawfish also should possess signs of adequate energy reserves in the hepatopancreas (or “fat”), the main energy storage organ (Figure 6.4). The hepatopancreas of dissected crawfish should appear full and fatty and golden or yellow, but not brown, green or watery looking, which indicates poor nutrition and body condition. Examination of a few dissected individuals from each population of crawfish stocked is the preferred way to estimate body condition and reproductive stage.

Preliminary evidence suggest that, in some cases, supplemental feeding of ponds prior to harvesting crawfish for broodstock may improve body condition and increase the reproductive performance of the stockers. Predictable, cost effective feeding protocols, however, have not yet been developed. Furthermore, given an adequate period from stocking to burrowing of several or more weeks in a new pond or rice field, crawfish may be able to gain sufficient energy reserves in the relatively food-rich environment without the use of supplemental feeds.



Figure 6.4. A full, fatty and bright yellow or orange hepatopancreas (digestive gland) inside the body of a mature female prior to burrowing indicates the much needed energy reserves for reproduction (left), whereas a small, watery, amber hepatopancreas indicates a less desirable body condition (right). Note, the dark eggs in the ovary of the crawfish on the left – indicating advanced reproductive development.

Post-stocking Recommendations

To achieve maximum results, stocked crawfish must survive and, if necessary, complete maturity, increase their energy reserves, mate and then burrow successfully. Therefore, environmental conditions in the pond should be maintained to support this process for the maximum number of stockers. This means water temperature and oxygen should remain within acceptable ranges, and water levels should remain relatively constant. Water replacement and/or flushing may be necessary. To provide crawfish every opportunity to burrow successfully and in optimal conditions, water should remain on the field as long as possible, or feasible, after stocking.

Premature draining can prevent some crawfish from reaching the desired state of maturity and/or condition, and also can make burrowing more difficult or impossible. Fluctuating water levels, especially in the absence of timely rains, also can hinder proper burrowing. Unchecked predators, especially fish and birds, can significantly reduce numbers of broodstock, and extensive levee work following burrowing can further reduce survival, reproduction and recruitment. Therefore, attention given to ponds after stocking is as important as other factors relating to the practice of stocking brood crawfish in new or idle ponds.

Summary

To ensure maximum benefits and achieve the most return for dollars spent while minimizing risks, care should be taken to optimize a stocking strategy. Receiving ponds should be completed and readied for animals in advance of stocking with adherence to recommendations for water quality, cover and predator control. All, or in some cases, most of the crawfish to be stocked should be red swamp crawfish, and the stocking rate should be carefully determined based on all applicable factors, including personal experiences for a particular geographical location and habitat. To prevent the proverbial “all the eggs in the same basket” syndrome, consider stocking any given pond on more than one date within an acceptable time frame and with crawfish from more than one source. Furthermore, mixing females with varying maturity/egg stages, depending on when ponds are stocked and the length of time ponds will remain

Stocking Guidelines

- New or idle crawfish ponds should be stocked with approximately 50 to 60 pounds of crawfish per acre.
- Add more if pond (or crawfish) conditions are questionable, and less if crawfish are already present.
- Stock healthy crawfish (sacrificed individuals generally have bright yellow fat).
- Be sure at least 50% are female.
- Be sure at least 50% of females are mature (sacrificed individuals will have yellow to brown eggs).
- Don't be concerned about individual size, or origin of stock, as long as the crawfish are mature and healthy.
- Red swamp crawfish only, from more than one source, is preferred.
- Stocking over several days is preferred.
- Do not use crawfish that were stored in a cooler.
- May to June is the preferred time to stock, although stocking in July may be possible under the proper conditions.
- Move crawfish as fast as possible to the pond; keep wet and shaded.
- Stock all sections of the pond and place crawfish directly in the water, not on dry ground.
- Do not drain fields for at least 2 or 3 weeks after stocking.

flooded after stocking, will aid in expanding effective spawning dates and lessen potential setbacks from unforeseen circumstances.

Stocking should be done with healthy animals of the proper ratio of females possessing a high level of energy reserves and proper handling during and after harvest. If possible, stocking should accompany rainy weather and/or occur when pond temperatures are the lowest in the day. Pond levels should remain mostly constant, at near normal depths, until a week or so before draining, when water level can be dropped substantially and held at that level until final draining to trigger last-minute burrowing. Ponds should remain flooded for as long as possible or practical following stocking. Lastly, hold levee disturbances during summer to a minimum. The initial stocking of brood crawfish is one of the least costly components of farming crawfish. Any attempt to “save” money by purchasing poor quality broodstock or failure to follow recommended stocking protocols will invariably be very expensive to the producer if reproductive failure is the result.

Chapter 7. Water Quality and Management

Poor water quality that persists for days and weeks is detrimental to crawfish production. Water quality is influenced by many factors, both environmental and biological. Some environmental conditions such as temperature and rainfall are beyond the control of the farmer. Other factors, such as the type of vegetation planted for crawfish in summer, when the vegetation is planted, how the vegetation is managed prior to flooding the ponds and when the pond is flooded will influence water quality in crawfish ponds. Most serious water quality problems occur in the fall, usually in the first two to six weeks after ponds are flooded and later in the early spring when pond water warms. All crawfish farmers will have water quality problems at some point during the production season, but the magnitude and severity is dramatically reduced at the outset by insuring ponds are properly designed, securing a stable and reliable water source, by matching the pumping capacity with production acreage, managing vegetation prior to flooding ponds in the fall and water after flooding and taking corrective management steps when water analysis tests indicate action is necessary.

Water Supply and Quantity Required

Both surface and subsurface water is acceptable for crawfish farming. Wells provide predator-free water, but they have a limited discharge capacity and higher investment and pumping costs. Because well water contains no oxygen and is usually high in soluble iron and toxic hydrogen sulfide, the water must be aerated to add oxygen and remove iron and sulfide prior to entering the pond (Figure 7.1). Surface water is satisfactory if it is pollution-free and if nuisance predatory fish are screened out. Although cheaper to pump, surface water is usually not as reliable in quantity and quality (Figure 7.2).

Pumps, motors and pipes must be matched to obtain the most efficient performance. Lift should be minimized as much as possible to reduce pumping costs. Pond location and local energy costs dictate the type of pump and power source best used for crawfish ponds. Surface water contains predatory fish that should be removed through a 1/2-inch mesh aeration screen (Figure 7.3). Smaller fish passing through the 1/2-inch mesh aeration screen usually don't pose a serious predation



Figure 7.2. Surface water is often more economical to use than well water, but its quality and availability vary much more often.

problem to young crawfish. These fish are killed when the pond is drained in the summer. If pools or puddles containing fish persist in the pond bottom during the summer, it is important that the puddles be dried or treated with a fish toxicant prior to filling the pond in the fall to prevent contamination of the pond with predatory fish.

A pumping capacity of 75 to 100 gallons per minute per surface acre is ideal for intensive management strategies for crawfish ponds that average 14 to 18 inches deep when fully flooded. This pumping rate is sufficient to exchange all the water in the pond over four to five days. Complete water exchange may be required in the early fall when water is flooded onto vegetation. Warm weather leads to rapid plant decay and high demand for oxygen. When the water is depleted of oxygen for long periods, significant crawfish mortality or stress that reduces growth can occur. Ponds can be designed to circulate water and maintain satisfactory oxygen levels, thereby reducing pumping and water management cost (see Design and Construction in Chapter 4). Replacing bad water in the pond with



Figure 7.1. Well water, while usually free from contaminants, must be vigorously aerated prior to use.



Figure 7.3. Aeration screens can be designed not only to aerate, but also to reduce the transfer of wild fish into ponds during pumping.

fresh, oxygenated water helps maintain satisfactory water quality. It is more effective to drain a portion of water from the pond and then pump oxygenated water to replace it than it is to drain and pump at the same time. By draining some of the water first and then re-filling, oxygenated water will be distributed through the entire pond. On the other hand, when draining and filling at the same time, many areas of the pond may not be properly flushed of bad water. Exchanging water in crawfish ponds to improve water quality is energy intensive and expensive, and decisions to do so should be based on the results from routine monitoring of water quality, especially oxygen content.

In reality, few crawfish farmers in Louisiana supply 75 to 100 gallons per minute of water per surface acre to crawfish

ponds. The following management plan can be used when the water supply is not properly matched to the production acreage. By filling ponds to one-half normal depth at fall flood-up, a pump that supplies 35 to 50 gallons per minute per surface acre will provide sufficient capacity to replace water in several days if required. For example, if the pond is sufficiently level,

it can be initially filled to 7 to 9 inches as opposed to 14 to 18 inches. Not only will there be less water to replace during low oxygen episodes, but less vegetation is submerged and oxygen demand is reduced. When temperatures have sufficiently cooled in winter, usually below 65 F, and oxygen demand is reduced, additional water can be added to bring the pond to full depth. One possible disadvantage of the shallow flood is that females with young burrowed near the top of the perimeter levee may not exit the burrow if rainfall in the fall and winter is limited. If the water supply is much less than 30 gallons per minute per surface acre, options for effectively managing water for optimal crawfish production are limited.

Water Quality

Water quality depends on management and on properly designed and constructed ponds that have a dependable water supply. Important water quality variables are dissolved oxygen, pH, total hardness, total alkalinity, iron, hydrogen sulfide content, ammonia, nitrite and salinity (salt content).

Dissolved oxygen is the most important and low oxygen may be responsible for the death of more crawfish in ponds, either directly or indirectly, than any other factor. Temperature has a major effect on oxygen levels in ponds (Figure 7.4). Warm water cannot hold as much oxygen as cold water. Also, rising water temperature increases biological activity, so oxygen is consumed at a faster rate. When the water temperature increases from 70 F to 80 F, the rate of oxygen loss caused by decomposition doubles. Potential problems with insufficient oxygen can be expected whenever water temperature exceeds 70 F. During warm periods, ponds with an inadequate pumping capacity

Water Requirements

As a general rule, crawfish farmers require a minimum of 2.5 to 4 acre-feet of water per surface acre of pond to initially fill the pond, replace water lost from evaporation and seepage and maintain satisfactory water quality during the 7- to 10-month production season. This amount is equal to adding 30 to 48 inches of water during the production season. Rainfall replaces some of the water loss from evaporation and seepage, but pumping is required to supply the difference.

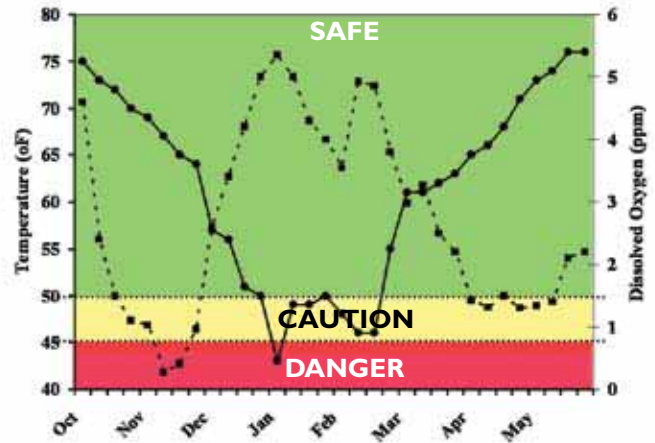


Figure 7.4. A graph illustrating the tendency for oxygen levels to fall as temperatures rise, and vice versa. (Solid line is water temperature and dotted line is oxygen level.)

and excessive amounts of decaying vegetation will suffer from severe oxygen depletion, which can slow crawfish growth and reduce production if the condition is allowed to persist.

Crawfish are generally tolerant of low oxygen, but persistent exposure to extremely low oxygen for weeks can reduce production. The first two to six weeks after the initial flood-up is the most critical time for juvenile crawfish. Ideally, dissolved oxygen should be maintained above 2 parts per million (ppm) for good crawfish production but this content can be difficult, if not impossible, to sustain in the warmer months. When oxygen levels remain consistently below 1 ppm throughout the day for several weeks, crawfish become sufficiently stressed that they may cease feeding. Growth will slow and catch may significantly drop until oxygen levels increase. When oxygen levels remain below 0.5 ppm throughout the day for a week or more, newly hatched juveniles and molting crawfish may die. Larger crawfish stressed by low dissolved oxygen climb to the surface on vegetation or traps and expose their gills to higher oxygen levels at the surface (Figure 7.5). This behavior is usually not



Figure 7.5. When oxygen levels become critically low, crawfish attempt to access the water surface, or may even leave the pond.

visually observed with juvenile crawfish because of their small size. The shelf life of live harvested crawfish in the cooler is reduced considerably if they have been exposed to low oxygen in ponds prior to harvest.

Because of high pumping costs, water management decisions should be based on oxygen measurements. No benefit to

crawfish health and survival is gained by exchanging water if oxygen levels are satisfactory. Although pond water lacking in oxygen is often clear and dark (the color of tea, coffee or cola) and may have a smell of hydrogen sulfide (“rotten egg” odor), one should not rely on visual observation or smell to determine oxygen concentration. Dissolved oxygen can be checked several different ways. Dissolved oxygen meters are best if you have many ponds

Monitoring DO

Dissolved oxygen (DO) should be measured regularly, especially during warm weather. Dissolved oxygen levels are lowest early in the morning, so this is when you should check. The first sample should be taken where oxygenated water enters the pond. Take the water sample at a depth half way between the surface of the water and the pond bottom. Also, check at two additional locations in the pond, preferably in one area of good water circulation and one area farthest away from the pump. The general rule is if oxygen levels are 2 ppm or more at dawn, the water quality is satisfactory for crawfish. If levels fall and remain below 1 ppm throughout the day for a week or more, corrective action to add oxygenated water to the pond should be started.

to check (Figure 7.6). Most producers, however, choose oxygen test kits because the kits are relatively inexpensive and simple



Figure 7.7. The key to good aeration during pumping is to maximize contact between air and water.

to operate. The easiest kit uses a vacuum ampule that draws in a water sample. The value is determined by matching the color of the sample to a chart.

Oxygen deficiency is corrected by replacing or exchanging pond water with fresh, oxygenated water or by circulating and aerating existing water in the pond. Mechanical aerators, though not commonly used in the crawfish industry, are effective in aerating water in the vicinity of the aerator but are mostly ineffective in larger ponds with dense stands of vegetation because oxygen can not effectively be distributed throughout the pond. Installation of an aeration tower is recommended to oxygenate well water or surface water prior to it entering the pond. The aeration tower, if constructed properly, also will remove large predatory fish when using surface water. Pumping water through an aeration tower divides the water into small droplets (Figure 7.7). This technique gives maximum oxygen transfer to the water droplets. Properly designed aeration towers will add 1 to 2 pounds of oxygen to the water per horsepower hour. Well water is also aerated to some extent when it is exposed to the atmosphere as the water travels through flume ditches.

The source water pH after being aerated should range from 6.5 to 8.5, and both total hardness and total alkalinity should range from 50 ppm to 250 ppm as calcium carbonate. As a general rule, most waters and soils used for crawfish production in Louisiana are sufficiently high in hardness and alkalinity and do not require additions of agricultural limestone other than what may be required for the forage crop being cultivated. If the pH, hardness and alkalinity are low, incorporate agricultural limestone into the pond bottom during the next dry cycle. The amount of agricultural limestone required must be determined from a soil test analysis and the kind of forage crop to be grown during the summer. Water and soil samples can be analyzed by the LSU AgCenter’s Soil Testing and Plant Analysis Laboratory for a nominal fee, and recommendations will be provided as to the suitability of the water and soil for crawfish production with the results of the analysis. Contact your local LSU AgCenter extension office for instructions on submitting water and soil samples for analysis.



Figure 7.6. Oxygen levels should be monitored not only to protect the crawfish crop, but also to avoid expenses associated with unnecessary pumping.



Figure 7.8. Well water often contains iron in the reduced (un-oxidized) form. This problem can be corrected by sufficient aeration.

Dissolved iron and hydrogen sulfide are toxic to crawfish at concentrations often found in well water, but the two compounds are lowered to nonharmful concentrations when the water is oxygenated (Figure 7.8). Where iron and hydrogen sulfide concentrations are high, it may be necessary to place a flume ditch or pond between the well and the crawfish pond to allow the iron to settle out before entering the pond. Non-ionized ammonia and nitrite are toxic to crawfish at concentrations exceeding 2 ppm and 5 ppm (as nitrogen), respectively. Concentrations this high are not likely to occur in crawfish ponds because the crawfish production intensity is low and ammonia is rapidly taken up by aquatic plants present in the pond.

As mentioned in Chapter 5, extreme care must be taken with pesticides in or around crawfish ponds. Only a few agricultural chemicals are labeled for use in crawfish ponds. Crawfish are very sensitive to various classes of pesticides, particularly insecticides, which can be toxic even at low concentrations. Because crawfish are often grown in rotation with other agricultural crops, such as rice, or near agricultural crops where pesticides are used, extreme caution should be taken to insure crawfish are not exposed to pesticides, particularly after the pond or field is flooded and crawfish have already emerged from their burrows. Be sure that your neighbors and aerial applicators are aware that you are farming crawfish nearby. Read and follow label instructions of any chemicals or compounds before using it in or near crawfish ponds. The toxicity of many agricultural pesticides on aquatic organisms, including crawfish, can be found in Southern Regional Aquaculture Center Fact Sheet 4600 “Toxicities of Agricultural Pesticides to Selected Aquatic Organisms,” which can be downloaded from the Southern Regional Aquaculture Center Web site. Contact your local LSU AgCenter county extension agent or other knowledgeable professionals when questions about pest problems arise or about the use any pesticides.

Although crawfish are fairly tolerant to salt water, areas subject to saltwater intrusion are not recommended for crawfish production. Tolerance to salinity is directly proportional to crawfish size. Newly hatched young die at 15 parts per thousand (ppt), and juveniles die at 30 ppt if kept in this salinity for a week. Salinity affects crawfish reproduction at much lower concentrations, and the effect of continuous exposure to low salinity on crawfish reproduction is not fully known. Ideally, crawfish ponds should not be located where salinities higher

than 3 ppt are likely to occur through most of the crawfish production season. Coastal areas with low salinity water usually have highly organic soils that are not ideal for pond construction or for maintaining adequate levels of oxygen throughout the crawfish growing season. The salinity of the source water should be less than 1 ppt if rice or sorghum sudangrass is the desired forage crop. Crawfish farmers in coastal regions should monitor tidal influenced surface waters for salt content particularly during a drought.

Management Considerations

Flooding date is important in water management. Flooding is usually timed to coincide with peak spawning and juvenile recruitment in September and October. For this reason, it is seldom beneficial to flood ponds to full depth before mid-September. If ponds are flooded too early, extreme heat could seriously deplete the water of oxygen, causing significant crawfish mortality if left unmanaged. Several inches of water can be held in ponds planted with rice in early August to suppress weed growth without serious harm to crawfish. Ideally, sustained air temperatures should be in the low to mid-80s in the afternoon and low to mid-60s in the morning before beginning fall flood up, and this is usually early October in southern Louisiana. If ponds are large and pumping capacity is low, or if large amounts of dead plant material are present, delaying flooding until late October or early November when temperatures are lower is usually better. On occasion, heavy rainfall associated with tropical depressions or hurricanes will dump several inches of water on crawfish ponds in late August and early September. Although holding this water to reduce pumping costs is tempting, because of the extreme heat at that time of the year, releasing this water is usually best even if some juvenile crawfish are present. Early rain, however, can usually be safely held at manageable depths on rice forage planted in early August (“green rice”).

The type of forage and how the forage is managed prior to flood-up affects water quality. (See monocropping and rotational cropping systems in Chapter 5). Best water quality is maintained in ponds with rice planted in early to mid-August solely as crawfish forage because the oxygen demand of green, actively growing rice is low. Rice-crawfish rotation ponds with large amounts of rice stubble and straw following rice harvest are likely to have serious oxygen problems after fall flood-up unless the straw is baled and removed, burned or chopped and irrigated to speed breakdown and reduce oxygen demand. Significant problems with low dissolved oxygen also can occur in ponds with a dense stand of sorghum-sudangrass because of the high amount of vegetation produced and inability to control other grasses in the pond that have a high oxygen demand. Ponds that are not planted and have large amounts of volunteer grasses usually have severe oxygen depletions soon after flood-up because grasses decompose quickly. Ponds with large amounts of aquatic plants, like alligatorweed, usually have fewer oxygen problems but alligatorweed alone is not a desirable food for crawfish (Figure 7.9).

Crawfish do not have the ability to congregate in high numbers around an oxygen source for short periods of time during low oxygen episodes as do fish. Therefore, aerated water must be transported through the pond to reach all the crawfish to achieve maximum survival, growth and yield. As stated in the Water Supply and Quantity Required section in this chapter, it is important to match pumps and transport systems (pipes, canals or ditches) to maximize energy efficiency and water distribution. Water can be guided through the pond with



Figure 7.9. Natural vegetation such as alligator weed often results in better oxygen levels, but overall lower production.

small internal baffle levees to direct the flow of water throughout most areas of the pond and reduce areas with stagnant or “dead” water unsuitable for crawfish. Ponds can be designed to recirculate and aerate water to maintain water quality using return ditches and re-lift pumps (Figure 7.10). Recirculating water is often less expensive than flushing ponds and has the added benefit of reducing impact of releasing low oxygen water on the environment.

Best Management Practices

In addition to providing a highly valued and desirable seafood product, crawfish ponds serve as favorable wetland habitat to many species of waterfowl, wading birds and furbearers. Often, land that is marginal for traditional row crops is used in crawfish production. Integration of crawfish aquaculture with traditional agricultural land uses serves as a practical means of land and water conservation. Voluntary best management practices (BMPs) are an effective and practical means for conserving water and protecting the environment. Effluent or “tailwater” is discharged when rainfall exceeds pond storage capacity, when ponds are flushed to improve water quality and when drained at the end of the production season. Crawfish effluent water is usually low in nutrients and oxygen demand, but turbidity and suspended solids can be high at certain times of the year. The following set of BMPs have been identified that



Figure 7.10. Re-lift pumps can help circulate and aerate water, reducing the need for water exchanges.



Figure 7.11. Allowing water levels to drop between rainfall events provides the opportunity to capture and use rainwater.

will minimize potential impact of crawfish pond tailwater (effluent) on the environment.

1. Capture and store rainfall to reduce effluent volume and pumping costs (Figure 7.11). Allowing the normal pond level to fall at least 4 inches below the level of the standpipe (or more, depending on the season and pond design) from normal evaporation without re-filling will greatly reduce the volume of water leaving ponds during rainfall events by increasing the storage capacity of the pond to accumulate rainfall. Drain pipes within ponds can be painted a bright color to indicate the target water depth at which pumping is needed. An added benefit of this practice is the reduced need for pumping well water to maintain ponds at or near maximum depths.

2. Install drain outlets to draw overflow from the pond surface. Water from the lower layers of a pond is generally of poorer quality than that near the surface. This difference can be especially true in terms of suspended solids, oxygen demand and nutrients. Pond drains should be constructed to allow water to leave the pond from the surface, not the bottom (Figure 7.12). Existing drains that draw from the pond bottom and



Figure 7.12. During the production season, ponds should drain from the surface, not the bottom, to minimize disturbance of surrounding drainages and watersheds.

incorporate external structures to regulate pond depth should be modified during regularly scheduled pond renovations, to draw water from near the pond surface.

3. Reduce pumping costs and improve flushing efficiency. When flushing crawfish ponds in the fall to improve water quality, avoid pumping and draining at the same time. Fill the pond to one-half to two-thirds of its maximum storage capacity at initial flood-up. To flush the pond, open the drains and allow the entire pond to drop to a depth of roughly one-fourth of storage capacity, then re-fill the pond with fresh water, again to no more than one-half to two-thirds of maximum storage capacity. This type of flushing ensures that stale water will be diluted with fresh water throughout the entire pond, preventing the establishment of “dead” areas where water will not normally flow with conventional flushing. Additionally, less water is used and released to the environment by not flooding the pond to maximum depth with the initial flood-up. The pond can be filled to maximum depth (storage capacity) in late November when temperatures have dropped sufficiently. Alternatively, baffle levees can be used to direct water flow through the pond to eliminate low oxygen areas. In areas where the quality of surface water is occasionally unacceptable or where well water must be pumped from great depths, water recirculation can be a cost-effective alternative.

4. Minimize sediment loading when draining. Harvesting activity, wind and waves and crawfish foraging actions cause turbidity, or muddy water (Figure 7.13). Although this condition can be alleviated somewhat in crawfish-only ponds by postponing draining until most of the crawfish present have burrowed in the early summer, it poses problems in ponds where draining must be accomplished much earlier to allow for a commercial rice or other crop to be planted. In these instances, no specific recommendations have been formulated to reduce suspended sediments in ponds or tailwater, but suspending harvest activities for 1-2 weeks prior to draining may improve water clarity prior to discharge. The use of vegetated filter strips and channel vegetation (vegetated drainage ditches) also will probably be beneficial in improving water clarity because heavy sediments settle out and are trapped as water velocity is reduced as it passes through the vegetation (Figure 7.14). Other approaches, such as maintaining in-pond buffer zones of natural aquatic vegetation like alligatorweed, reduce the level of suspended sediments in water caused by disturbance of the pond bottom from wind and wave action and erosion of pond levees.



Figure 7.13. Weather, harvesting activities and the crawfish themselves all contribute to muddy water in crawfish ponds.



Figure 7.14. While some reduction in flow is unavoidable, allowing drainages to become vegetated with aquatic plants provides an important means of reducing sediment and nutrient losses.

5. Practice water detention during summer drawdown. A majority of suspended solids and nutrients are discharged from crawfish ponds in the remaining 10 percent to 20 percent of the pond water. Retaining water several days prior to complete draining or allowing the remaining water to evaporate if the production practice will allow for this can significantly reduce nutrient loads in tailwater because many nutrients are bound to particles of sediment, which can settle out of the water column prior to discharge (Figure 7.15).

6. Reuse pond water. To save on pumping costs, conserve groundwater and reduce tailwater discharge, if possible; pond water can be pumped into adjacent ponds or reservoirs and then reused. Transfer can usually be accomplished with a low-lift pump, and water can be replaced later by siphon. In some circumstances, it may be possible to drain water directly into ponds with lower elevations.

7. Use tailwater for irrigation. Under some conditions, pond water discharge can be used to irrigate crops. Most crawfish aquaculture in Louisiana occurs in areas used for rice agriculture, and crawfish ponds are frequently adjacent or in close proximity to rice crops. Tailwater discharged in spring and summer into drainage ditches can be re-lifted or, in some



Figure 7.15. Allowing crawfish ponds to sit for several days or weeks prior to final draining can reduce loss of nutrients and soil.



Figure 7.16. Water remaining in crawfish ponds at season's end can be a valuable resource.

cases, directly used to irrigate and replenish water in rice fields, which are planted in mid-March through April (Figure 7.16). Under some circumstances, diverting pond discharge can result in excessive erosion, so care must be taken when considering this practice.

8. Use natural or constructed wetlands and sedimentation ditches to reduce tailwater solids and nutrients. Natural wetlands are an effective means of treating aquaculture effluents, but care must be taken not to overload these systems. The presence of established stands of aquatic plants in spring and summer in ponds with volunteer vegetation increases nutrient uptake and reduces the level of suspended sediments in water caused by disturbance of the pond bottom from wind and wave action and erosion of pond levees. Although dense stands of volunteer aquatic plants are usually considered problematic in commercial crawfish operations, establishing manageable stands or strips of aquatic plants, such as alligatorweed, inside ponds, even when using cultivated forages such as rice or sorghum-sudangrass, may help to improve effluent quality as well as provide cover and food when other forages have become depleted. Drainage ditches, particularly those with a slight gradient and containing emergent aquatic plants, can effectively function as settling basin for heavier solids. Sediments that accumulate in drainage ditches over time and hinder drainage can be removed in some cases and used to rebuild levees (Figure 7.17).

9. Practice erosion control in drained ponds. When ponds are drained and idle, especially in winter in Louisiana, substantial erosion of the exposed pond bottom can occur, affecting both the serviceability of the pond and the receiving waters on the outside of the drain



Figure 7.17. Drainages that are managed to capture solids as they leave production ponds can often provide a ready source of soil for levee maintenance.

pipe. For this reason, drains should always be closed if possible when ponds sit empty, and ponds should be partially or completely refilled as quickly as possible.

10. Minimize environmental impacts during pond renovation. Use sediment from within the pond to rebuild levees and fill in low areas (Figure 7.18). Do not remove it from the pond unless absolutely necessary. During renovation, drains should be kept closed to minimize erosion and discharge of sediment. Levee height usually can be increased at this time to allow more management flexibility in capturing and storing rainfall or water from surrounding ponds. In this way, effluents also will be further reduced.



Figure 7.18. Sediments from the pond bottom itself should be the first source of soil for rebuilding levees and filling low areas.

Chapter 8. Harvest

The low-intensity production technology used in farming crawfish requires a harvest method unlike those used to harvest fish. A passive system is used, employing baited traps beginning as early as November and continuing through the following April-June. If fall and winter production of juveniles is low, or where crawfish are grown in northern portions of the state, initiation of harvest seldom begins before March and is often extended into late July.

Crawfish recruitment is continual over much of the 7- to 10-month growing season. Regular, frequent harvests are necessary, in contrast to the infrequent batch harvest with seines common with fish culture operations. Harvesting crawfish with seines or trawls is typically not feasible because of dense vegetation. Crawfish may be harvested with traps from well-managed ponds 40 to 90 days per year. In Louisiana, two-thirds of the crop is generally harvested from March through June, when densities of marketable crawfish are highest and crawfish are most active. Trapping is labor intensive, and over half of all production expenses are associated with harvest. Bait and labor are typically the major harvesting costs. Efficient harvesting is essential for crawfish farming profitability.

Factors Influencing Catch and Harvest Size

Crawfish catch from production ponds can vary two- or three-fold from day to day (Figure 8.1) and is influenced by many factors. Water temperature and density of marketable crawfish are the primary factors that govern seasonal changes in crawfish catch. However, water quality, type and quantity of vegetative forage, weather, lunar phase, as well as crawfish reproduction, growth and molting patterns all play significant roles in the variation observed in daily catch. A summary of the major factors affecting crawfish catch is outlined in Table 8.1.

Size at harvest is largely influenced by environmental conditions – much more so than genetic factors. Crowding reduces growth and usually leads to stunting. Crawfish are aggressive and territorial. Larger crawfish intimidate and out-compete smaller individuals, thereby suppressing growth. To ensure

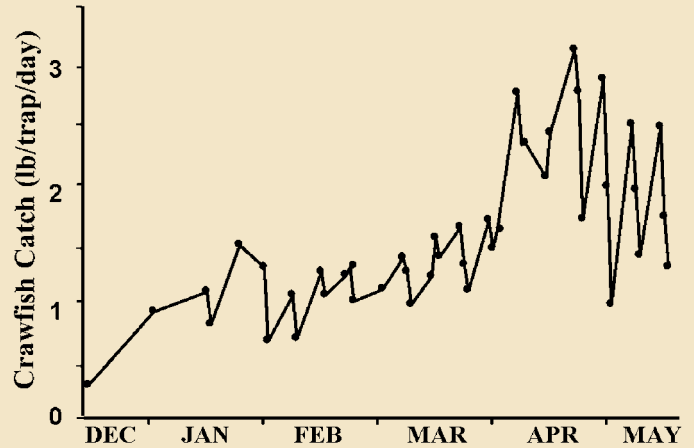


Figure 8.1. An example of seasonal trend in crawfish catch from a Louisiana crawfish pond.

growth of smaller size classes and achieve high yields, crawfish should be harvested soon after attaining acceptable marketable size. Harvesting removes larger individuals from the population, reducing aggression and leaving space and food resources for undersized animals.

The minimum acceptable size for crawfish for consumption varies with season, abundance and price; however, consumer preference is typically for 23 individuals (“count”) per pound and larger (3 1/2 inches and longer). Large crawfish, 10- to 15-count per pound, usually command premium prices.

Traps

During the early history of crawfish farming, many styles and sizes of traps were used by crawfish farmers, and all caught crawfish with varying degrees of efficiency. Presently, the “pyramid trap,” with three entrance funnels has become the industry standard (Figure 8.2). For years, most traps were made from 3/4-inch mesh, plastic-coated hexagonal-shaped (hex) poultry

Table 8.1. Some factors that influence daily and seasonal crawfish catch.

Factor	Catch Decreases	Catch Increases	Reason
Water temperature	With cooling	With warming	Regulates crawfish feeding activity.
Crawfish density	When sparse	When abundant	Regulates amount of harvestable crawfish.
Relative abundance of vegetation	When abundant	When sparse	Abundance of natural foods and bait attractants not easily dispersed.
Short-Duration Rain Showers and Flowing Water	-	Usually	Aids in bait attractant dispersal and reduced light and stimulates crawfish movement.
Mass molting	Usually	-	Crawfish cease feeding during pre-molt, molt and post-molt phases.
Lunar phase	With full moon	-	Appears to increase the frequency of molting.
Cold fronts	Usually	-	Cooling water decreases feeding activity.
Harvesting intensity	With intense harvesting	With less intense harvest or after a “rest” period	Influences the amount of harvestable crawfish.

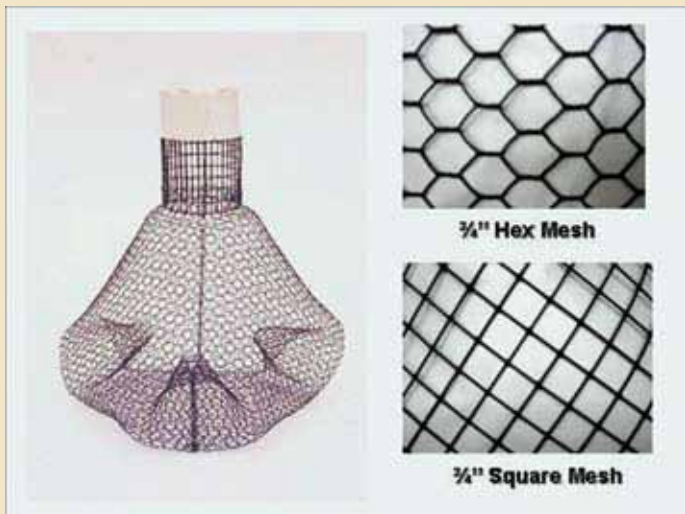


Figure 8.2. Pyramid crawfish trap with optional vertical extension.

wire (19 or 20 gauge). These mesh-sizes typically retained crawfish of minimum marketable size, about 3 inches and longer (35 count per pound). Although hex wire traps dominated the industry prior to 2003, today most traps are made from 3/4-inch or 7/8-inch welded square mesh wire. Traps made of square mesh wire are more durable. Traps made from square mesh wire also retain smaller crawfish than comparable size hex-mesh wire. Research by the LSU AgCenter has shown that 3/4-inch square wire will catch on average about one-third more crawfish than 3/4-inch hex wire traps with an overnight set. The catch with 7/8-inch square mesh traps is roughly equivalent to that of 3/4-inch hex mesh traps.

Pyramid traps are constructed from wire formed into a three-sided, three-dimensional form shaped like a pyramid. Optional cylindrical vertical extensions, usually 6 inches long, are often added to increase the height of the trap for use in deeper water (see Figure 8.2). A 6-inch diameter plastic pipe (or extruded collar) is placed at the top of the trap to function as a handle and prevent crawfish escape through the open top. Traps made from 24-inch wide by 44-inch long to 24-inch wide by 54-inch long wire are the most prevalent sizes. Final overall dimensions of the traps are approximately 17 inches wide at the base and, with a 6-inch extension, about 26 inches tall.

The inside diameter of entrance funnels is usually 1 3/4 to 2 inches. Since wind and wave action and avian predators (herons and egrets) that perch on the plastic collars can cause traps to topple, metal supporting rods (5/16-inch diameter) are often added to minimize toppling. Crawfish traps do not have bait protection containers (bait wells) as is often found in crab traps because catch is usually substantially reduced with their use.

Baits

Bait, which is required to attract crawfish into traps, is the single highest expense in crawfish production and accounts for nearly one-third of production costs. Bait cost depends on the type, amount used per trap, trap density and trapping frequency. Two types of bait commonly used are natural fish baits and formulated baits.

Fish baits are usually sold frozen in 80-pound or 100-pound boxes. Clupeid or “sardine-like” fishes, specifically gizzard shad and Gulf menhaden or “pogy” (Figure 8.3) are the most widely used natural baits in Louisiana where commercial fisheries exist for both species. Common carp, buffalofish,



Figure 8.3. Commonly used crawfish baits: (top) gizzard shad; (middle) menhaden or “pogy”; and (bottom) manufactured baits.

herring (“slicker”), suckers and catfish are also used. Shad, menhaden and carp are superior to other natural fish baits as attractants. Beef pancreas (“beef melt”) commonly used by recreational trappers, is an effective attractant but too expensive for commercial use. When a shortage of bait occurs in the Louisiana bait fisheries, significant quantities are shipped in from other states.

Formulated crawfish baits, often referred to as “artificial” or “manufactured” baits, were commercialized in the early 1980s and are produced by several feed companies, both within and outside of Louisiana. These cylindrical pellets consist mainly of cereal grains, grain by-products, commercial flavoring agents and a binder. They are generally one-half to 2 inches in diameter and 1 1/2 to 3 inches long and sold in 50-pound bags.

Fish baits are seasonal in supply and price and more expensive than formulated baits. Large farms may have freezers or coolers for storage, but smaller farms require daily deliveries. Labor is needed to cut the fish to puncture the swimbladder so it will sink and to portion it into efficient sizes, which further adds to its cost. Formulated baits do not require refrigeration and are easier to handle. Some companies offer different formulations for use in cool or warm water.

Baiting Strategies

Significant cost reductions can be achieved by employing efficient baiting strategies. The main considerations are selection of bait type relative to season and quantity of bait used per trap. Shad and menhaden are more effective attractants than formulated baits at water temperatures below 70 F (Figure 8.4), and, in Louisiana, fish baits are used almost exclusively during winter and early spring trapping (November through March). Even though fish baits are more expensive, the average two- to three-fold increase in catch over formulated baits under these conditions compensates for the additional bait cost. When water temperature exceeds 70 F to 75 F and ponds become depleted in forage (corresponding to late March to early April in South Louisiana), formulated baits become equally effective or more effective than fish baits, and they are the most cost-effective

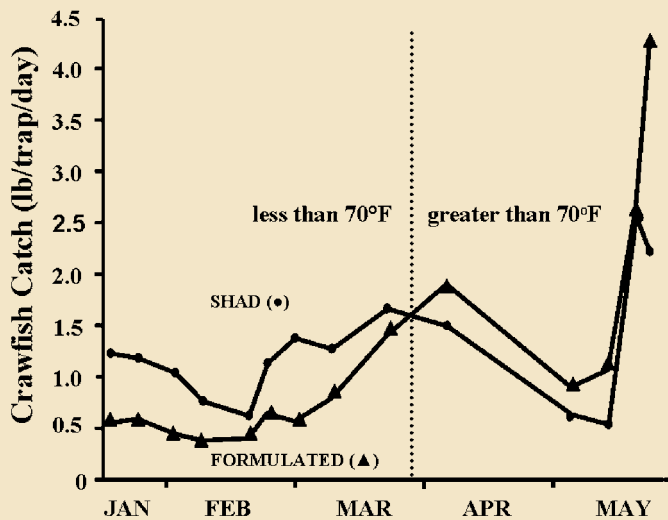


Figure 8.4. Example of the effect of water temperature on attractability of shad (●) and a formulated bait (▲).

attractants. At water temperatures of 65 F to 75 F, a combination of fish and formulated bait added to traps in approximately equal portions can increase catch as much as one-third over fish alone or formulated bait alone; however, the logistical inconvenience of handling two baits at the same time in harvesting boats must be considered when employing this strategy.

During winter, when crawfish feeding activity is minimal and the number of harvestable crawfish is still relatively low, studies suggest that one-fourth pound of bait per trap is sufficient to harvest available crawfish. When waters warm in the spring and the crop of harvestable crawfish nears maximum levels, the quantity of bait should be increased to about one-third pound per trap. Although it is not practical to portion bait into each trap carefully, farmers can gauge and monitor bait use by keeping good records on the total quantity used for the number of traps in a pond or the farming operation. For example, when using one-third pound of bait per trap per day, a 100-pound box of fish bait should be sufficient to bait 300 traps. If only 200 traps are baited, too much bait is being used. A 50-pound bag of formulated bait is sufficient to bait 150 traps. The trapper should pay attention to the amount of bait remaining in the trap after a 24- or 48-hour soak (set time). If significant bait residue remains in the trap the amount can be reduced somewhat. If bait is rapidly consumed, however, consideration can be given to increasing the amount of bait. Fresh bait should be used each trapping day, especially with fish baits. To maximize crawfish movement to freshly baited traps, bait residue should not be disposed of in the pond.

Trapping Strategies

Traps are placed in rows to facilitate harvesting by boat (Figure 8.5). Distance between traps depends on trap density (Table 8.2) and a spacing of 40 to 60 feet between individual traps and between rows is most common. Where annual yields of harvestable crawfish are expected to exceed 1,000 pounds per acre, a trap density of 18 to 22 square-mesh pyramid traps per acre, baited and emptied three to four days per week is recommended. It is not uncommon for farmers to use a lower trap density of 10 to 15 per acre if a low-standing crop of crawfish is present or if large areas are to be trapped and labor is limited. Trap density should be increased by two to three traps per acre if hex-mesh pyramid traps are used. If buyers require daily delivery of crawfish, or the price is high and catch justifies the effort, crawfish can be harvested five to six days per week,

Table 8.2. Spacing between rows (in feet) and the distance between traps (in feet) to obtain a specified number of traps per acre.

Distance Between Traps	Distance Between Rows	Traps Per Acre
40	40	27
40	50	22
40	60	18
40	72	15
50	40	22
50	50	17
50	60	15
60	40	18
60	50	15
60	60	12
66	66	10



Figure 8.5. Spacing of pyramid traps in a commercial crawfish pond.

but the average size of crawfish and catch per trap will usually decrease after a few days. If multiple ponds are present on the farming operation, harvesting activities can be rotated among production ponds.

Normally, traps are emptied 24 or 48 hours after baiting. The 48-hour soak time is generally employed in late fall and winter when crawfish activity is slow and standing crop of harvestable crawfish is low. Typically, it is best to harvest three or four consecutive days per week with several days rest between trapping episodes when crawfish are abundant and active.

Following nonharvest days, unbaited traps need not be lifted from the water and emptied prior to baiting because no additional yield is obtained by removing these crawfish (often referred to as “walk-ins”) prior to baiting. To some extent the average size of crawfish caught is correlated with the time traps remain in the water. The shorter the trap set, the higher the number of small crawfish caught. After the bait has been consumed, or the attractants in the bait have dissipated, some crawfish are able to escape through the entrance funnels, and escape is easier for the smaller animals. After several days of intense trapping, the average size of crawfish decreases and the catch often declines as larger animals are removed and the standing crop of market-size crawfish decreases.

Insufficient harvesting in ponds with dense crops of crawfish hastens forage depletion and increases aggression among animals, resulting in growth suppression and stunting. Ultimately, yields and profitability can be greatly reduced. Conversely, excessive trapping may reduce harvest size by removing crawfish before they have had sufficient time to grow to larger sizes, and harvest efficiency is decreased in this way. Because of the basic inefficiency in current trapping methods and gear, there is no evidence to indicate crawfish can be over-harvested. The more farmers monitor and understand the structure of their populations, the better equipped they can be to make decisions regarding harvest intensity.

Occasionally, harvesting schedules and strategies must be adjusted to accommodate markets. Buyers may prefer to have the product delivered only on certain days, such as Thursday through Sunday, when demand is usually highest. Additionally, market demand for crawfish early in the season may allow for various sizes of crawfish to be sold with little problem, but when supplies are more abundant, trapping strategies may need to be adjusted to maximize crawfish sizes, even at the expense of overall yield. As markets evolve and conditions change, maximizing profits in crawfish production no longer automatically means maximizing yields. Planning and good communication with potential buyers early in the season can allow trapping strategies to be developed that respond to market preferences and improve a producer’s competitive position.

Harvesting Machinery

Methods used to empty traps vary within the industry. Producers with ponds less than a few acres in size rarely use motorized boats because of the added expense. Traps may be emptied by harvesters who walk shallow-water ponds while

pulling or pushing a small boat. One person can empty about 400 traps per day. Other trappers use small, flat-bottom boats propelled by push-pole or paddle, but this method is no more efficient than walking.

In larger ponds, a boat propelled with an engine and drive mechanism adapted for use in shallow water is the most efficient harvesting equipment. One approach used widely in the crawfish industry is the Go-Devil® or similar designs, with 8- to 18-hp air-cooled engines or larger and long shafts with weedless propellers (Figure 8.6). The boats have flat bottoms, are made from aluminum and are typically 14 to 16 feet long by 4 to 6 feet wide. It is common for

Crawfish Harvest Recommendations at a Glance

- Three-funnel pyramid trap, 3/4-inch or 7/8-inch square wire
- 18-22 traps/acre in high-density ponds, (typically permanent monocropping ponds)
- 10-15 traps/acre in low-density ponds, (typically rice-crawfish field rotations)
- Trap 3-4 days/week
- 24-hr or 48-hr trap soak time
- 40-90 trapping days per season
- Use fish baits below 70°F, formulated baits above 70°F



Figure 8.6. Crawfish harvesting boat powered by Go-Devil® propulsion unit.



Figure 8.7. Crawfish harvesting boat powered by rear-mounted hydraulic wheel.

and motor to propel a metal wheel attached to the boat. Metal cleats are welded to the wheel, which is mounted either to the front to pull the boat forward, or to the rear to push the boat in shallow water. The wheel's hydraulic steering can be operated with foot pedals, leaving the driver's hands free to empty and re-bait traps. A single person can handle about 150 to 200 traps per hour. Up to 300 traps per hour can be emptied and baited with two persons. Rigs with the hydraulic wheels mounted in the rear are preferred whenever boats must cross levees, either within or between ponds. Some hydraulic-propelled boats are also equipped with side-mounted rubber wheels to allow travel down farm roads for short distances.

Boats are equipped with sacking tables to consolidate harvested crawfish. Trap contents are emptied onto

these boats to travel down trap lanes with fishermen emptying and re-baiting each trap from one side of the boat without stopping. The first trap is lifted, dumped and re-baited in the time it takes to reach the next trap. The freshly baited trap is set beside the next trap, and the process continues throughout the pond. A boat powered in this manner generally requires two persons, one to empty and re-bait the traps, and a second to steer. As many as 300 traps per hour can be emptied and re-baited.

Many crawfish producers prefer to use a rig designed specifically for harvesting crawfish (Figure 8.7). This boat uses a 12- to 24-hp air-cooled engine that operates a hydraulic pump

the sacking table, which usually has two to six loose mesh "vegetable" sacks temporarily attached. Each sack can hold 35-45 pounds of crawfish depending on how tightly the harvester packs them before changing sacks. Bait residue and other debris remain on the table to be discarded while crawfish drop into the hanging sacks. Producers are increasingly using in-boat graders to cull submarketable animals while still in the pond (Figure 8.8). Larger crawfish remain on the grader and are sacked. Smaller crawfish are usually returned to the pond but this may not be advisable in many situations (see Managing Harvest, Chapter 9).



Figure 8.8. Typical shop-built "in-boat" grader designed to allow submarketable crawfish to be returned to the pond immediately after harvest via a chute placed below the parallel bars.

Pond Flood-up

Crawfish are confined to the burrow until the hard plug that seals the burrow is sufficiently softened by external moisture. (See Chapter 2). Pond flooding, especially when associated with heavy rainfall, facilitates and encourages the emergence of crawfish from burrows. Brood females emerge with young (and sometimes eggs) attached to the abdomen, and hatchlings are quickly separated from the females to become independent. Because reproduction is somewhat synchronized in pond-reared crawfish, ponds are routinely flooded in autumn to coincide with the main period of recruitment. Continuous recruitment and differential growth often results in a population of mixed sizes, especially in monocropping situations (Figure 9.1). Typically, spawning in burrows, hatching (either in burrows or ponds) and emergence of females from burrows all take place more or less continuously from September through November. As a result, sufficient young-of-the-year crawfish are usually available throughout this time period to produce the season's crop.



Figure 9.1. Many established crawfish ponds contain a wide range of size classes most of the season.

Timing of fall flooding is particularly critical in crawfish farming. The goal is to time flooding to provide the best habitat for young-of-the-year recruitment, and the most fundamental factor relating to the timing of flooding involves water temperature. Warmer water is more conducive to faster growth of crawfish. The warmer the water is, however, the less oxygen it can hold. At the same time, the warmer the water is in a newly flooded field, the more rapidly oxygen will be consumed in the breakdown of vegetation. Unless extremely high amounts of water are available for daily exchanges, early flooding almost always results in depressed oxygen levels. This situation is aggravated if most of the vegetation is already dead or begins breaking down rapidly upon flooding. This occurrence can significantly reduce survival and growth of any early emerging crawfish and reduces profitability through increased pumping costs and reduced yields (because of poor utilization of forage and reduced crawfish recruitment). Therefore, timing of pond flood-up should reconcile water quality issues with optimal crawfish growth opportunities associated with warm weather.

Flooding also must be timed to coincide with the development of the forage crop, whether it be rice, sorghum-sudangrass or volunteer vegetation. If terrestrial vegetation is flooded too

early, growth may be curtailed, and the breakdown process may be accelerated. In cooler waters, even poor quality forage will persist longer, and the slower breakdown process generally results in more nutrition for the crawfish crop.

It is important to remember that ponds need not be fully flooded during the 1- to 2-month period when brood crawfish and their young emerge from their burrows. In some situations, young-of-the-year crawfish can successfully begin growing in as little as 4 to 6 inches of water, especially if abundant green vegetation provides cover. During the period following initial flooding, maintaining good water quality and high oxygen levels is more important than filling the pond to its full depth.

Population Management

Despite some efforts to limit farmed crawfish populations only to the red swamp crawfish, excluding the white river crawfish from ponds whenever possible, both species are responsive to routine culture practices and often coexist in production ponds. In general, these two species have environmental requirements that are conducive to the low input aquaculture systems used in Louisiana and surrounding states, and they are frequently found in the same water body. Though the abundance of one species may vary among and within culture ponds from year to year, red swamp crawfish most often dominate and are the desired species in the marketplace. It has been hypothesized that the abundance of red swamp crawfish is linked to their greater reproductive potential because growth and survival do not differ greatly between the two species. Other factors also may be involved. In some cases, white river crawfish increase in abundance as the culture pond ages and can become the dominant species over time.

It also has been speculated that ponds flooded in November, rather than in September or October (in Louisiana), may favor the white river species because later flooding dates better coincide with the timing of reproduction for that species. Research has shown that the species of crawfish that enters the pond first in greatest numbers after fall flood-up has the best likelihood of dominating the population. Thus, if red swamp crawfish become established first after the pond is flooded, they will dominate the population and later harvest. If juvenile white river crawfish become established before red swamp crawfish juveniles enter the population, white river crawfish will dominate the population and subsequent catch.

Currently, no reliable management recommendation is made for ridding a pond of white river crawfish once they have become established. If the problem with white river crawfish is so severe that it interferes with a farmer's ability to market the catch, a few management options can be considered, but it must be emphasized these recommendations are not known to be reliable nor have they met with predictable success. They include (1) draining a pond quickly in March or April before white river crawfish mature and burrow in large numbers, followed by re-stocking the pond with red crawfish; (2) flooding a pond in September to allow red swamp crawfish hatchlings to emerge before white crawfish. Extra caution must be taken to manage water quality associated with September flooding; (3) if the crawfish farming operation is large enough, taking a pond out of production for 1 or 2 years to kill most of the resident crawfish, followed by restocking with red swamp crawfish can be tried.



Figure 9.2. While there is no mathematical relationship to predict overall yield based on the number of small crawfish in dip net samples, this type of monitoring can provide an indication of population density.

Management of a crawfish population after flood-up is complicated by the inability of producers to assess the population accurately. Because of continual recruitment and difficulties in sampling, crawfish producers have little knowledge of the density and structure of the crawfish population in their ponds. Sampling is crude and accomplished by dip net sweeps and baited traps (Figure 9.2). Population management entails little more than controlling timing of the flood to coincide with normal reproduction peaks, ensuring adequate water quality and food resources and adequate harvesting pressure to remove market size animals. Reducing densities to control overpopulation in ponds has shown promise in limited research but has not yet become a common practice. Supplemental stocking in underpopulated ponds within a production season sometimes occurs but may not always be feasible.

Supplemental Feeding

As described in the forage section of this manual (Chapter 5), crawfish production in the southern United States relies almost solely on established forage crops for providing nourishment to growing crawfish. Feeding of prepared feeds is not a common practice as it is in shrimp farming or most fish farming enterprises. Rather, crawfish receive their sustenance from sources within a complex food web, similar to that which occurs in natural habitats. The natural food chain, at times, may be inadequate to sustain maximum crawfish production, especially when forages become depleted or when adequate forage crops are not established. It is also likely that, as crawfish density increases beyond some optimum density, natural food resources become depleted. Under these conditions, production of highly nutritious invertebrates, important components of the crawfish's diet, may be lacking, resulting in poor crawfish growth or, worse, stunting at submarketable sizes.

Feeding or supplementing natural food resources has been tried by some producers to increase crawfish production. Farmers have provided hay in place of, or in addition to, growing vegetation. Hay has been added either at the beginning of the season prior to flood-up or later in the season after the depletion of standing vegetation. Large round bales or numerous smaller square bales have been placed in ponds, often marginally distributed within the ponds, with bales either left intact or broken up to some degree. Conventional thinking at the time was that hay would undergo decomposition similar to forage crops to furnish the needed "fuel" for the food chain. Positive results, in terms of more or larger crawfish harvested, were usually

nondetectable and often the practice resulted in deterioration of water quality.

Lack of (or poor) results from hay supplements was due to the fact that the hay did not function as plant fragments from standing forage crops would. First, the distribution of hay, even if bales were well dispersed in the pond, usually only covered a small fraction of the entire surface area of the pond. This restriction was not conducive to maximum benefit because crawfish, and their prey, are well scattered throughout the pond and commonly do not congregate to feed. Second, decomposing plant material is most nutritious for a relatively short period (days to weeks, depending on water temperature), so anything less than regular offerings of fresh hay, well-dispersed over the entire pond area, does not meet the nutritional needs of the organisms in a pond over the course of a season. Furthermore, large amounts of decomposing hay are wasted because it cannot be fully utilized by the target organisms and can lead to oxygen depletion, either locally surrounding the bale or over the entire pond.

Various agricultural byproducts, such as manures, sweet potato and sugarcane products have been evaluated as supplemental feeds for crawfish production, but most have provided no noticeable or only marginal results and are considered nonpractical. The problems arise more from practical aspects of handling, frequency requirements of feeding and distribution over the pond, rather than strictly nutritional limitations.

Feeding of formulated, pelleted feeds, much like those used in catfish culture, have been tried in a number of commercial and experimental crawfish ponds over the years. Positive results were inconsistent and difficult to measure, and feeding practices frequently proved uneconomical even when a positive biological response was observed. Although some carefully controlled studies showed a positive response of crawfish to supplemental feed additions, results were variable and unpredictable. Some studies reported no increase in average yield or harvest size after feeding. Others reported significant increases in yield; however, yield increases were mostly from an increase in the harvests of smaller, low-valued crawfish.

Supplemental feeding studies under simulated pond conditions in outdoor tanks or in a laboratory setting with high densities of crawfish consistently demonstrated the limitations of forage-based culture systems and usually yielded more, or larger, crawfish. Yet, repeatedly, responses from supplemental feeding in ponds were marginal and unpredictable at best and proved disadvantageous at times. It was found that feeding while harvesting could actually result in lower yields – possibly because of satiation of crawfish appetites or interference with the attractant from the bait in traps, resulting in lower catches. Feeding immediately after the last day of harvest each week, when using

Broodstock Feeding

One objective that may justify the use of supplemental feeds in crawfish culture, short of increasing overall yield or harvest size, is to increase body condition and energy reserves of broodstock. Recent research, although limited and preliminary, has indicated that crawfish survival and reproduction within the burrow during summer/fall may be better in females with the greatest energy reserves. Feeding practices may be better applied toward animals to be used for broodstock, rather than for growing crawfish for harvest.

an intermittent harvesting schedule of three to four consecutive days per week followed by a three- or four-day reprieve from harvesting lessened the chance of reduced yields when feeding but did not always eliminate it. (Also see Managing Harvest below).

In short, there are probably times when the food chain associated with a forage crop is limited and nutritional supplementation may be needed to sustain maximum production. Aside from concerns with feeding and harvesting, however, other constraints that currently limit the economic use of supplemental feeds include knowing when feed is needed, how much to feed, how often to feed, specifically what nutrients are limited and when feeding will predictably produce positive results. If most of the crawfish population has reached or is nearing sexual maturity (even at a small size), further growth is limited, even with ample food. Therefore, much of the benefits of supplemental feeding will not be realized. Furthermore, it is difficult to obtain an accurate assessment of crawfish populations, and, based on research, it has been determined that supplemental feeds offered to highly overcrowded crawfish populations may be only marginally effective at increasing average size or yield. Therefore, without the ability to accurately assess situations in a pond and counter with cost-effective feeding practices that will yield positive results on a consistent and predictable basis, no dependable recommendations exist for use of supplemental feeds in forage-based crawfish ponds.

Feeding expensive feeds, formulated to meet all the nutritional requirements of the cultured animal (as in catfish production), may not be the most cost-effective means of supplementing the nutritional needs of crawfish. Since forage-based systems inherently furnish much of the required nutrition for growing crawfish, low-cost, incomplete feeds used as true supplements to the natural food web may provide the most cost-effective alternative. Because of the intermittent feeding nature of crawfish and the presence of other invertebrates, much of the dispensed feed will cycle through the food web to be utilized indirectly by crawfish. Therefore, supplemental feeding must be viewed as “feeding the total system” and not just the crawfish. Based on what is known about crawfish ponds, it is likely that protein and/or energy are the primary limiting factors when natural foods become scarce. Therefore, single feedstuffs high in energy or protein may provide adequate nutritional supplementation at a fraction of the cost of expensive, formulated “complete” feeds containing vitamins, minerals and other expensive nutrients.

Certain agricultural grains and seeds may be appropriate supplemental feeds for crawfish raised in ponds containing some natural foods. Agricultural seed crops are usually high in protein and/or energy, are routinely available in crawfish farming regions, are easy to apply and are usually a fraction of the cost of high protein formulated feeds. Damaged (broken) or low-grade products are often available at reduced prices. Rice grains and whole soybeans, among other grains, have been investigated as supplements to crawfish with encouraging results in highly controlled conditions. When repeatedly evaluated under realistic field conditions, however, similar problems existed with harvesting, timing, assessments and predictability, as with the use of pelleted feeds. Nonetheless, research is continuing to investigate strategies whereby supplemental feeds might be used to effectively augment the forage-based system and increase economic returns in a more reliable manner. As of yet, no feeding recommendation is available for increasing production or average harvest size in forage-based systems on a predictable and feasible basis.

Some research has been directed at the use of feeds in “off-season” or “year-round” nonforage-based crawfish ponds. Under that scenario, feeds are intended to furnish nearly all of the nutritional needs of growing crawfish – much like intensified catfish operations. Although experimental results were encouraging, no large commercial operation has yet employed this type of production system. Moreover, because of the increased cost of producing crawfish in such a system, the breakeven price is increased dramatically, making it more suitable for crawfish culture outside of Louisiana near prime out-of-state markets.

Although in high-density permanent monocropping ponds low reproduction efficiency may be offset by large numbers of crawfish, this balance is usually not the case in new or rotational ponds requiring stocking. Since a limited number of brood crawfish are initially stocked in first year ponds, reproductive condition is important. Crawfish broodstock are often obtained from densely populated ponds and at a time when food availability is at its lowest, so improvement in reproductive condition through short-term feeding prior to capture of broodstock may improve survival and reproductive success after stocking, especially if new ponds will be drained soon after crawfish are stocked. Little research has been completed with regard to this objective for feeding, but an active research program is underway to determine the merits of such short-term feeding practices and to establish some possible guidelines.

Managing for Larger Crawfish

Factors affecting crawfish size

Developments in the Louisiana crawfish industry and its major market outlets over the last 15 years have led to an increased interest and economic incentive for production of larger crawfish. Until about the late 1980s farm-gate pricing was influenced largely by supply and demand with little regard to crawfish size as long as it was above the minimum acceptable size of about 30-count crawfish to the pound. Therefore, the principal emphasis of management for crawfish producers was to maximize total production of harvestable crawfish. A number of factors, however, combined to result in the development of price differentials according to crawfish size. These included a small, short-lived export market (demanding only the largest crawfish), development of mechanical grading practices and an increased reliance on live markets as Louisiana’s processing industry was undercut by cheap imports of crawfish meat from the People’s Republic of China during the 1990s.

Price differentials favor the larger crawfish (Figure 9.3); however, there are currently no industry standards as with



Figure 9.3. Most wholesale and retail markets pay higher prices for larger crawfish. Occasionally, when supplies are abundant, having large crawfish to sell can guarantee access to markets that would otherwise reject smaller crawfish.

the shrimp industry and many other seafoods. The number of grades and grade category classifications vary depending on geographic region and time of the year, as well as among individual wholesalers and distributors. Aside from price differentials, producers of small crawfish are further constrained because of the lack of opportunity for selling smaller crawfish at certain times of the year at any reasonable price. With the loss of much of Louisiana's processing industry during the 1990s, opportunities for salvaging the catch of smaller crawfish at those times when consumer demand is only for the largest animals have been greatly reduced.

Small crawfish are often associated with higher overall yield potential. If the percentage of small crawfish in the catch becomes great enough, however, buyers will often refuse delivery, leaving producers with few viable options. Also, in times of oversupply, those producers with the largest crawfish are most able to sell their product. Currently, excess production of small, low-value crawfish is a major industry problem and can be economically devastating to individual producers. Therefore, the principal focus of managers is now on maximizing yields of larger crawfish and/or on increased production within the early season when demand exceeds supply.

Although not thoroughly characterized, some of the factors influencing crawfish growth or size-at-harvest are thought to include harvesting strategy, certain water conditions, food quality and quantity, population density, genetic influences or combinations of these factors. Little information exists of direct genetic influences on crawfish growth or size-at-maturity, and most data indicate that environmental factors are far more important than genetic effects.

The first form of grading, or size selection for harvested crawfish, is the wire-mesh trap. As indicated in Chapter 8, the industry has largely moved to the 3/4-inch square mesh trap, which retains smaller crawfish. Harvest intensity also can affect the size of crawfish in the catch. Intense trapping efforts (with high trap density and/or frequent harvests) usually increase overall yields, but can decrease the average size by temporarily decreasing the density of larger crawfish and removing some crawfish before they have sufficient time to grow to larger sizes. Insufficient harvesting can foster overpopulation, which in turn hastens forage depletion and contributes to the stunting of crawfish at sub-desirable sizes. Trap-soak (set) time also can affect the size of crawfish in the catch, because small crawfish are more effective at exiting the trap. Longer trap soak times generally yield larger crawfish.

The most obvious effect on crawfish harvest size relating to water conditions is water temperature. At temperatures below about 60 F, growth slows considerably and, while trap catch efficiency is also reduced, smaller crawfish size is usually the result of concerted harvesting efforts at the lower temperatures. Chronic low oxygen concentrations also can suppress crawfish growth, and rising water temperatures and highly fluctuating water levels are thought to encourage growth to slow or stop in conjunction with maturation, even at smaller sizes.

It was once thought that the overwhelming factor causing the excessive production of small or stunted crawfish in production ponds was food deficiency. Harvests of stunted populations are nearly always associated with premature depletion of the forage resource. It is likely that as crawfish density increases beyond some optimum level, food resources are depleted and nutritional shortages limit growth. Research has shown, however, that crawfish grown at more than about 15 per square yard will have a slow growth rate and small size at maturity even

with supplemental feeding of high-quality feeds. It has been clearly demonstrated that crawfish exhibit density-dependent growth. Final size appears to be inversely related to density, and high feeding rates with high quality diets are unable to counteract the effects of density on crawfish growth. Research suggests that the overwhelming factor affecting size-at-harvest in commercial crawfish ponds is not simply food shortages, as was once thought, but principally overcrowding.

Managing density

Few sound management strategies exist for the predictable production of large crawfish in commercial ponds, mainly because stock replenishment depends on natural recruitment, which is affected by many variables outside of the control of pond managers. High population density has been identified as the single most limiting factor affecting crawfish growth and harvest size, yet control of crawfish numbers is possibly one of the most elusive aspects of crawfish pond management.

The density of young-of-the-year crawfish in ponds is influenced by many factors but is basically a function of the number and size of successfully spawning broodstock and the survival of their young. Overpopulation is most likely to occur in permanent monocropping ponds after several annual production cycles and is least likely in newly established ponds or in ponds previously out of production for some time. Therefore, rotating production into different fields, as is commonly used in some rice/crawfish rotational practices, or allowing a permanent pond to remain drained for one or more complete cycles can be a management technique for preventing overpopulation when production resumes. For producers with limited land, however, suspension of production in ponds for an entire season could lead to loss of revenue that might outweigh the benefits of population control.

If overcrowding is expected, delaying the permanent flood to December or later, well after the peak spawning period, might be a suitable method of preventing stunting in ponds because delaying would likely reduce the number of recruitment classes, although this method has not been well documented. It also could delay the bulk of crawfish production, which is usually accompanied with lower prices. Caution must be emphasized with this approach because if cool weather prevails late into spring and/or ponds become deficient of food resources, many late recruits may not have time to attain large harvest size before ponds are drained in summer.

When permanent monocropping ponds are overcrowded, another possible technique to reduce recruitment the following season is to drain the ponds earlier than normal, before too many crawfish become sexually mature and begin mating, and to drain them rapidly, thereby stranding many crawfish before they have sufficient opportunity to burrow (Figure 9.4). This



Figure 9.4. Draining ponds early and/or rapidly can sometimes reduce overpopulation problems the following season by stranding some of the adult crawfish present before they have a chance to burrow.

method may not always be effective, particularly in older ponds where established burrows are plentiful and mature broodstock are available at all times. If sufficient broodstock mature and burrow before the drain and reproductive success is high, this technique will fail to achieve the desired result. Early drains also can cause a significant loss of income since harvesting ceases prematurely.

Since most mature broodstock establish burrows in exposed surfaces of the pond, namely the levees, farmers have an additional opportunity to reduce population density for the subsequent season. After the ponds are drained for the summer, they could conduct maintenance or renovation on a substantial portion of the levees. Such activities can significantly reduce crawfish reproduction and/or recruitment. Although not a very precise method, major disturbance of burrow entrances can reduce the survival, reproduction or emergence of the occupants.

If the right proportion of linear levee, especially the interior area of the levee, is reworked with heavy equipment between seasons, overpopulation may be corrected or reduced from one season to the next. If too many burrows are compromised in this manner, however, overcorrection is possible and yields and profits suffer. Because of the many variables associated with reproduction and recruitment success, and the typical non-uniform burrow patterns in the levees, general management recommendations cannot be provided for this imprecise method of population control. It is recommended however, that at least some percentage of the levee area remain undisturbed during the critical burrowing period to provide an opportunity for some reproduction and recruitment to occur normally.

All of the previously mentioned methods for correcting overpopulation are based on preventative measures, taken to prevent recurrence in a subsequent season. Since the cause of overpopulation is highly variable and largely dependent on environmental factors beyond the manager's control, preventative measures are frequently ineffective, or to the contrary, over-compensatory, and loss of production (and income) is a possibility. Practices required to readily identify overcrowding and corrective actions that yield predictable results within a production season are lacking. Some research, however, has been focused on this approach with mixed results.

Pond sampling, beginning six to eight weeks after flood-up, is important in determining population density and potential for overcrowding. Although accurate sampling protocols are lacking for crawfish aquaculture, an experienced manager should be able to ascertain relative density estimates with a combination of sampling gear such as dip nets and baited traps (both small and large mesh traps) and visiting the pond at night with a light around the edges. If overcrowding is anticipated, actions taken to reduce crawfish densities within a current production season should probably occur after peak recruitment, which occurs from October to December, but before ponds warm in the spring. Density reductions before peak recruitment occurs may not be adequate if large numbers of subsequent recruits appear. Reductions too late in the spring may accompany food shortages and reduced opportunity for maximum growth.

Research and anecdotal evidence has indicated that when overcrowding was determined, temporary and partial pond draining in February or early March in South Louisiana was sometimes sufficiently effective in reducing crawfish density to result in larger crawfish after refilling. Ponds were drained, except for puddles and ditches amounting to about 10 percent to 30 percent of pond bottom areas, for two to seven days and then

refilled. Density reduction occurred as a result of concentrating the crawfish in a limited area where they were more exposed to the hazards of predation and cannibalism.

In theory, although not verified, more deaths should occur in the younger age classes with this method – and this would be the preferred outcome. It should be clearly noted, however, that mixed results have been obtained with this risky approach. In some cases, crawfish reductions were insufficient to affect a positive response after refilling, and in other cases over-reductions occurred, resulting in larger crawfish but also in a substantial reduction in yield. Because of the unpredictability of this method and various circumstances that could affect outcomes, no management recommendations have yet been devised. The success of midseason draining to reduce overcrowding and produce subsequent harvests of larger crawfish depends first on accurate assessment of population density and then appropriate density reduction at the appropriate time – a difficult task with any measure of predictability.

Other possible means of reducing density within a season, including intensive harvesting with both small-mesh and commercial traps, have been investigated without success. Because of the inefficiency of current harvest methods, it is unlikely that sufficient reduction in density can occur using only baited traps.

Managing food resources

Although population density appears to be the single most important factor determining crawfish growth and size-at-harvest in typical production ponds, limited food resources also can be a significant contributing factor. Moreover, high crawfish density can significantly increase the rate of depletion of the forage in ponds, creating food shortages that act to exacerbate density's effect on harvest size. To date, supplemental feeding has had little impact on increasing size-at-harvest in ponds; however, its use at various densities and under varied conditions has not been thoroughly investigated. A well-managed forage-based system seems to be an appropriate feed delivery strategy and remains the best way to ensure the most cost-effective transfer of nutrients to growing crawfish when population density is within the optimum range.

Certain management considerations are necessary to ensure maximum use of food resources from forage-based production. Probably the single most desirable aspect in any vegetated system is the ability of the forage to continually and consistently furnish adequate amounts of material to the food chain for the duration of the production season. As detailed in Chapter 5, research has shown that plant type (and variety) and plant maturity status have major effects on persistence and re-growth potential. The ability to achieve adequate re-growth, as a function of variety selection, planting date, standing density of crawfish and, if necessary, water management have been directly linked with increased production of larger crawfish late in the harvest season – where it is often the most beneficial. Mixtures of plant types that bring complimentary benefits in terms of food value and vertical structure, especially late in the season, also may yield positive results related to increasing average crawfish size at harvest.

Research is continuing to investigate management approaches to improve forage-based systems and their application in crawfish production. Also, with a better understanding of crawfish population dynamics, feeding habits and nutritional needs, a cost-effective supplemental feeding program eventually may be devised to aid producers in achieving larger crawfish.

Managing harvest

Modification of the typical harvesting routine also has shown some potential to increase crawfish size-at-harvest. Intense trapping five to six days per week can reduce harvest size by removing some animals from the population before they could otherwise grow to a more desirable market size. A three- or four-day per week harvest approach, as discussed in Chapter 8 usually can increase efficiency of harvest as well as overall crawfish size. Intermittent or rotational harvest schedules also have been shown to increase the proportion of large crawfish in the catch. When an entire pond or portions of a pond are harvested on an intermittent basis, crawfish have an opportunity to undergo additional molt(s), thus increasing crawfish size and value between trapping episodes. Various periods of trapping/nontrapping, as well as use of supplemental feeds during the nontrapping period, have been investigated, although additions of pelleted feeds in a limited number of studies did little to increase yield or size-at-harvest. Generally, in controlled studies, short term (two to four weeks) intermittent trapping has increased crawfish harvest size but at the expense of total yield, probably from decreased trapping frequency – that is, fewer trap-sets per season.

The usefulness of an intermittent harvest schedule depends on many factors, such as population density and size structure, food availability, time of year, trap density and marketing conditions. It should be clearly noted, however, that under some conditions of pond culture, notably overcrowding, food shortages or when a majority of crawfish are nearing or have reached their maturity molt, harvesting reprieves are not effective at increasing crawfish size. LSU AgCenter researchers, as well as individual producers, are continuing to explore different trapping strategies and trap designs for their effectiveness with regard to producing larger crawfish.

Another option that is currently used to reduce small crawfish offered for sale is the use of “hand grading” or “in-boat graders” (see Chapter 8). Some low-volume producers may hand cull subdesirable crawfish, while many producers currently use a device that consists of parallel bars attached to an in-boat sacking table. Various bar spacings are used, but the intent is for sub-desirable size crawfish to fall through a platform of parallel bars mounted in the bottom of the sacking table when crawfish are emptied onto the table from the trap. Crawfish that fall through the bars are usually funneled back into the pond, while crawfish that are retained above the bars are moved into sacks for sale.

A common misconception with this approach is that the smaller crawfish returned to the pond will be harvested later at a larger, more valuable size. Though in some cases this may be true for a small percentage of animals, many crawfish will never be recaptured because of natural or predator-related mortality and the inefficient nature of trap harvesting. In many cases, reharvested crawfish will be caught later at reduced prices. Moreover, returning crawfish to a pond that is overcrowded and/or deficient in food resources may exacerbate those problems, resulting in a reduction of average crawfish size in subsequent harvests. In many cases, it may be better, and more profitable, to sell the smaller crawfish, even at a much reduced price, than to return them to the same pond. Alternatively, submarketable crawfish may be deposited in a pond that is known not to be overcrowded, with the intentions of harvesting later, a practice known as “relaying,” although the economic advantage of this practice is not always certain and should be scrutinized carefully.

Relaying to increase crawfish size

The presence of small, stunted crawfish in the catch usually occurs near the end of the production season (late April-June in Louisiana), which normally coincides with the period of lowest prices. By that time, forage resources often have been depleted, crawfish have reached maturity and further growth is unlikely. On some occasions it has been possible to achieve further growth from severely stunted populations by transferring, or relaying, crawfish from their original surroundings in poor environments to improved environments. Although this practice has been rarely used, research has demonstrated its potential for increasing crawfish size, thus their value and marketability. Suitable conditions exist on many farms for use of this practice, not only to increase market value of crawfish but to extend the harvest season and increase net returns from already-integrated agriculture operations. Because many farmers co-culture crawfish and rice in rotational systems and because these cropping seasons overlap, it is common to have newly established rice fields at a time when crawfish stunting normally occurs in forage-depleted crawfish ponds. Overlapping seasons provides the opportunity of using the rice production acreage as a valuable resource for obtaining additional growth and increasing the market value of crawfish. Research has shown that, with careful management, acceptable rice yields can be obtained following harvest of relayed crawfish, and potential net farm income could be substantially increased by intercropping crawfish in a rice crop in this manner. It should be noted, though, that some rice yield will invariably be sacrificed because of crawfish harvesting activities, primarily through plant destruction associated with trapping lanes. Extreme caution should also be exercised regarding pesticide use in the rice crop.

This intercropping approach may be particularly suitable to rotational culture systems where crawfish culture follows the rice crop. In lieu of the normal practice of stocking broodstock, this practice calls for stocking of stunted animals at much higher densities in the young rice crop. Following several weeks of growth, most of the larger, higher-value crawfish would be reharvested prior to rice maturity, and any remaining animals would suffice as broodstock for the subsequent crawfish season. Stocking rates of up to 1,000 lb/ac have been investigated, but it should be noted that, although individual crawfish weight more than doubled, retrieval rates were lowest for the higher stocking rates, and the overall harvest recovery rate was equal to the amount of crawfish stocked.

The economical feasibility of relaying or any other management practice intended to increase the production of large crawfish in a commercial operation depends on a price structure to the producer that favors larger crawfish. The magnitude of the price differential for large crawfish will determine the economic benefit of management practices that focus on anything other than optimum yields of medium-size animals. Market demands and price differences should always be taken into account when implementing or recommending costly management practices.

Diseases

Serious disease problems associated with nonintensive crawfish culture are thought to be rare. Individual crawfish are known to be susceptible to various pathogens, such as bacteria, virus, fungi, protozoans and parasites; however, epidemic outbreaks sufficient to affect commercial production in earthen ponds have not been demonstrated. Significant disease problems are more likely to be encountered in intensive, high-density holding systems, such as purging and soft-shell production

facilities. One study reported that of 15 outbreaks of bacterial septicemia (*Vibrio mimicus* and *V. cholera*) diagnosed in Louisiana crawfish, four cases were from ponds and 11 were from high-density holding systems. Diseases are most likely to occur during periods of elevated temperatures and/or periods of oxygen stress.

All North American crawfish are suspected vectors of the *Aphanomyces* fungi, or plaque fungus, that was notorious for eliminating many populations of native European crawfish in numerous lakes, rivers and streams. Although carriers, North American crawfish, including those cultured in the South, are not normally affected by the fungus. Procambarid crawfishes are sometimes affected by other agents that do not necessarily have an effect on production but may hinder crawfish marketability because of certain physical effects. Microsporidia can infest the abdominal muscle, giving it an unattractive milky-white appearance (porcelain disease), and various ectocommensal organisms that attach to the exoskeleton can limit the acceptability of crawfish if the infestation is heavy. These conditions are not usually common and have little economic impact, although at times buyers may refuse to accept lots of crawfish with heavily soiled exoskeletons.

Because of the insignificance of known diseases in pond culture of crawfish, disease management is not deliberate. Practices that prevent food shortages, overcrowding and low oxygen (common stressors) are the extent of practices related to disease management in the crawfish industry.

Predators

Crawfish are, however, susceptible to any number of predators that thrive in and about the shallow, vegetated waters of crawfish ponds. Predaceous aquatic insects consume young, recently molted crawfish. Bullfrogs, amphiumas (a large eel-like salamander) and several species of water snakes flourish in crawfish ponds and readily consume all sizes of crawfish (Figure 9.5). Various turtles and the occasional alligator will

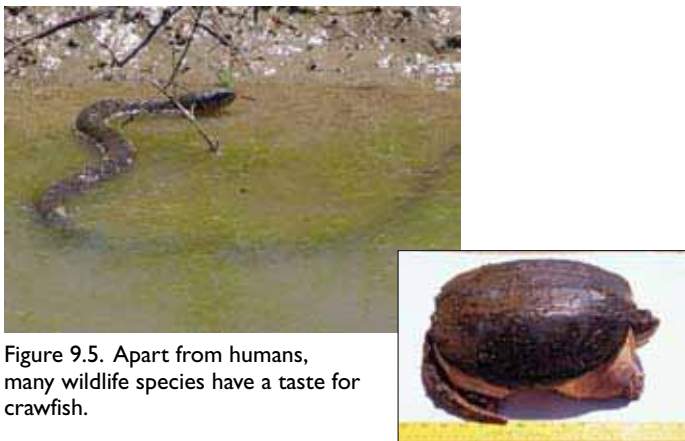


Figure 9.5. Apart from humans, many wildlife species have a taste for crawfish.

prey on crawfish. Small mammals, such as the Norway rat, mink, raccoon, opossum and otter are often abundant and will consume crawfish and sometimes the bait placed in crawfish traps. Raccoons and otters also will damage traps when getting to the crawfish and/or bait. Although collectively these predators can consume large quantities of crawfish, crawfish reproduction and growth rates are usually sufficient to prevent major harvest losses.

Even though predatory fish, if not controlled, can be the most significant predator encountered in crawfish ponds, avian predators, especially carnivorous wading birds, are perceived by many producers to cause the most harm. Fish are easily controlled, though often difficult to eliminate from ponds if they become established (Figure 9.6). Fish are controlled by thoroughly drying pond bottoms during the interval between



Figure 9.6. Wild fish, such as these green sunfish, can cause large losses of young-of-the-year crawfish. Unless ponds can be completely dried each summer, these fish can be very difficult to eradicate.

seasons or by treating standing pools of water with a fish toxicant, followed by proper screening of incoming water. Some fish manage to enter ponds by swimming up drain structures or on the feet, feathers or fur of other animals visiting the ponds. If not controlled, fish will consume large quantities of crawfish and/or compete with crawfish for the natural food items that crawfish rely on.

Avian predators are not as easy to control as fish. Many bird species consume crawfish, and, except for allowable hunting seasons for certain waterfowl, nearly all piscivorous (fish-eating) birds are federally protected (Figure 9.7). Although the actual impact on operational costs and production is not known, many producers perceive bird depredation as a significant and growing problem. Carnivorous waterbirds find crawfish ponds to be food-rich havens, and these ponds often offer water and food resources when they are in short supply in natural habitats. Some researchers have provided convincing evidence of a direct relationship between the increase in colonial wading bird numbers from the 1960s to 1980s and the increase in crawfish pond acreage in Louisiana during that period. Anecdotal evidence also suggests that some noncrawfish-eating species have recently adapted their feeding habits to take advantage of the plentiful supply of crawfish from aquaculture ponds. Effective control measures are lacking, and the size and shape of most commercial crawfish ponds prevent the economical use of netting or other enclosures.



Figure 9.7. Many crawfish producers perceive bird predation to be a serious problem, but their actual impact on production and profits is not well documented.

Nuisance Wildlife

Note: These recommendations are in accordance with Louisiana Revised Statutes (RS) at the time of publication. Always check with your local wildlife authorities (Enforcement Division, Louisiana Department of Wildlife and Fisheries, USDA Wildlife Services, US Fish and Wildlife Service) for the most up-to-date rules and regulations prior to undertaking animal control activities.

From time to time, nuisance wildlife species invade crawfish ponds and in some cases cause serious damage. You can do some things but not others to take care of the problem, depending on the species.

Raccoons and otters are the most frustrating pests since they turn over traps and sometimes mash, mangle and twist the wire so badly that the trap is destroyed. Mink may swim to a few traps, consume some crawfish, and steal cut fish, but this problem is usually limited. Nutria and muskrats will dig holes in levees, costing the producer both in time repairing levees and in pumping costs to replace water (Figure 9.8). Beavers can cause problems by blocking drain pipes. These nuisance animals are classified as “fur bearers” and are protected or regulated by certain wildlife laws. During trapping season these animals may be trapped by a licensed trapper, skinned and the



Figure 9.8. If left uncontrolled, burrowing rodents can cause costly damage to crawfish ponds, occasionally resulting in levee failures.

hides sold [RS56:259 C. (1)]. In certain other situations, farmers and landowners may trap or shoot these animals when they are a nuisance. The technicalities are different for each species, however.

Farmers and landowners can hunt raccoons and opossums with a .22 caliber rifle anytime during the year when they are found destroying crops [RS56:116.1 C.(2)(a)]. Raccoons also can be hunted by licensed hunters at night with at least one dog and using one .22 caliber rifle [RS56:116.1 C.(1)]. There is no bag limit during the trapping season, but the limit is one per night after trapping season [RS 56:116.1 C. (3)]. The law also allows raccoons and opossums to be taken by licensed hunters during rabbit season [RS 56:116.1 C. (4)].

Landowners, or their designees with written permission, can use live traps for raccoons, otters, mink and muskrats and relocate the animals to suitable habitat without a permit. If live traps cannot be used, a licensed trapper can catch and dispatch these animals during trapping season. Outside of trapping season, a special Nuisance Wildlife Permit can be obtained from the district offices of the Louisiana Department of Wildlife and Fisheries (LDWF) or USDA Wildlife Services, to trap or shoot these animals when causing problems. USDA Wildlife Services offices are located in Crowley (337-783-0182), Port Allen (225-389-0229) and Monroe (318-343-6499).

Nutria and beaver are considered nuisances and can be taken by trapping or shooting by a farmer or landowner without a license, except during trapping season when a trapping license is required. They can be shot only during the day (sunrise to sunset) [RS56:259 E]. Under Title 76 (Section 125) of the Louisiana Administrative code, a landowner or his designee with written permission, can trap or shoot nutria and beaver (and opossums, coyote, skunks and armadillos) during daylight hours anytime during the year when causing a nuisance. Muskrats are not included in these laws. Muskrats must be trapped during trapping season by a licensed trapper.

Poisons generally are not recommended for controlling any of these fur-bearer species. Directly poisoning nontarget species (pets and other wildlife) and secondary poisoning of animals eating on the carcasses of the dead animals are likely dangers. The only exception is the use of zinc phosphide for controlling nutria. This gray powder is a restricted-use pesticide (a private applicator’s license is required to purchase this chemical) and is available from USDA Wildlife Services. Animals should be pre-baited to feeding sites for several days with carrots or sweet potatoes before applying the zinc phosphide to the bait.

The only other approved use of poison is for Norway rats and field rats. These are a nuisance around the boat and bait-cutting station, and can harbor serious and even deadly diseases. Weather resistant blocks of rat poison need to be placed in bait boxes or deep in holes or places where rats hide. The poison should not be broadcast in the open. Reducing hiding places by burning bait boxes and keeping the area clean also helps to control rats.

Birds are sometimes a problem when they feed on crawfish or turn over traps. In ponds with high numbers of crawfish, egrets and herons may not hurt the crop at all. In ponds with few crawfish, every crawfish is valuable. Egrets and herons along with ibis and seagulls are protected by federal laws and can only be harassed to leave the field. Pop guns used for blackbirds do not typically work with these birds. Pyrotechnics (fireworks) are the best thing to use to discourage these birds, but persistence is the key. Scaring the birds once a week won’t do any good.

Cormorants often tip over traps in an effort to get to the crawfish or eat the fish bait. In areas where cormorants are plentiful, scare tactics are not effective without some lethal control. Federal regulations make it legal for lethal control of double-crested cormorants at “commercial freshwater aquaculture” facilities in 13 states, including Louisiana, when it is determined that cormorants are damaging an aquaculture crop. Although no special federal permit is required steps must be taken to insure compliance with federal law. First, USDA Wildlife Service personnel must confirm that damage is being done by double-crested cormorants to crawfish, and the producer must show evidence that he/she has used other established non-lethal options to minimize damage by cormorants. The USDA Wildlife Service can then issue to the producer Form 37 which allows for the lethal take of double-crested cormorants. The producer must meet the requirements of the federal depredation order, and these include the following: (1) Records (log) of the kill must be kept that include date, number killed and location. The producer must also report any accidental take of other cormorant species. Records must be kept for 3 years and a copy provided annually to the United States Fish and Wildlife Service. (2) Cormorants can be taken only within the boundary of the crawfish farming facility during daylight hours using firearms, and shotguns must use steel shot. (3) Cormorants must be disposed of by donation, burial or incineration. They cannot be traded or sold. (4) No lethal control of double-crested cormorants can be taken within 1,500 feet of nesting wood stork colonies, within 1,000 feet of wood stork roosts, within 750 feet of feeding wood storks and more than 750 feet from bald eagle nest.

A trap with only crawfish heads left in it is probably the result of turtle predation. Turtles will circle the trap and pinch off the crawfish tails that poke out through the trap wire. Turtles can be trapped using a wire “box” with an open top and sides sloping inward that allows the turtles to climb in but not out.

Fish predators can eat a significant amount of crawfish, especially in the fall when young crawfish leave their mothers. Bullhead catfish (pollywogs) and green sunfish (“bream”) are the worst culprits and are difficult to remove from the pond once they invade.

Control Methods

Raccoons

1. Find a licensed trapper to catch the animals during trapping season.
2. Buy a trapping license and trap during the trapping season.
3. Hunt raccoons with a .22 caliber rifle during daylight hours if the animals are causing crop damage.
4. Hunt raccoons at night with a dog and .22 caliber rifle. No limit during trapping season. A hunting license is required.
5. Obtain a Nuisance Wildlife Permit from LDWF or USDA Wildlife Services to shoot during daylight hours or trap the raccoons.

A good trap for catching raccoons is a leg grabber trap called Lil Griz Get’rz, baited with liquorish candy or marshmallows. Leg-hold and body-grip traps are effective but are more tricky to set.

Otters

1. Find a licensed trapper to catch the animals during trapping season.

2. Buy a trapping license and trap during the trapping season.
3. You don’t need a permit to live trap and relocate otters. Live trapping otters is not practical, though.
4. Obtain a Nuisance Wildlife Permit from LDWF or USDA Wildlife Services to shoot during daylight hours or trap the otters.

The best trap for otters is the 8-inch or 10-inch body gripping trap such as the Conibear 220 or Duke 280. This trap should be set in a run where the otter is crossing a levee or rigged in a bucket as a curiosity set. Otters are extremely difficult to trap with standard leg hold traps or box type traps.

Muskrats

1. Find a licensed trapper to catch the animals for you during trapping season.
2. Buy a trapping license and trap during the trapping season.
3. Obtain a Nuisance Wildlife Permit from LDWF or USDA Wildlife Services to shoot during daylight hours or trap the muskrat.

The best muskrat trap is the 4.5-inch body gripping trap (Conibear 110) set by holes in the levee. Baiting with a piece of sweet potato sometimes helps.

Nutria and beavers (also coyotes, armadillos, skunks and opossums)

No permit is necessary to trap or shoot during daylight hours when they are causing problems. Nutria can be trapped using leg hold traps set on levees where the animals are crossing. Body gripping traps will also work on nutria. Snares are easy devices to set to catch beavers where they enter the water. The large body-gripping traps (10-inch Conibear or Duke) also work well on beavers.

Norway rats

1. Limit problems by keeping boats and bait storage areas clean.
2. Weather resistant poison baits are effective if used in bait boxes or other hidden areas to avoid nontarget species.

Birds (herons, egrets, ibis, sea gulls, pelicans, etc.)

Pyrotechnics and other scare tactics are the only approved means to drive away these pests.

Double-crested cormorants

When cormorants are damaging freshwater aquaculture operations, and scare tactics are ineffective, shooting is allowed with approval by USDA Wildlife Services and compliance with certain stipulations as listed above.

Summary

Technical advice on animal damage control is available from the USDA Wildlife Services, Louisiana Department of Wildlife and Fisheries and the LSU AgCenter. No state or federal agency, however, will send personnel to take care of this problem for a producer. Producers are required to follow all state and federal laws governing the control of these nuisance wildlife species.



Developing Your Business

Attention to details during the planning and operations will increase your chances of business success in crawfish production. As with any enterprise, it is often best to start small, learning and growing into an economically viable farming enterprise. When considering a crawfish farming business for the first time, consider these factors, requirements and the following questions:

- Do you have a realistic business plan developed with monthly objectives and projected cash flows for the first year and annually for each of the next three to five years?
- Do you have access to capital for start-up, operation or expansion? Are your cost estimates and pricing projections reasonable? Do you have adequate cash reserves for equipment failure and other unforeseen problems?
- Will a lender accommodate your production/marketing cycle?
- Have you identified your primary and alternative markets?
- Are the estimated profits worth your labor and resources? Is the profit potential for crawfish farming competitive with other possible investments or activities?
- Are you willing to work long hard hours, daily, during the harvest season?

The economic analysis of crawfish production has evolved as the crawfish industry has grown in technology, sales and complexity. Production cost estimates and knowledge about markets are essential. Abundance of wild crawfish has a depressing effect on prices when wild and farm-raised supplies overlap. A crawfish farmer must be aware of varying market conditions and how the market changes will affect the profitability of the operation. A key to success is the understanding and estimation of production costs. Precise investment requirements, production and harvesting costs are not available for every farming situation. Projected costs and breakeven prices for various crawfish cropping systems are developed annually by the LSU AgCenter's Department of Agricultural Economics and Agribusiness and be accessed from the LSU AgCenter's Web site.

A record-keeping system is needed to generate financial reports and production records. The basic purposes of records are reporting, control, evaluation and planning, but good records can be an important resource when dealing with government crop programs or litigation. Financial reports that give the manager vital information about the business are the most important function in record-keeping. Through financial statements, a

manager can determine profits (or losses), the feasibility of the business plan, the accumulation of net worth in the business and the profitability of each part of the business. Financial reports consist of income statements, balance sheets, cash-flow statements and enterprise reports.

A good records system allows the manager to see what is going on in the business, decide what is working and what is simply costing too much. A good example in crawfish farming involves multiple fields within an operation and the decision process to allocate harvesting and pumping resources. Evaluation during the year is critical to keeping costs as low as possible while increasing income. Producers often don't know how much has been spent in total or by item (bait, fuel, supplies, etc.) and therefore cannot stop wasteful practices. Financial planning for the coming year is needed to decide if sufficient net income will be generated to meet business goals. As prices paid and received change, the ability to pay bills on time and service debt can change. A projected cash flow will show the feasibility of the proposed business plan.

Production records and reports contain information about the technology used in production. It's important to maintain records of pumping time, traps used, bait (type and amount), water quality information, crawfish production time (hours, labor), results of grading and sales income per acre and per day. Careful analysis will identify the strengths and weaknesses of the production process. Future management decisions concerning forage, water, population dynamics, harvesting strategies and marketing are easier and more accurate if good records are kept. Correction of problem areas results in increased production efficiency. Also, when a crop is lost because of a natural disaster or pollution, records are needed to prove losses.

Records can be kept either in handwritten ledgers or by computer. Either method takes about the same amount of time to record information. The LSU AgCenter's Cooperative Extension Service has several publications that can be used to form a basis for your own system. These include the "Louisiana Farm Record Book" and the "Louisiana Farm Inventory Book." Computer technology allows reports to be prepared much more easily and quickly. Computer record systems should be given careful consideration when choosing a record-keeping strategy. More experienced computer users may prefer to use spreadsheet programs rather than prepackaged business management software. Contact your local parish office of the LSU AgCenter Extension Service office for more information about financial planning for farming operations.



Records of maintenance, repairs and hours of operation should be kept for all equipment.

Chapter 10. Markets and Marketing

Whether from aquaculture or the natural fishery, the supply of live crawfish is highly seasonal, with peak of the harvest occurring from March through June (Figure 10.1). Historically, most of the domestic supply has been consumed in Louisiana and surrounding southern states, particularly Texas, the Mississippi Gulf coast and the Florida panhandle (Figure 10.2). Because of restricted geographical areas of production, seasonal supply, unstable prices and cultural mores, crawfish sales nationally have been limited, but have increased in recent years.

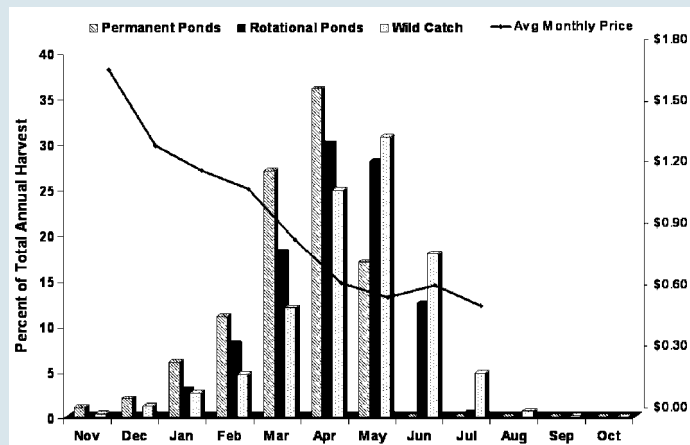


Figure 10.1. Distribution of annual Louisiana crawfish harvest from aquaculture and the commercial wild fishery from the Atchafalaya River basin. Percentages depict a 10+ year average. Average monthly price is the 5-year average (2000 through 2005) for pond-raised crawfish in southern Louisiana.



Figure 10.2. Major regions of live crawfish sales, usually within a day's drive of southern Louisiana. Markets for live crawfish and tail meat continue to grow in other areas of the United States. Stars represent major metropolitan cities for crawfish sales including, but not limited to, New Orleans, Baton Rouge, Shreveport, Houston, Dallas, Biloxi, Mobile, Pensacola and Atlanta.

Product Forms

Live crawfish

All crawfish are marketed live by farmers, and live crawfish comprise most of the final sales to consumers. Producers of large crawfish have a competitive advantage, especially when the supply of live crawfish exceeds demand. In times of over-supply, generally the larger crawfish remain in the live market and smaller crawfish are processed for meat. Most producers sell live crawfish to a primary wholesaler (Figure 10.3) or a processor, although a limited volume is sold directly to retail

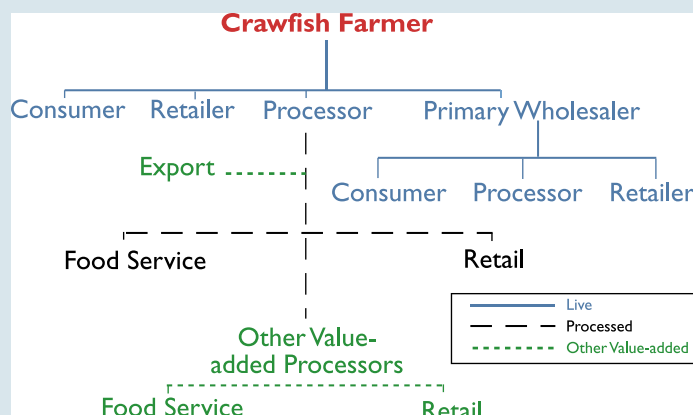


Figure 10.3. Marketing avenues for Louisiana crawfish.

stores, restaurants and consumers. In Louisiana, red swamp crawfish have higher consumer appeal in the live market than white river crawfish, although this distinction is usually not made outside of traditional southern Louisiana markets.

Highest demand by retail consumers and restaurants is on weekends, even in Louisiana, with limited retail sales early in the week. The live product, with its restricted shelf life of no more than several days, largely dictates harvesting schedules and market plans. Shelf life of the live product also effectively limits regional and national distribution.

Whether served in households or retail outlets, live crawfish are typically boiled (or steamed) and consumed hot and fresh in a festive atmosphere (Figure 10.4). Crawfish are not considered a staple food; rather, they are generally associated with social occasions, and no food exemplifies the Cajun cultural atmosphere like fresh, boiled crawfish coupled with its requisite condiments of spicy vegetables and cold beverages.

Processed and prepared products

When crawfish are abundant or when live markets become saturated, a portion of the annual crop is processed and sold as fresh or frozen abdominal or "tail" meat. The most popular processed product is cooked, hand peeled and deveined meat



Figure 10.4. Cooking, peeling and eating whole boiled crawfish is a common springtime weekend activity in Louisiana.

that is usually sold in 12-ounce or 1-pound packages (Figure 10.5). Tail meat may be packed with or without hepatopancreatic tissue (in Louisiana frequently referred to as “fat”), which is an important flavoring condiment in Louisiana cuisine and is savored for its distinctive rich flavor. The smaller size classes of crawfish are usually those processed for the tail meat market, leaving the larger individuals for the more profitable live market.



Figure 10.5. The most popular processed product is cooked, hand-peeled and deveined meat that is usually sold in 12-ounce or 1-pound packages.

The abdominal meat yield for cooked crawfish is, on average, about 15 percent of live weight, but meat yield varies with factors such as sexual maturity and size. Immature crawfish generally yield 4 percent to 5 percent more meat than mature individuals because they have smaller claws and thinner shells. Cooking time and peeling technique can also influence meat yield because all processing is by hand. Early in the production season (November-March) when a high percentage of the crawfish are immature, meat yield can be as high as 22 percent to 23 percent. Late in the season (April-July) when most crawfish are mature and have heavier exoskeletons and large claws, meat yield can be as low as 10 percent to 12 percent of body weight. Abdominal meat is used in diverse ways and can be an appropriate substitute in many shrimp recipes. The amount of crawfish processed for tail meat in Louisiana varies annually, but since the introduction of inexpensive procambarid crawfish meat from China, it is estimated that less than 10 percent of the annual crop is now processed for meat.

Another product form is cooked whole crawfish, usually served fresh and hot, with small volumes also sold as frozen product later to be warmed and served. Traditionally, crawfish in the southern United States are cooked with red pepper-based spices/seasonings, often with onions, potatoes and corn that complement the meal. The consumer extracts the edible portions of the whole crawfish by hand (Figure 10.6).

Increasing in popularity in Louisiana, and within the range of delivery for live crawfish outside of Louisiana, are retail outlets and restaurants serving hot, boiled crawfish. Small, seasonally “take-out” outlets (Figure 10.7) have developed wherever live crawfish can be readily obtained, and many businesses also cater boiled crawfish to large groups, parties and festivals using custom boiling rigs (Figure 10.8).

Prepared frozen crawfish dishes, although still only encompassing a small portion of total sales, have helped increase the distribution of processed abdominal crawfish meat through value-added products.

Marketing Influences

Marketing of domestically produced crawfish has been complicated in recent years by imports of crawfish products. Millions of pounds of imported frozen processed meat and whole boiled procambarid crawfish, principally from the Peoples Republic of China, are imported into the United States



Figure 10.6. Crawfish being processed (“peeled”) to obtain abdominal (“tail”) meat.



Figure 10.7. Small retail outlet specializing in boiled crawfish.



Figure 10.8. Custom mobile crawfish boiling rig used for catering large crawfish boils.

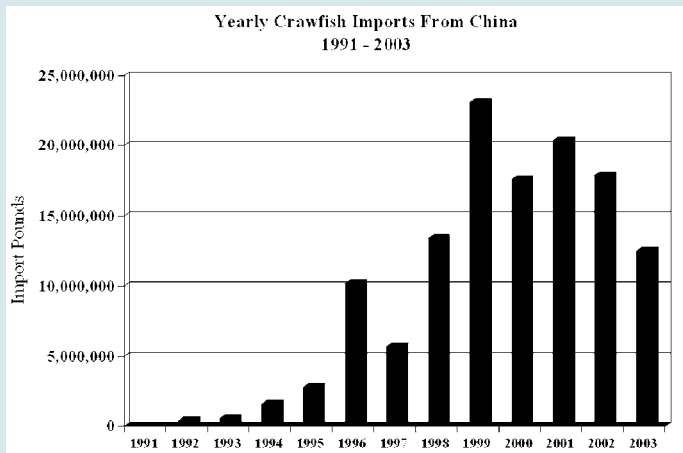


Figure 10.9. Imports of Chinese crawfish (tail meat and whole, boiled product) into the United States (Source: Port Import Export Reporting Service, PIERS, a division of the “Journal of Commerce”).

annually (Figure 10.9). Although a tariff has been imposed by the United States Department of Commerce on much of the imported Chinese crawfish meat, damage to the U.S. industry has occurred. Prior to Chinese imports over 100 licensed crawfish processors existed in Louisiana. Today, the number of processors number in the low 30s and this has led to dramatic reduction in processing (peeling) capacity in Louisiana. As a consequence, each year thousands of tons of smaller crawfish are not harvested for lack of adequate live markets and processing infrastructure.

Although demand for crawfish in Louisiana is high, and markets are expanding in adjacent states, on a national basis, crawfish are in direct competition with products such as shrimp, prawns, lobster and crabs. Unlike Louisiana, the public in other states have historically and culturally not consumed crawfish. Nonetheless, crawfish imports provide for year-round availability and more stable prices, which reportedly have had some positive influences in development and expansion of new markets for crawfish products outside of traditional crawfish consuming areas. The growing popularity of southern Louisiana “Cajun” and “Creole” cuisine throughout the United States

offers excellent opportunity for expanded market development and sale of both live and processed domestically produced crawfish products in the southern United States and elsewhere.

Pricing

Supply and demand relationships are reflected in price variations from year to year and from week to week during the crawfish harvest season. In Louisiana, average annual pond bank price paid to producers from 1997 through 2005 has averaged between \$0.55 and \$0.82 per pound, when annual supply ranged from 70 to 85 million pounds, except in 2000 and 2001 when low supply from both aquaculture and the wild crop pushed average statewide wholesale prices over \$1.24 per pound (Table 10.1). Seasonally, prices to producers are highest in winter and early spring when supply is relatively low (Figure 10.1 and Table 10.2). Prices decline significantly in late spring and summer when supply peaks and the supply and demand for other locally produced fresh seafoods such as shrimp and crabs increase. In Louisiana, price declines as high as 40 percent to 55 percent for “field run” crawfish can occur within several weeks during peak production (April and May) if crawfish quality (usually size) decreases, but the drop in price for larger crawfish is usually substantially less. In recent years, large crawfish have commanded a wholesale price 2 to 3 times higher than paid for medium to small crawfish.

Although prices for live crawfish are relatively uniform among wholesale buyers from day to day or week to week, no single buyer or group of buyers exerts excessive control over pond-bank prices. But when crawfish supplies are high, wholesalers and processors do have the ability to exert price leverage on producers, and this is usually based on their ability, or inability, to move large volumes of crawfish in the live market. Some buyers offer premium prices for their larger, more loyal or more consistent suppliers.

Although wholesale prices for peeled crawfish tail meat are not published, prices typically track the price of live product and, as a “rule of thumb,” the wholesale price of a pound of tail meat is 10 to 12 times higher than the wholesale price of a pound of live crawfish.

Table 10.1. Average annual supply and wholesale price for live crawfish in Louisiana from aquaculture and the wild commercial fishery, 1997 through 2005.

Year	Source				Total	
	Aquaculture		Wild Fishery		Pound (millions)	\$/Pound
	Pounds (millions)	\$/Pound	Pounds (millions)	\$/Pound		
1997	46.9	0.60	30.1	0.52	77.0	0.57
1998	36.1	0.62	30.2	0.63	66.3	0.63
1999	41.2	0.66	21.2	0.65	62.4	0.66
2000	16.2	1.75	2.3	1.48	18.5	1.71
2001	27.7	1.33	6.4	0.84	34.1	1.24
2002	60.5	0.82	14.0	0.52	74.5	0.76
2003	73.0	0.65	10.2	0.52	83.2	0.63
2004	70.0	0.60	8.3	0.58	78.3	0.60
2005	73.8	0.55	8.1	0.57	81.9	0.55

Source: “Louisiana Summary: Agriculture and Natural Resources,” Louisiana State University Agricultural Center, Baton Rouge, Louisiana.

Table 10.2. Estimated average monthly wholesale price and maximum and minimum prices for live “field run” crawfish (mixed sizes) in southern Louisiana, 2000 through 2005.

Price	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Average	\$1.65	\$1.28	\$1.16	\$1.07	\$0.82	\$0.61	\$0.54	\$0.60	\$0.50
Maximum	\$2.00	\$2.00	\$1.33	\$1.21	\$0.90	\$0.75	\$0.65	\$0.72	\$0.50
Minimum	\$1.42	\$0.95	\$0.88	\$0.92	\$0.68	\$0.53	\$0.38	\$0.47	\$0.50

Source: Aquaculture Research Station and Rice Research Station, LSU AgCenter, Baton Rouge, Louisiana and Crawfish Research Center, University of Louisiana at Lafayette, Lafayette, Louisiana.

Production Strategies for Identified Markets

A crawfish producer should be familiar with potential markets, both wholesale and retail, and match production to estimated needs. Since crawfish are harvested several times per week, reliable buyers are paramount to a farmer’s success. Direct sales to retail customers by farmers are not particularly high in large production areas like southern Louisiana. Therefore, most large producers in these areas must sell most of their harvest to wholesale buyers and processors. Small-scale crawfish producers outside of Louisiana have few established and knowledgeable wholesalers who are experienced in marketing live crawfish. Many small-scale producers, however, have successfully developed markets for both direct retail sales to consumers and to retail seafood establishments.

Occasionally, harvesting schedules and strategies must be adjusted to accommodate available markets. Buyers may prefer to have product delivered only on certain days, such as Thursday through Sunday. Additionally, market demand for crawfish early in the season may allow for various sizes of crawfish to be sold with little problem, but when crawfish supplies are more abundant, trapping strategies may need to be adjusted to maximize crawfish sizes, even at the expense of overall yield. Planning and good communication with potential buyers early in the season can allow trapping strategies to be developed that respond to market preferences and improve a producer’s competitive position.

Regulations and Permits

Various permits may be required to market crawfish, such as wholesale or retail fish distributor’s license, or to transport them across state lines. Permits are specific for each state. Imports of live non-native crawfish are restricted or forbidden in a number of states, especially where there are concerns over establishment and competition with native species. Before shipping live crawfish, always verify regulatory requirements in the receiving state, or states in which crawfish are being transported, to avoid serious legal problems.

In Louisiana, live haulers are usually required to possess permits or licenses to transport crawfish, depending on whom their crawfish are being purchased from or sold to. These may include municipal or parish permits as well as a state transport license and seafood wholesale/retail dealer’s license. For interstate shipments of live crawfish, pass-through states and the receiving state also will likely have license requirements.

Transport and Storage

Storage and transport of live crawfish is unusual in that they are not transported in water, but rather consolidated in plastic mesh sacks (Figure 10.10). Sacks hold about 35 to 45 pounds of crawfish depending on how tightly the trapper



Figure 10.10. In Louisiana, crawfish are transported to market and sold as a live product, in mesh bags (sacks) that usually hold 35 to 45 pounds of crawfish.

chooses to pack them. This method is preferred over more rigid containers such as totes (Figure 10.11) because crawfish can be packed in the sacks in a manner that prevents damage from pinching, which can happen when animals are not sufficiently restricted.

To minimize crushing, sacks should not be packed too tightly, but sufficiently tight to restrict crawfish movement. Sacks of live crawfish can be transported in open bed trucks for short distances, but sacks should be covered with a tarp to minimize drying of gills. Wholesalers or jobbers haul sacks of live crawfish over long distances, or in larger quantities, in insulated trucks, with or without refrigeration (Figure 10.12). Crushed ice is placed over the sacks in nonrefrigerated trucks and, in some cases, refrigerated trucks, to reduce crawfish metabolism and maintain a high level of humidity, which increases shelf life of live crawfish.

High survival rate during live transport begins by insuring crawfish are harvested from ponds with good water quality. Live crawfish should be transported to on-the-farm coolers or to the terminal market as soon after harvest as possible. Transport vehicles should be clean and free from petroleum products or other contaminants. If hauled long distance in the harvest boat or transported in an open vehicle, exposure of crawfish to excessive wind and bright sunlight should be minimized by covering the sacks with wet burlap or a tarp. Sacks should not be stacked so high that crawfish in the bottom sacks are crushed.



Figure 10.11. Crawfish totes, an alternative method for holding and transporting crawfish.

Sacks of live crawfish in good physical condition can be held in high humidity coolers at 38 F to 46 F for up to several days prior to peeling or further transport to the terminal destination. Maintenance of gill moisture is crucial for survival of crawfish held in coolers. Gill moisture is usually accomplished by periodic wetting of crawfish and/or placement of wet burlap or ice over the sacks of crawfish. If placed in plastic tote boxes, the top tote should be filled with ice. Melting ice trickles down through the totes to provide the necessary moisture. Placing unchilled crawfish in totes is not recommended because physical damage from pinching by active crawfish may occur.

A relatively small volume of live crawfish is shipped in sacks by air-freight throughout the United States in insulated seafood shipping boxes containing frozen gel packs. During warm weather, crawfish shipped by air freight should be cooled overnight prior to shipping.

Purging and Cleaning

To provide a more appealing product for live markets, a small number of producers have adopted the practice of “purging” crawfish before selling them. This requires that crawfish be confined in water or very humid environments where food is withheld for 24 to 48 hours. This process cleans the exoskeleton of mud and debris and eliminates or reduces digesta in the



Figure 10.12. Crawfish transport truck and transport with ice.

intestine (Figure 10.13), which consumers may find unappealing. This method should not be confused with the practice of immersing crawfish in salt water immediately before boiling, which is not effective in evacuating the gut and is little more than an external wash.

To facilitate removal of the intestinal contents, crawfish are commonly held in tanks within specially constructed boxes or baskets (Figure 10.13) that are usually suspended in water. Recommended loading rate is about 1.5 pounds of crawfish per square feet of submerged surface area with adequate aeration and water exchange. Equally effective, but seldom used, is a water spray system where crawfish are held in shallow pools of water (1/2-inch deep) under a constant spray or mist. Holding crawfish in aerated vats or purging systems under crowded conditions for more than 24-48 hours is not recommended because of the possibility of excessive mortality. Though purging increases the cost of the product, purged crawfish have high consumer acceptance, particularly outside of traditional Louisiana markets. Some people who have eaten crawfish for many years are accustomed to nonpurged crawfish and do not find them objectionable; nonetheless, many would probably prefer purged product if cost was reasonable.

Although the current market for purged crawfish is small from a lack of public awareness and price differences (15 percent to 25 percent higher), purging has contributed to repeat sales and loyalty to certain producers or distributors. Mortality during purging is the largest contributor to increased prices, but



Figure 10.13. Purged versus nonpurged crawfish (top photo). Note the difference in the intestinal contents of nonpurged crawfish (left) and purged crawfish (right). Crawfish purging system (bottom photo).

research has recently demonstrated that shorter purge duration (12 hours) can be nearly as effective and contributes significantly to less mortality.

The external surfaces of crawfish, which can be fouled and/or stained, are reasonably cleaned during purging. Abrasive actions of crowded crawfish rubbing against one another effectively “polish” the shells. For nonpurged animals and excessively stained batches of crawfish, however, additional cleaning is sometimes accomplished prior to cooking. External cleaning of the carapace of live crawfish with food-service chemicals (ascorbic or citric acid and baking soda) to enhance appearance and increase marketability is becoming increasingly common.

Grading

Crawfish markets have changed considerably since the mid-1980s when crawfish were sold without consideration of size. Development of an export market in Scandinavia in the late 1980s for crawfish 15-count (number per pound) or larger, first provided the impetus for size grading. Louisiana’s export markets for crawfish were eventually lost to competition from the Peoples Republic of China, but size grading remained and is widely used in the domestic market. Grading by size is usu-



Figure 10.14. Large commercial grader at a crawfish buying dock.

ally not practiced early in the production season when crawfish supply is low and demand is high for crawfish of all sizes, but as the volume of crawfish increases in early spring size grading becomes a standard practice for servicing the market demand for large crawfish. Nearly all grading occurs at wholesale outlets or processing plants, using modified vegetable graders or custom-made graders (Figure 10.14).

At present, no uniform size and grade standards exist for the crawfish industry as with other seafoods, and this to some degree hinders out-of-state market development and expansion. Based on a number of production and marketing conditions, crawfish are typically graded into two or three size classes. Generally, the largest crawfish are sold to specialty restaurants, and the smaller ones are processed for tail meat or blended with larger individuals for large volume sales. One example of a commonly used grading system for crawfish in Louisiana is shown in Table 10.3. Other grading standards are used by various crawfish wholesalers depending on their markets.

Table 10.3. Example of a common grading system used for live crawfish in Louisiana.

Size Classification	Size Classification by Number	Number (Count) of Crawfish per Pound
Large	1	15 or fewer
Medium	2	16-20
Small	3	21 or more
Field run		Mixed sizes

Glossary

Abdomen – Refers to the tail of a crawfish. Used in locomotion and swimming. Peeled after cooking for consumption.

Age class – Also synonymous with size class, recruitment class. Generally refers to pulses or “waves” of crawfish hatched around the same time. For example, if large numbers of crawfish were hatched and released into the water in the first two weeks of October and the last two weeks of November, two age classes of juvenile crawfish would be in the pond. (Also see “Recruitment.”)

Agronomic – Refers to terrestrial plant agriculture.

Aquaculture – Cultivation of aquatic organisms in a controlled and managed environment.

Baffle levees – Small levees built within the interior of a crawfish pond to direct water flow when pumping water into ponds. They also serve as reproductive burrowing area for crawfish.

Biomass – The weight of all the organisms forming a given population or inhabiting an environment. Can also be used to describe the total quantity or weight of plants, as in biomass of the forage crop.

BMP – “Best Management Practices”; procedures followed by agricultural producers to control the generation and delivery of pollutants from agricultural activities into water resources of the state thereby reducing the amount of agricultural pollutants entering surface and ground waters.

Best management practices – see “BMP.”

Burrow – A hole or excavation in the ground made by a crawfish for reproduction, shelter and habitation.

Broodstock – Reproductively active adults or immature sub-adults obtained for breeding.

Cannibalism – Eating of a crawfish by another crawfish. Crawfish are most vulnerable to cannibalism after molting.

Carapace – External upper shell of a crawfish.

Clay loam – A soil that consists of about 20% to 45% sand and 27% to 40% clay.



The fossil record suggests that crawfish and their relatives have been around for 285 million years.



The red swamp crawfish (rear) and white river crawfish (front) are closely related and often occur side-by-side, but natural hybrids between the two have never been documented.

Count per pound – Number of crawfish that equals 1 pound in weight. Often referred to as simply “count.” For example, 20-count per pound crawfish or 20-count crawfish will consist of 20 crawfish that collectively weigh 1 pound.

Crop rotation – Agronomic term that refers to growing a different agricultural crop following the harvest of a crop, usually in the same field. Growing crawfish in a rice field following the harvest of rice grain is an example of a crop rotation.

Density – Number of individual crawfish per unit space area.

Density dependent growth – A term that means that the growth rate of a crawfish is dependent on the overall population density of crawfish in the pond. The higher the density the slower the growth and vice-versa.

Detritus – Organic debris from decomposing plant and animal material. Detritus has many microorganisms and can be used a food by crawfish directly or is used as food by other organisms that crawfish eat.

Detritivores – Organisms that eat detritus.

Dewatering – To remove water from a pond or field by draining.

Dissolved oxygen – Oxygen gas dissolved in water and is required by crawfish for respiration and survival. Often referred to as “DO.” Low dissolved oxygen is detrimental to the health and survival of crawfish.

Ecosystem – A community of organisms, interacting with each other, plus the environment in which they live and with which they also interact.

Effluent – Water that is discharge or released into the environment from a crawfish pond. Also referred to as “tailwater.”

Epiphytic organism – Refers to organisms growing on the outside of a plant, not as parasites, but as using it for support. For example, algae growing on the outside of a rice plant is an epiphytic organism.

Exoskeleton – External shell covering the outside of a crawfish.

Fallow – Usually refers to cultivated land that is allowed to lie idle following the harvest of another crop.

Fat – Common reference for the hepatopancreas. Sometimes referred to by scientists as the digestive gland or organ.

Fecundity – Number of mature eggs or oocytes in a female crawfish just prior to spawning.

Formulated feed – A food that is manufactured from various ingredients and meets most, or all, of the nutritional requirements of an animal. It may also be referred to as manufactured feed.

Filter strip – Usually refers to a vegetated strip of land through which or over which effluent or tailwater can flow to remove suspended matter and nutrients.

Flushing – To replace all or a portion of water in a pond, usually in an attempt to increase the dissolved oxygen content.

Food chain – Chain of organisms through which nutritional energy is transferred. Each link in the chain feeds on and obtains energy from the one preceding it and in turn it is eaten by and provides energy for the one following it.

Food web – All the food chains in a crawfish pond make up the food web.

Gastroliths – Two small mineral stones found in the stomach lining of a molting (soft) crawfish. They consist largely of calcium minerals that are extracted from the old shell prior to molting. The gastroliths dissolve as the crawfish hardens to return calcium to the newly formed shell.

Genotype – The genetic makeup of a particular organism.

Germination – Process by which a seed sprouts.

Habitat – The environment where a plant or animal normally lives and grows.

Hatchlings – Refers to juvenile crawfish as they emerge from hatched eggs. They may be referred to as “hatchlings” for several weeks.

Hepatopancreas – A glandular organ in a crawfish that aids in the digestion of food. It has the same function as the liver and pancreas and acts as a reserve for stored energy. It supplies a significant amount of nutritional energy to crawfish when they are in burrows, and it is also important in crawfish reproduction. In southern Louisiana it is commonly referred to as “fat.”



On extremely flat lands, water can be circulated and aerated using paddlewheels designed for catfish production.



Natural surface waters provide a resource for flooding and flushing crawfish ponds in many parts of the state.

Herbivores – Organisms that eat plants.

Holdover crawfish – Crawfish that survive the previous production season, successfully burrow, and can be found in the current season’s crawfish crop. Holdover crawfish may be mature or immature.

Hybrids – Animals or plants resulting from the cross of parents that are genetically different, as in a cross of two different species.

Hydrological cycle – As it relates to crawfish production in Louisiana, the hydrological cycle refers to the annual summer low water and spring high water cycles in Louisiana’s Atchafalaya River Basin on which the annual wild crawfish crop is predicated.

Hypothesis – A tentative assumption made from an interpretation of a practical situation or condition.

Invertebrate – A collective term for all animals that do not have vertebrate (spinal column).

Intercropping – Growing of two or more different crops in the same field simultaneously. For example, relaying stunted crawfish into the same field as an actively growing rice crop is an example of an intercropping system.

Intermolt – Stage in the molting cycle of crawfish between the post-molt and next pre-molt stage. In the intermolt stage the crawfish does not increase measurably in length but will increase in tissue weight with proper nutrition and environmental conditions.

Juveniles – A term used to refer to crawfish that have not yet attained sexual maturity or adult stage.

Levee – An earthen embankment for impounding or holding water.

Intermittent harvesting – A process in which crawfish are harvested intensely for several or more days followed by a rest period of several days or more in which no harvesting occurs to allow for additional growth in individual crawfish.

Life cycle – The series of stages an organism passes through during its lifetime.

Lodging – The leaning or falling over of plants, particularly cultivated crops like rice or sorghum-sudangrass.

Metabolism – The general chemical processes occurring within a living organism.

Microorganism – Microscopic organism; a unicellular plant, animal or bacterium.



The three-funnel pyramid trap represented an important innovation in trap design and harvest efficiency. The version pictured here has since been replaced by newer variations on this design, using square mesh wire and plastic collars which also serve as handles.

Molting – To shed or cast off the old exoskeleton periodically to allow the body to grow.

Monocropping – Cultivation of a single agricultural or aquacultural crop in a field or pond. Also known as “monoculture.”

Noxious weeds – Nondesirable plants present in crawfish ponds or agricultural fields; examples include cattails, indigo weed, water lilies.

Omnivores – Organisms that eat both plant and animal matter. Crawfish are considered to be omnivores.

Organic – Any material derived from living organisms.

Ovary – The organ in female crawfish that produces ova or eggs.

Oxygen demand – Oxygen consumed in respiration by all organisms in a crawfish pond. The higher the oxygen demand the more difficult it is to maintain oxygen levels in the water. Also commonly referred to as “Biochemical Oxygen Demand” or “BOD.”

pH – A measure of the acidity or alkalinity of soil, water or solution. Values range from 0 to 14 with 7 being neutral, less than 7 is acidic and above 7 is alkaline.

Pathogen – A specific agent or organism that causes infectious disease in crawfish.

Perimeter levees – The larger levees that define the outside boundary of a crawfish pond. Perimeter levees are usually higher and wider than interior baffle levees.

Pesticide – A chemical or biological agent used to destroy pests. Pesticides include fungicides, herbicides and insecticides.

Plankton – Microscopic plants and animals present in water.

Population dynamics – A term that refers to the rates of abundance, reproduction, growth and mortality in crawfish populations.

Population structure – A term that refers to the age, size and number of crawfish in a pond population.

Procambriid – A taxonomic classification term that includes both the red swamp crawfish and white river crawfish. Other species of crawfishes are procambriids in Louisiana and elsewhere.

Purging – Process of cleaning crawfish by water immersion or spray immersion to empty the intestinal (gut) contents of fecal material as well as removing mud and grit from the gill cavity.

Ratoon – Refers to the regrowth of rice plant from the stalks after grain harvest.

Recruitment – Entry of young-of-the-year crawfish (“recruits”) into the population as they leave their mother when she emerges from a burrow and enters the open water of a pond. Pulses of recruits that enter the population throughout the various months in a production season are referred to as “recruitment waves” or “waves of recruitment.” (Also see “age class.”)

Relaying – The process of transferring small crawfish from ponds deficient in food into other ponds or fields with few crawfish, and where food is abundant, to stimulate growth.

Senescence – The process of aging leading to death after the completion of growth in plants.

Silty clay – A soil that consists of about 40%-60% silt and 40%-60% clay.

Set-time – The number of hours that a baited crawfish trap is left in the water to catch crawfish before being emptied and re-baited. Usually trap set times are approximately 24 or 48 hours. May also be referred to as “soak-time.”

Specimen – An individual considered typical of a group.

Spawn – To produce and deposit eggs in the reproduction process.

Standing stock – Refers to either the number or weight of crawfish in a pond or field at any particular moment in time.

Stunting – A term that refers to a significant reduction in the growth of a population of crawfish, usually associated with high density and deficient food resources.

Suspended sediments – Clay, silt, sand particles suspended in water.

Swimmerets – Small appendages under the abdomen (tail) of a crawfish that function in locomotion and reproduction. Eggs when laid are attached to the swimmerets. (Also known as “pleopods.”)

Terrestrial grasses – Volunteer (nonplanted and noncultivated) grasses of nonaquatic origin that usually grow in the pond during the summer dry period when no water is present.

Toxicant – A toxic compound.

Tailwater – Water that is discharged or released into the environment from a crawfish pond. Also referred to as “effluent.”

Turbidity – Opacity in water caused by suspended particles from bottom muds or organic matter such as plankton.

Wetland – A land or area containing a significant amount of soil moisture. The federal government has specific criteria for defining wetlands that are used in regulatory matters.

Young-of-the-year – A term that refers to hatchling or juvenile crawfish hatched within the current crawfish production season.

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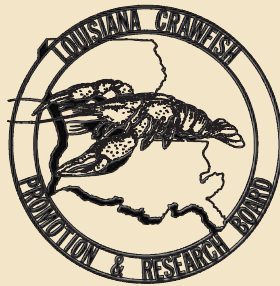
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Mr. de la Bretonne served as state aquaculture extension specialist with the LSU AgCenter's Louisiana Cooperative Extension Service for more than 15 years prior to his untimely death in 1991.

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