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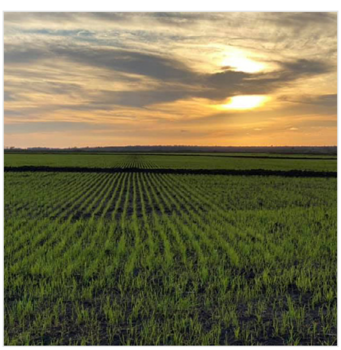
TEXAS CRAWFISH PRODUCTION MANUAL



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CHAPTER 1:
INTRODUCTION

Crawfish boils are a tradition in the South and throughout Texas. Their centerpiece and namesake, crawfish, are a tender delicacy that have generated a booming industry in the past 50 years. Referred to as crayfish, crawdads, and mudbugs, the two most popular species for aquaculture are the red swamp crawfish and the white river crawfish. Throughout this manual, we will use the term crawfish to refer to both.

HISTORY

Throughout history, from the Native Americans to the European settlers, crawfish and culturing crawfish have been an important part of local culture in many states in the South. In 1880, a harvest of 23,400 pounds—valued at $2,140—was the first record of commercial harvest of crawfish in the United States (US).

Louisiana

A US Census report in 1908 stated that crawfish harvested in Louisiana held a production of 88,000 pounds with a value of $3,600. Following the Great Depression, the development of cold storage, and improved transportation, crawfish markets shifted within Louisiana from local consumption to marketing in larger cities like New Orleans. During this time, the crawfish industry was introduced to wire mesh traps, which improved the efficiency of commercial harvest tremendously. By 1950, the study of the life history of crawfish by the Wildlife Commission in small ponds was funded by the Louisiana State Legislature. Up until this time, most of the crawfish available for people to consume had come from wild harvest habitats like the Atchafalaya Basin (Louisiana Crawfish Production Manual, 2007).

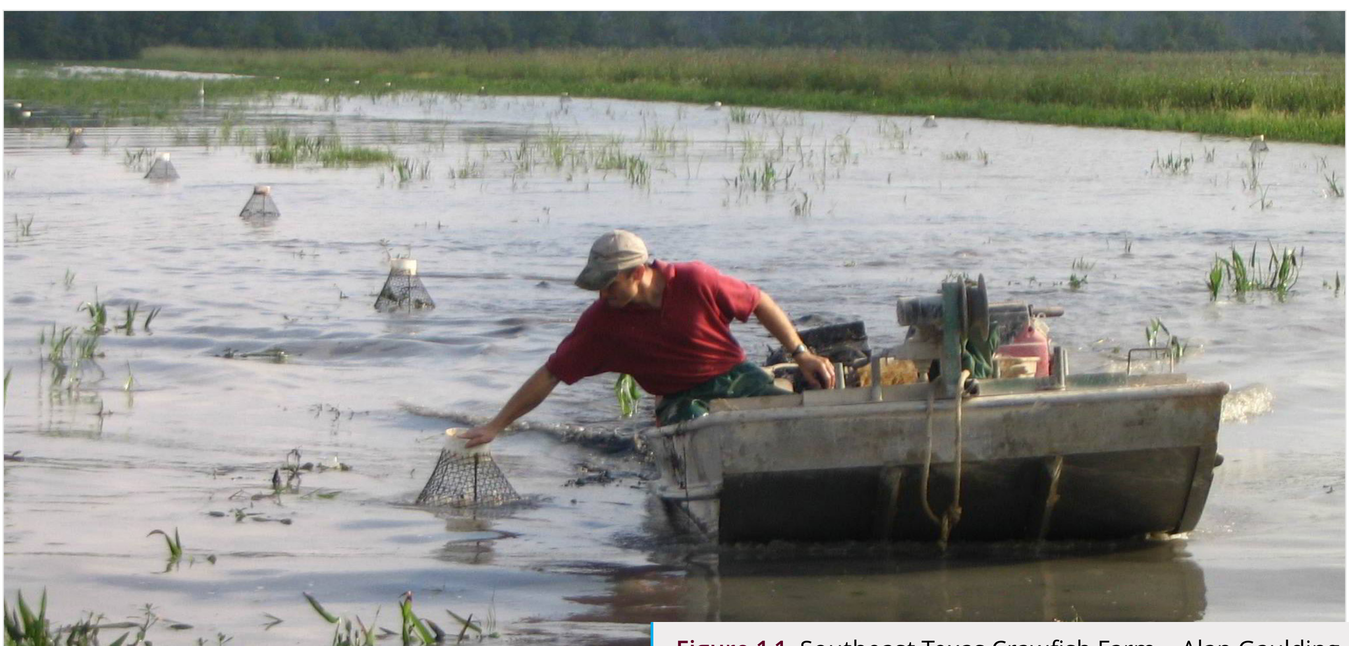

Figure 1.1. Southeast Texas Crawfish Farm—Alan Gaulding.
Photo credit: Southeast Texas Crawfish Farms

Louisiana's crawfish farming industry grew to include more than 10,000 acres of managed ponds by the 1960s. Acreage continues to increase in Louisiana, from approximately 44,000 acres in the mid-1970s to around 260,000 acres today.

Historically, significant harvests of wild crawfish have occurred in Louisiana. This production moves through the same market as farmed crawfish, affecting prices received by farmers. Many of the traditional areas of wild harvest have failed to produce large volumes of crawfish (Louisiana Crawfish Production Manual, 2007).

Since the 2000s, less than 20 percent of Louisiana's harvests on average have come from the wild fishery.

Small harvests of farmed crawfish for human consumption occur in other states such as Texas, Arkansas, Mississippi, Alabama, and the Carolinas, but Louisiana is the largest producer of crawfish in the US. Louisiana usually accounts for 90 to 95 percent of the US production year to year (Louisiana Crawfish Production Manual, 2007).

Texas

In Texas, there are a growing number of farms that produce crawfish for local markets. In the 1980s, there was a large push to compete with production in Louisiana. The push in the 1980s encouraged producers to use innovative techniques to produce and market crawfish, which remain popular in Texas. A survey mailed to farmers in the 1980s indicated that 80 percent of the crawfish farmers in Texas had been in the crawfish business for no more than 3 years. The production base was reported with 81 percent of the acreage located in Chambers, Jefferson, Orange, and Liberty Counties.

Between 1987 and 1988, just over 600,000 pounds of crawfish were produced, with 84 percent coming from this four-county area. The Texas Aquaculture Association was founded in 1988 from the combination of catfish farmers and crawfish farmers of Texas.

Figure 1.2. Rice dryers and crawfish traps.
Photo: Nikki Fitzgerald

Beginning in January 1989, some Texas producers began distributing substantial quantities of farm-raised crawfish into the retail food sector at a fixed price throughout the season. This event was not captured via the mail survey since the time period for surveying industry conditions was from November 1987 through June 1988. It represents a departure from traditional marketing practices for live crawfish in that:

1. A new outlet was developed (sales to retail food stores accounted for only 2 percent of total marketing from 1987 to 1988);
2. Forward contracting enabled producers to increase their annual weighted average selling prices;
3. Producers and retailers agreed upon size standards for live crawfish as a condition of sale and acceptance; and
4. Participants in this pooling program, i.e., individual crawfish farmers, did not have to distribute their product to the contracting food retailing firm.

CHAPTER 2:
CRAWFISH BIOLOGY

Crawfish are crustacean arthropods belonging to the superfamily Astocoidea. The red swamp crawfish (*Procambarus clarkii*) and the white river crawfish (*Procambarus zonangulus*) belong to the family Cambaridae, the largest group of freshwater crawfish that are mostly native to North America. Red swamp crawfish and white river crawfish (Fig. 2.1) are the two most commonly cultured species in the US, and due to their similar ecological requirements, adaptations to annual flooding cycles, and behaviors, they are typically found and grown in the same ponds. The red swamp and white river crawfish are successful in commercial, low-energy input and extensive aquaculture systems because they are hardy and adaptable creatures whose life cycles can be easily manipulated to fit culture practices. Together, the two species make up over 90 percent of the total crawfish cultured in the US. Red swamp crawfish, the more desirable product species, comprise approximately 70 to 80 percent of the total harvest. Although red swamp crawfish are often more abundant, the white river crawfish may become the more dominant species in ponds that have been in continuous cultivation for several years. Other notable species raised in the US include the northern crawfish (*Orconectes immunis*), which may be better adapted to areas with water shortages, and from the western US, the signal crawfish (*Pacifastacus leniusculus*), which is the largest crawfish native to the country.

The red swamp and white river crawfish are excellent candidates for culture and are well adapted to the conditions found in commercial culture ponds. How these two species interact in crawfish ponds is not fully understood.

How are crawfish classified?

Biologists use a classification system to better group organisms. This makes it easier to communicate and retain information about organisms when they are organized into groups. Scientists often refer to animals and plants by their genus and species classification.

Kingdom – Animalia (animals)

Phylum – Arthropoda (crustaceans, spiders, insects, etc.)

Class – Malacostraca (crab, krill, pill bugs, and related species and groups)

Order – Decapoda (meaning “10 legs”: lobsters, shrimp, crabs, crayfish)

Family – Cambaridae (cambrid crayfish, one of three major groups of crayfish)

Genus – Procambarus

Species – Clarkii (for red crawfish); zonangulus (for white crawfish)

Figure 2.1. The red swamp crawfish (rear) and white river crawfish (front).
Photo: LSU AgCenter

RED SWAMP CRAWFISH VERSUS WHITE RIVER CRAWFISH

The red swamp crawfish may be distinguished from white river crawfish by several characteristics (Fig. 2.2). In red swamp crawfish, the two halves of the carapace (upper shell) meet and form a thin line. On the underside of the red crawfish's tail, there is a dark-pigmented line running the length of the tail. The claws of the red swamp crawfish tend to be broader and thicker, and the adults often have dark-pigmented walking legs and bodies, which give them their name. On the white river crawfish, there is a separation between the halves of the carapace called an "areola." The white river crawfish have more elongated cylindrical claws and lighter-colored walking legs. The red swamp crawfish are more prolific, produce more eggs, and may spawn at any time of the year, whereas the white river crawfish reproduce seasonally in the fall and winter.

Usually, red swamp crawfish are found in abundance in waters with lower dissolved oxygen (DO) content. They appear to do better in more nutrient-rich waters than the white river crawfish. Feeding rates of the red swamp crawfish are

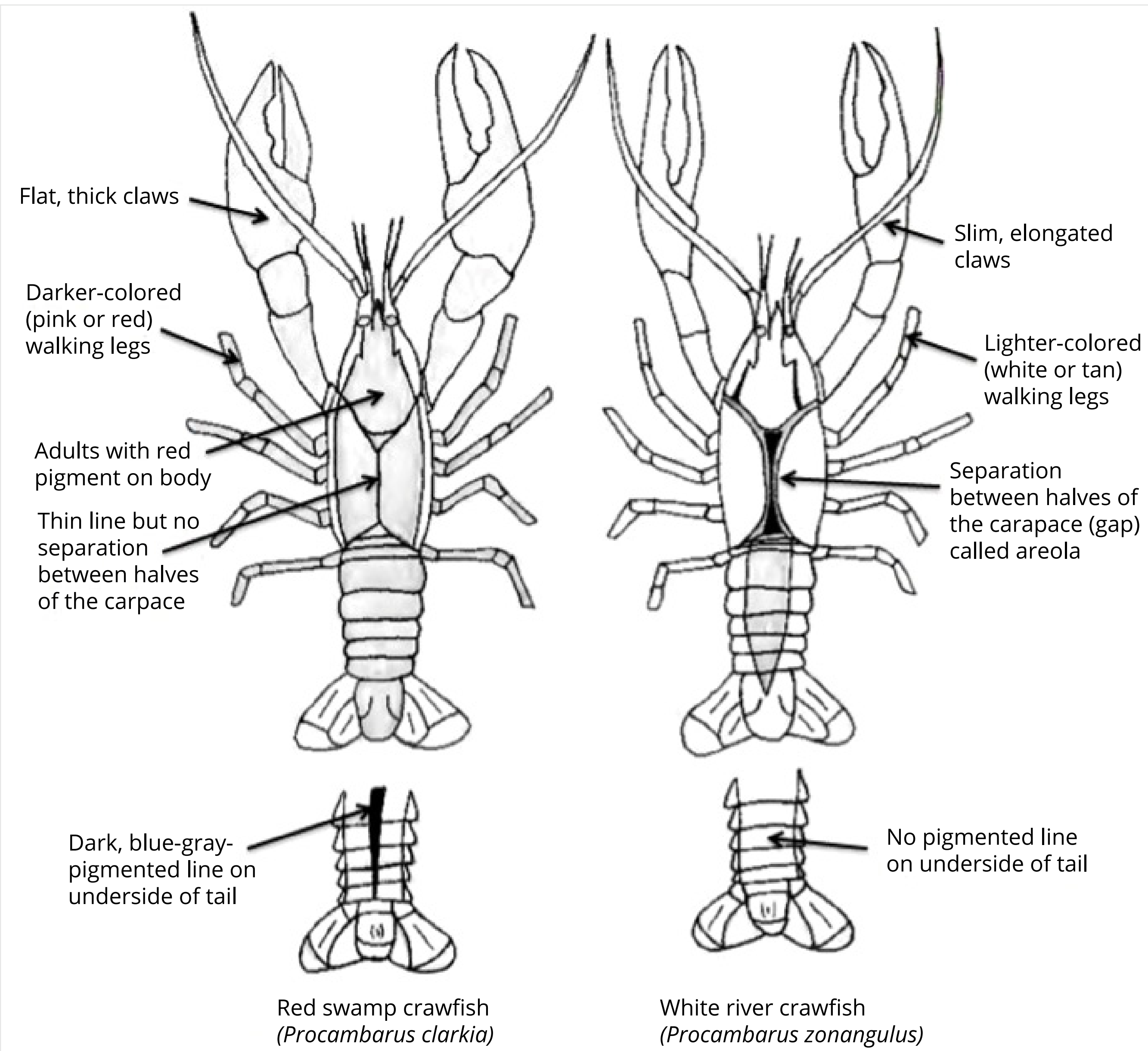

Figure 2.2. Red swamp crawfish versus white river crawfish.

higher at temperatures above 86°F and may provide a competitive advantage over the white crawfish. The red swamp crawfish can tolerate higher water temperatures, are native to states with warmer climates, and have been introduced to many countries. Red swamp crawfish are native to the states along the Gulf of Mexico from Texas to Alabama, up the Mississippi River drainage basin into Tennessee and Illinois, and in eastern Mexico.

White river crawfish are also found along the Gulf of Mexico and up the Mississippi River drainage basin and are only found in the US. Their distribution extends farther north and eastward in rivers along the Atlantic Coastal Plain into southern New England because they are more cold tolerant.

The two species of crawfish are excellent candidates for culture and are well adapted to the conditions found in commercial culture ponds. Abundance between species may vary within a specific pond, but the red swamp crawfish is commonly the most abundant species and the most desired in the commercial market. White river crawfish are generally the most abundant species when a pond has been in production for several years. Not much is known about the interaction between the two species, and there is evidence that red swamp and white river crawfish crossbreed naturally.

CRAWFISH DIET AND NUTRITION

As crustaceans, crawfish have a hard outer shell made of chitin. This requires that they molt or shed this exoskeleton in order to grow. Their food must contain an adequate amount of calcium carbonate (limestone) to provide the necessary nutrients for shell development. Crawfish eat almost any plant material. They prefer fresh, tender vegetation but readily consume decaying plants for the microorganisms and invertebrates associated with decomposition. They are attracted to fresh meat and fish but tend to avoid decaying animal matter. Crawfish are found in a variety of habitats, generally preferring areas with cover, such as rocks or dense vegetation. They rarely surface, normally occupying only the bottom portions of the lake, pond, or stream.

Red swamp crawfish
Procambarus clarkii

- Account for more of the annual catch
- The two halves of the carapace (upper shell) meet and form a thin line
- There is a dark, blue-gray-pigmented line on the underside of the tail
- Claws tend to be broader and thicker
- Adults have dark-pigmented walking legs and bodies, which give them their name
- More prolific, produce more eggs
- Spawn at any time of the year
- More abundant in swampy areas and standing water habitats that are nutrient rich and have low dissolved oxygen (DO) concentrations
- Feeding rates higher at 86°F
- May be able to tolerate higher water temperatures and are native to states with warmer climates—the states bordering the Gulf of Mexico (from Texas to Alabama), up the Mississippi River drainage basin into Tennessee and Illinois, and in eastern Mexico
- Introduced to many countries

White river crawfish
Procambarus zonangulus

- Exhibit a separation between the halves of the carapace called the “areola”
- More elongated and cylindrical claws
- Lighter-colored walking legs
- No pigmented line on the underside of the adult tail
- Reproduce seasonally in the fall and winter
- Produce fewer and larger eggs than red swamp crawfish
- Spawn later in the year
- Hatchlings are larger than red swamp crawfish
- Usually mature from April to June
- Grow faster at lower temperatures and typically have greater maximum sizes than the red swamp crawfish
- White river crawfish are also found along the Gulf of Mexico and up the Mississippi River drainage basin and are only found in the US
- Native range is Alabama, Louisiana, Mississippi, and Texas

The red swamp and white river crawfish are extremely aggressive and are known to cannibalize smaller individuals.

Crawfish are described as many types of feeders: herbivores, which eat vegetation; detritivores, which consume decomposing organic material; omnivores, which consume both plant and animal matter; and more recently, obligate carnivores, which require at least some animal matter for optimal growth and health. This variety in food resources is understandable because crawfish occupy a variety of habitats and must adapt to available resources. Living plants are frequently the most abundant food resource in habitats occupied by crawfish and in commercial ponds. However, they do not offer much energy or many macronutrients and do not contribute much to the direct nourishment of the crawfish. The living plant material is not as readily consumed when other food supplies are limited. In fact, decomposing organic material (detritus) is consumed in greater quantities and is thought to have a higher food value than living plants, though it does not generally provide the protein and energy needed for maximum growth. Rather, the microorganisms and invertebrates that consume the microbial-rich detritus offer a source of high-quality nutrition to crawfish. Starchy seeds may also provide a good source of energy.

Mollusks, insects, worms, small crustaceans, and some small vertebrates depend on the microbe-rich detritus as their main food source as well. These small animals can furnish high-quality, protein-rich nutrition to crawfish, allowing them to grow at their maximum rate. Some culture farms choose to provide supplemental feed to ponds, although it is not a universal method. A majority of farms rely on the self-sustaining pond system, or polyculture of crops and crawfish, to provide for all the dietary needs of crawfish. Managing and production of a forage crop, such as rice, is not only an economically sound way to farm, but it also provides nutrition to crawfish. An established (or at least encouraged) vegetative forage crop provides the basis of a complex food web (Fig. 2.3) that ultimately fuels crawfish production. Once ponds are flooded in the fall, a continuous supply of plant fragments from the decomposing vegetation provides fuel that drives a detritus-based production system that puts the crawfish at the top of the food chain.

DISTINGUISHING BETWEEN SEXES

Males can be distinguished from females by the claws, which are longer and wider in males. Male crawfish develop hooks at the base of the third and fourth pairs of walking legs which serve to grasp the female during mating (Fig. 2.4). When males become sexually mature, their first two pairs of modified swimmerets next to the thorax (gonopods) calcify and harden. They function to transfer sperm to the female's seminal receptacle (annulus ventralis), which stores sperm until fertilization. Mature females exhibit a distinct groove in the annulus ventralis, which is located between the walking legs (Fig 2.5).

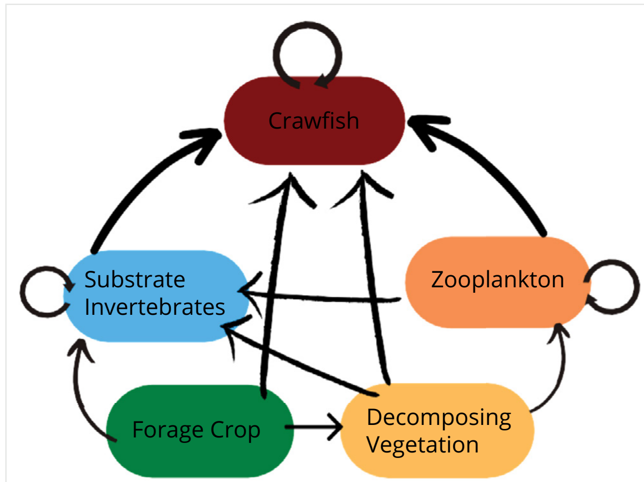

Figure 2.3. A simplified diagram of nutrient pathways of the food chain in crawfish ponds, with the forage crop serving as the principal fuel and crawfish at the top of the food chain (Louisiana Crawfish Production Manual, 2007).

Figure 2.4. Mature male crawfish.
Photo: Mark Shirley

Figure 2.5. Mature female crawfish.
Photo: Mark Shirley

REPRODUCTION AND LIFE CYCLES

Crawfish are classified as a "temperate" species and will tolerate cold winter conditions. These species have several traits, such as short life spans, high juvenile survival rates, and the alternation between inactive and active states that are usually associated with animals that live in warm waters. The peak mating time is usually between the months of May and June in the Deep South. Crawfish life cycles are easy to coincide with farm production strategies. Mature crawfish mate in open water. Sperm is stored in a special receptacle, but most often, the female will then retreat to a burrow to eventually spawn where her eggs and young are protected. Females may mate with many males, receiving and storing sperm in the annulus ventralis before building their burrows. Burrows provide protection because females carrying eggs or hatchlings are highly susceptible to predators due to the inability to use their normal tail-flapping response with eggs attached on the underside of their tails (Fig. 2.7).

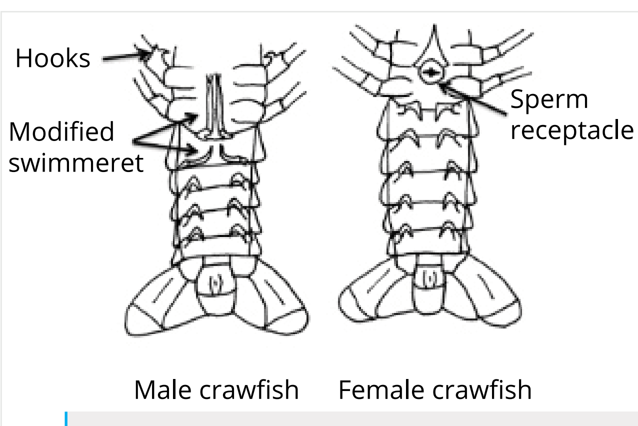

Figure 2.6. Male crawfish versus female crawfish.

Mature or immature crawfish of all ages, sizes, and sexes will dig or retreat to burrows to survive periods of dewatering. During the summer months, crawfish ponds are usually drained for planting and growth of vegetation, which encourages females to retreat to their burrows and lay their eggs. Ovarian development begins prior to burrowing and is completed within the burrow, where females exude and fertilize the eggs. The number of eggs laid will vary depending on the female's size and condition. Red swamp and white river crawfish can lay 300 to 500 eggs, which they attach to the swimmerets on the underside of their bellies. Under ideal conditions, the incubation period for the eggs is about 2 to 4 weeks, with the red swamp crawfish incubation being shorter than that of the white river crawfish. After the eggs hatch, the young cling to the mother until they have molted twice and are able to fend for themselves. While crawfish can survive within the burrow as long as humidity remains elevated, standing water within a portion of the burrow is necessary for reproduction. The hatching process usually takes about 3 weeks and is dependent on temperature. Hatched crawfish are attached to the female's swimmerets through two molting phases.

Figure 2.7. 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 (Louisiana Crawfish Production Manual, 2007).
Photo: LSU AgCenter

After molting twice, hatchlings will resemble adult crawfish and begin to feed. The hatchlings will remain with the female for several weeks after their second molt. When heavy rainfall or pond flooding occurs, it encourages females to leave the safety of their burrows and emerge with their young. Often, farmers will flood their crawfish ponds in the fall to encourage crawfish to leave their burrows. After the pond floods, the young detach themselves from the female while she moves about the pond, generating a crawfish population of mixed sizes and age classes. The female typically dies after the young are mature enough to live on their own.

BURROWS

Crawfish have adapted to deal with annual flood cycles by growing and maturing during the wet period and surviving the dry periods by digging burrows. Burrows consist of a single vertical (unbranched) tunnel about 1 to 4 feet deep with several inches of wet slush at the bottom to humidify the burrow. The majority of burrows are built at night, usually by a single individual, and take several days to complete. The diameter of the tunnel will be slightly larger than the individual crawfish that dug the burrow and extends down to a slightly larger chamber. The entrance of a burrow is eventually closed with a mud plug (Fig. 2.8).

Burrows are often clustered around standing vegetation along the levees of commercial ponds or built into the pond bottom. Most burrows contain a single female or sometimes a male and female together. Depending on the producer's flooding schedule, a crawfish can live in its burrow for 2 to 4 months. In addition to serving as a moist environment for crawfish until flooding, burrows provide safety from predators, especially during the vulnerable period of egg development. Burrowing usually occurs in late spring or early summer as the water level drops, and then autumn rains and pond flooding soften the mud plug enough to allow crawfish to emerge.

Figure 2.8. The entrance of a burrow is often closed with a mud plug or cap.
Photo: Nikki Fitzgerald

Survival in the burrow depends on the severity and length of the dry period, the structural characteristics of the burrow, and the health of the animal.

Very rarely, a farmer will have a problem with white river crawfish overpopulating a pond system. While having a few white river crawfish mixed in with a large population of red swamp crawfish is not a marketing problem, research suggests that an overpopulation of white river crawfish may become an issue in ponds that have been in use for a long period of time. Some solutions for keeping the white river population smaller include draining a pond before white river crawfish can mature (March or April) and then restocking the pond with red swamp crawfish or flooding the pond in September to allow red swamp crawfish to emerge from their burrows before white river crawfish can do so. If finances allow, a pond can be taken out of crawfish production, which kills most of the resident white river crawfish and allows the pond to be restocked with red swamp crawfish.

MOLTING

Juveniles exhibit rapid growth, reaching a harvestable size within 3 to 4 months, and have a natural lifespan of no more than 2 or 3 years. Crawfish must shed their exoskeleton (hard external shell) by molting to increase in size, just like other crustaceans. Young crawfish need to molt approximately 11 times to reach maturity. A molt cycle is hormonally controlled and should be understood to be a continuous process, but it is recognized as having five major stages (Table 1). Growth rate is affected by many factors, including water temperature, population density, DO levels, food quality and quantity, and genetic influences; however, environmental factors have the most influence. Crawfish can increase up to 15 percent in length and 40 percent in weight in a single molt if conditions are optimal.

Table 1. Crawfish molting stages	
Molting stages	**Description**
Intermolt	This period is when the exoskeleton is fully formed and hardened. During this phase, crawfish eat and increase tissue and energy reserves.
Pre-molt	Preparation for molting takes place in this stage. A new underlying (soft) exoskeleton forms while minerals from the old shells are reabsorbed.
Late pre-molt	Crawfish stop feeding and seek shelter because they are particularly vulnerable to predation and cannibalism during molting.
Molting “ecdysis”	The actual shedding of the old exoskeleton and takes only minutes to occur. The brittle exoskeleton splits between the head (carapace) and tail (abdomen) on the dorsal or back side, and the crawfish usually withdraws from the old exoskeleton by tail flapping.
Post-molt	Calcification or "hardening" of the exoskeleton takes place during this phase. Calcium stores from within the crawfish are mobilized and transported during hardening to strengthen the new exoskeleton. Calcium is stored in the body in soft tissue, in blood, and, for a short period, in two hard "stones" or gastroliths located in the head on each side of the stomach.

Figure 2.9. Gastroliths, paired bodies formed within the wall of the foregut “stomach” during the pre-molt phase, store minerals from the old exoskeleton during molting.
Photo: LSU AgCenter

Figure 2.10. Soft, freshly molted crawfish (top) and its cast exoskeleton (bottom).
Photo: LSU AgCenter

POPULATION STRUCTURE

Crawfish aquaculture relies on natural recruitment from mature adults to populate a pond. The density of stock is dependent on environmental factors that farmers have no control over. Population density depends largely on broodstock survival, successful reproduction, and survival of offspring. Additionally, improper management after autumn flood-up, abundance of predators, low oxygen levels, and exposure to pesticides can negatively impact crawfish populations and production.

There are usually several sizes of crawfish in a pond. Spawning does not take place at one time, so there are several age classes of crawfish. These various size/age groups are what make up the population structure (Fig. 2.12).

Natural recruitment in crawfish farming has many advantages, but a disadvantage is that crawfish producers have little means of accurately controlling or even determining population density and subsequent yield.

An example of sampling methods (Fig. 2.11) includes using a dip net to sweep various locations in the field after flooding to monitor the young crawfish in the population. "Test" traps are sometimes used. Highly productive ponds may develop as many as five distinct age classes by winter. 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 (Louisiana Crawfish Production Manual, 2007).

DISEASE

Serious disease problems in crawfish aquaculture have been rare in the southern US. Although individuals may be susceptible to various pathogens, epidemic outbreaks have not been encountered, possibly due to the extensive nature of production systems and preventative management strategies such as minimizing food shortages, overcrowding, and low DO levels. Disease is more likely to occur in stressful conditions such as intensive, high-density holding systems or when water temperatures are high and DO is low.

White Spot Syndrome

Originally described in shrimp farms in Thailand in 1992, white spot syndrome virus (WSSV) has been a problem in Louisiana crawfish ponds since it was first confirmed in the state in 2007. Cases have been reported in farmed crawfish in Louisiana, usually in March or early April every year since it has been confirmed. WSSV is a virus that only affects crustaceans and does not infect people or other animals.

Figure 2.12. Different-sized crawfish caught in a population check.
Photo: Nikki Fitzgerald

Figure 2.11. Louisiana and Texas Sea Grant agents checking the population of a crawfish pond.

Recruitment is the term used to refer to the appearance of new hatchlings in a pond. These crawfish usually constitute the bulk of the annual harvest, even when significant numbers of holdover crawfish are present after flooding. Pond crawfish populations usually include (Louisiana Crawfish Production Manual, 2007):

1. holdover adults from the preceding production season or stocking;
2. holdover juveniles from the proceeding season; and
3. the current young-of-the-year (YOY) recruits.

If crawfish have grown in the same pond location for consecutive seasons, then usually the population densities are higher, and the population structures are more complex. This can affect the pond yields and size of crawfish at harvest. In new ponds and ponds held out of production for a year or longer, crawfish density is lower, and the number of age classes is fewer. In these situations, crawfish are often larger and more uniform in size; however, yields may be lower (Louisiana Crawfish Production Manual, 2007).

Signs

Typical signs of the WSSV outbreak are a drastic drop in catch over a few days, a large number of deaths of mostly medium to large crawfish with smaller crawfish acting normal, and a cluster of dead crawfish seen floating throughout the pond or windblown along the levees (Fig. 2.13). Large crawfish that are not dead are usually slow moving and uncoordinated.

When a pond has an outbreak of WSSV, the producer faces severe economic loss. The Louisiana State University (LSU) AgCenter and the School of Veterinary Medicine are working together to determine several factors that influence crawfish susceptibility to the virus.

Researchers suspect that the consumption of infected tissue is typically how WSSV spreads. Results of the research support the theory that when a crawfish dies from the virus, large crawfish eat it and become infected, while small crawfish avoid interacting with larger ones and, therefore, remain uninfected. Further research suggests that resistance to the virus is not transmitted from survivor to its offspring, which helps producers make decisions to manage surviving populations and crop rotations in impacted ponds. Populations of crawfish with WSSV tend to die more quickly at intermediate pond temperatures—around 80°F—which explains why WSSV outbreaks are usually observed in March and April.

Figure 2.13. Crawfish infected with WSSV windblown on the side of a levee.
Photo: Nikki Fitzgerald

How can WSSV spread to different ponds or rice fields?

- Feeding infected shrimp or using them as bait in crawfish traps
- Introducing infected crawfish as stock into the pond
- Shorebirds carrying infected crawfish from one place to the other
- Infected crawfish migrating from one pond to another
- Moving contaminated equipment like traps or boats from an infected location to a clean pond
- People carrying the virus from one place to another on their boots or equipment
- This disease cannot be spread by bird feces. No viable WSSV has been found through the gut of either sea gulls or chickens.

OTHER DISEASES AND PROBLEMS IN CRAWFISH

North American crawfish are carriers of the plague fungus of the genera *Aphanomyces*, which has devastated native populations of European crawfish, but appear to be resistant to diseases that are caused by the fungus. An uncommon disease, Porcelain Disease, is caused by a microscopic protozoan that may infest the abdominal muscles, giving them a milky-white appearance. Additionally, various ectocommensal organisms attached to the exoskeleton may hinder marketability but do not cause serious health problems. The water boatmen insect has been known to lay eggs on crawfish, giving them an odd, fuzzy appearance. This does not harm the crawfish itself.

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. These predators can consume large quantities of crawfish, but crawfish reproduction and growth rates are usually sufficient to prevent major losses (Louisiana Crawfish Production Manual, 2007). These predators can be controlled by proper trapping methods. If not controlled, predatory fish can be the most significant predator encountered in crawfish ponds.

Fish are controlled by thoroughly drying pond bottoms during the interval between seasons and following up by proper screen covering of incoming water. Avian predators, especially carnivorous wading birds, are perceived by many producers to cause the most harm. Avian predators are not as easy to control as fish (Louisiana Crawfish Production Manual, 2007).

Apple Snails

The apple snail, *Pomacea maculata*, is a global invasive rice pest and has established itself in the southwestern region of Louisiana (Fig. 2.14). The adult snails have large brown-green or gold shells and lay large pink egg masses. They have fast reproductive rates and a large appetite which allows them to reach high population densities in natural bodies of water as well as in rice and crawfish ponds. The snails are very disruptive to crawfish trapping, and evidence shows water-seeded rice can be devastated if high snail populations are present at planting. Severe weather events, such as floods and hurricanes, can create opportunities for the snails to expand into new areas. Farmers should be mindful of purchasing stock crawfish from areas that may be heavily infested. Toxicity assays investigating potential chemical controls are being conducted on the LSU campus as well as at the crawfish laboratory at the Rice Research Station in Crowley, Louisiana. Copper sulfate has been identified as a potential solution. The use of copper sulfate demonstrated a high snail mortality without impacting crawfish. Slowing the spread of these snails and snail eggs before moving it between locations is the primary way to combat apple snails. Farmers and boaters are encouraged to check equipment, boats, and stock crawfish before entering a new location. It is important to contact local AgriLife Extension agents or the Texas Parks and Wildlife when new appearances of apple snails are discovered.

Figure 2.14. A large apple snail at the entrance of a crawfish trap.
Photo: Mark Shirley

CHAPTER 3: CRAWFISH PRODUCTION SYSTEMS

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. Crawfish are cultured in areas where the soil has sufficient clay to hold water and accommodate burrow construction. Water requirements for crawfish production are similar to other freshwater aquaculture ventures, with the possible exception of water quantity. Ponds are flooded in the fall and drained in the late spring, and because of the oxygen of the decaying vegetation, additional water exchanges are sometimes necessary. Equipment requirements for culturing crawfish include irrigation systems, harvesting equipment, and agriculture implements to establish the forage crops and maintain levees. Access to labor and alternative marketing outlets are essential for successful commercial operations (Louisiana Crawfish Production Manual, 2007).

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 Table 2 on the next page). One strategy is monocropping, or monoculture, where crawfish are the sole crop harvested and production typically occurs in the same physical location for several production cycles or even longer (Louisiana Crawfish Production Manual, 2007).

A second strategy is the crop rotational system in which rice and sometimes soybeans or other crops are raised in rotation with the crawfish (Fig. 3.1). In these systems, crawfish are either rotated with rice in the same physical locations year after year or crawfish are cultured in different locations each year to conform to normal field rotations of the other crops (Louisiana Crawfish Production Manual, 2007).

Despite many similarities between these two production strategies, the producer's production goals will normally dictate the management concerns, which may vary among the two production strategies.

Figure 3.1. Newly planted rice field being flushed for its initial rice growth. There is no standard size, shape, or design for crawfish ponds across the industry. However, crawfish ponds must be built on flat land that will hold water and support a forage crop for the crawfish to be successful.
Photo: Nikki Fitzgerald

Table 2. Summary of major crawfish production strategies with common practices (Louisiana Crawfish Production Manual, 2007)			
Months	Crawfish monoculture	Crop rotational systems	
		Rice-crawfish-rice	Rice-crawfish-soybean/fallow
Jul–Aug	Planted forage crop 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	Pond flooded and water quality monitored, stock crawfish (50 to 60 pounds per acre)	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 to 4 days per week according to catch and markets	Crawfish harvested 2 to 4 days per week according to catch and markets	Crawfish harvested 2 to 4 days per week according to catch and markets
Mar–April	Crawfish harvested 3 to 5 days per week according to catch and markets	Crawfish harvested 3 to 5 days per week until late April, pond is then drained and ready for replant	Crawfish harvested 3 to 5 days per week according to catch and markets
May–Jun	Crawfish harvested until catch is no longer justified, 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 is 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

MONOCROPPING SYSTEMS

Most crawfish ponds in Louisiana are permanent ponds, producing crawfish in the same location and utilizing the same management scheme every year. These production systems allow the producer to maximize crawfish yield and harvest the crawfish for a longer period than in rotational ponds. As a result of not needing to consider planting date requirements, draining times, and pesticide use for agricultural crops, these ponds commonly have the highest crawfish yields.

Crawfish monoculture or "single-crop" systems are 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 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 (Louisiana Crawfish Production Manual, 2007).

Crawfish yields in monocropping systems typically range from less than 200 pounds per acre in large, low-input ponds to more than 1,200 pounds per acre with intensive management. In many "permanent" crawfish ponds, yields tend to increase annually up to 3 or 4 years of consecutive production. Smaller ponds usually have higher yields than larger ponds. 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 (Louisiana Crawfish Production Manual, 2007).

Figure 3.2. Despite the presence of adequate or even abundant forage and good water quality, crawfish growth rates will slow if densities become too high.
Photo: LSU AgCenter

Cultivated Forage Ponds

A cultivated forage crop must be annually established in such permanent ponds and planted and managed for rice or other agronomic crops. Rice is the most common cultivated forage in crawfish production. The variety of rice chosen should produce high vegetative biomass, be resistant to disease and lodging, senesce slowly, and persist throughout the production season.

Forage rice should be planted early enough to produce adequate vegetative biomass without reaching full maturity, thus reducing decomposing organic matter by the time of fall flooding. Rice that has not reached full maturity has a higher resistance to flooding and will be more likely to produce additional growth in the spring. Rice may require some irrigation during dry periods, but standing water on the seed or seedling may negatively influence growth if temperatures are too high. A soil test may be needed for soil fertility to determine if fertilizer will be needed to encourage rice production.

After planting, rice fields are gradually flooded to a depth of 0.3 to 0.7 meters. When flooding occurs, crawfish emerge from their burrows and can be trapped for harvest. A farmer can choose to harvest rice and crawfish or just crawfish.

After a rice harvest, the ratoon crop, or regrowth, occurs. When temperatures reach freezing, the ratoon crop begins to decompose, and bacteria and other organisms feed upon it, in turn becoming food for crawfish.

Crawfish are generally caught in traps and harvested from January through May but can be harvested as early as November in warmer temperatures. This applies to all types of crawfish pond systems.

Alternative crops include sorghum-sudangrass, which grows rapidly, produces larger quantities of vegetative matter than rice, is drought resistant, and is more reliable than rice for late-summer stand establishment.

Only use sorghum-sudangrass in ponds where forage is planted in the late summer months due to its propensity to mature before flood-ups (this can be detrimental to water quality). Sorghum-sudangrass can be drilled or broadcasted onto moist soil, with drilling being the preferred method due to lack of risk. Seeding rates should be 20 to 25 pounds per acre for drilling and 25 to 30 pounds per acre when broadcasting. The optimum germination temperature is 70 to 85°F. Producers may add fertilizers to increase growth and vegetative biomass. Producers may also decide to mow trapping lanes in the fall before flooding, when tall plants may obstruct vision during an early season harvest. Cultivated forage ponds are intensively managed and customarily designed with baffle levees and recirculation systems to promote better water quality and production. Cultivated forage ponds generally have the highest yields in pounds of crawfish per acre. Forage provides an array of benefits to crawfish production, such as supporting natural food production for crawfish. Forage also provides refuge for crawfish to escape predators and minimizes cannibalism. Larger standing plants allow crawfish to escape to the bottom and reach the surface during periods of low DO and provide the perfect substrate for epiphytic organisms and invertebrates, which are a large part of a crawfish's diet.

Naturally Vegetated Ponds

Usually located in wetland areas, these ponds tend to be marsh impoundments or agricultural lands unsuitable for growing grain crops, so naturally occurring vegetation growth is encouraged. They are characterized by high amounts of organic matter in the soil. This often lowers water quality, decreasing crawfish production. Although these ponds may be managed exclusively for crawfish, production is often sporadic, and marsh ponds usually have the lowest yields of all permanent ponds.

Wooded Ponds

Built-in forested areas with heavy clay soils in close proximity to drainage canals, wooded ponds are another type of permanent crawfish pond. Trees can hinder water movement, and the rapid deterioration of leaf litter can limit crawfish production by depleting oxygen and decreasing water quality. Access by boats during harvesting may be obstructed by trees in the water. Leaf litter provides most of the available forage, and the shading causes lower water temperatures. Though wooded ponds produce fewer pounds of crawfish per acre, larger crawfish can be profitably produced. After several years of intensive production, these ponds may lose a lot of hardwood trees that are replaced by terrestrial grasses and aquatic plants more typical of naturally vegetated ponds, which may improve habitat for crawfish.

ROTATIONAL PONDS

Rotational ponds are production systems that either rotate the annual sequence of crops grown or rotate the physical location of the field in which crawfish are grown. Rotational ponds efficiently utilize available resources, diversify production, and can serve as an added source of income for farmers. Such systems are profitable because multiple products may be harvested throughout the year, but compromises must be made in culturing each type of crop so that both can reach full harvest potential.

Rice-Crawfish-Rice Ponds

Rice fields offer the most readily adaptable area for cultivating crawfish because producers can use the same land, equipment, pumps, and farm labor already in place and more flexibility exists in management operations. Such ponds are double-cropped, meaning both rice and crawfish are harvested annually. After harvesting the grain, the field is fertilized and flooded, and the regrown ratoon (regrowth) crop provides the forage for crawfish. Crawfish are typically only stocked initially, usually after 3 to 8 weeks post-rice planting. In this system, rice cultivation typically takes precedence over crawfish production, and management schemes are designed towards optimal rice yield. For example, draining the field early to replant rice, which shortens crawfish harvest season.

As mentioned previously, the major disadvantage with this system is that neither crop, rice nor crawfish, can be maximized for maximum yield. Draining a crawfish pond prematurely decreases total crawfish harvest, and rice is usually maximized when planted in early spring. It is important to take care with pesticide and fertilizer application, as this can have a detrimental effect on crawfish production if not monitored closely. It is important to understand the primary goals of a pond—if maximum crawfish production is the goal, then rice harvest will suffer, and vice versa.

Rice-Crawfish-Fallow or Soybean Ponds

In these systems, three crops are produced in 2 years' time. Such ponds have the advantage of better weed and disease control and a longer crawfish harvesting season than in rice-crawfish-rice systems. However, pesticide use may limit maximum crawfish production and is an important management consideration.

Following the rice-crawfish-rice rotational strategy, crawfish culture follows rice cultivation, and crawfish production does not occur in the same physical location from one year to the next. This adds economic cost in stocking and water quality monitoring.

Disadvantages of monocropping compared to rotational

- The need to construct dedicated ponds, whereas with rice-crawfish rotational cropping, the established rice fields serve the purpose
- Land, overhead, and operating costs must be amortized over one crop only
- Crawfish overcrowding frequently occurs after several annual cycles, especially in smaller ponds, and yields become composed of smaller-sized, lower-priced crawfish that are harder to market

Disadvantages of rotational strategy compared to permanent ponds

- The need to restock more frequently
- Routine low population densities
- A late-season harvest when prices are in decline and marketing is more difficult because of abundant supplies

This method also requires sufficient land resources and management input to grow and maximize crops that will be grown at staggered intervals. It does, however, allow for better management of specific crops. For example, instead of having to drain ponds early to utilize and maximize rice yield, crawfish can be harvested for a much longer period of time. 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 (Louisiana Crawfish Production Manual, 2007).

After fields are drained and crawfish harvest has reached maximum yield or until demand for the crop falters, the field is then planted with a third crop. Some farmers may choose to utilize different crops, such as hay, pasture, or grain sorghum, but many choose to seed the field with soybeans, which provide additional enrichment to the ponds.

In rice-crawfish-fallow systems, the land is left fallow for a certain period of time to control weeds and crop diseases and prevent the overpopulation of crawfish. Rice and crawfish are both optimally produced, but the fallow period reduces potential income, and the system requires more land. There are several disadvantages to this system, such as the need to restock every year, lower population densities, and a later seasonable harvest when prices for crawfish are low.

Field Rotation

When ponds become overpopulated and produce stunted crawfish, some farmers overcome this issue by rotating the physical location where the crawfish are grown. Mature crawfish from the overpopulated pond are used to stock a new pond that will then be used in a crawfish-agronomic rotation. The original pond is left dry during the part of the year when crawfish would normally be harvested to reduce the density of viable crawfish, decrease overpopulation, and ultimately produce fewer crawfish with stunted growth. This management approach allows for a healthy crop of crawfish to be harvested and a variety of ponds to be utilized.

Figure 3.3. Picture of rice stubble with crawfish traps.
Photo: Nikki Fitzgerald

STATE AND FEDERAL PERMITTING REQUIREMENTS AND REGULATIONS

Permitting requirements from both the state and federal governments have a definite effect on development costs. Many areas that may be considered for crawfish production are classified as wetlands and may not be altered without permits. Many states have requirements limiting the amount and quality of water that may be used and discarded for aquaculture systems. It is imperative to check and abide by all state and federal regulations before investing in property and business.

In Texas, check with the Texas Department of Agriculture (TDA), the Texas Parks and Wildlife Department (TPWD), and the Texas Commission on Environmental Quality (TCEQ) for updated requirements on the licensing of aquaculture facilities and vehicles transporting cultured species.

CHAPTER 4: STOCKING

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. Crawfish have a life cycle that is suited to fluctuating periods of flooding and dewatering. Temporary dewatering, in both natural habitats and crawfish ponds, promotes aeration of bottom sediments, reduces the abundance of aquatic predators, and allows for the establishment of vegetation that serves as cover for crawfish and the source of important food resources when water returns (Louisiana Crawfish Production Manual, 2007). During dry intervals, crawfish dig burrows to retreat to avoid predators, acquire moisture for survival, and reproduce in safety.

Farming practices are based on annual water cycles and conditions that crawfish have naturally adapted to over millions of years. Producing crawfish has several benefits over wild-caught crawfish. While wild crawfish are only available during certain times of the year, farmed crawfish can be harvested for a longer duration. Crawfish are usually produced in four categories: brood crawfish used to stock ponds, recreational crawfish used for bait, soft-shell food crawfish, and hard-shell food crawfish.

General production schedules start in the spring with the selection of crawfish for a pond. In late summer, the water is drained to encourage burrowing. If crawfish are being raised along with crops, they are planted when the field is drained. In October, reflooding causes the crawfish to emerge from their burrows and vegetation. They grow larger until it is time for harvest in November. Harvest continues until the following spring, and the cycle starts again.

Crawfish aquaculture relies on natural reproduction as well as the naturally available food web for nourishment. Supplemental feeding is not a common practice and has not been shown to predictably increase yields or size of crawfish.

Crawfish ponds are shallow earthen ponds 8 to 24 inches deep. The fields or ponds are relatively flat, easily drained, and contain suitable levees for production, harvest, and management of vegetation (Louisiana Crawfish Production Manual, 2007). The ponds contain a clay-like soil that is sufficient enough to hold water and allow burrow construction. Equipment requirements (Fig. 4.1) for culturing crawfish include irrigation systems, harvesting equipment (boats, traps, sacking tables, etc.), and agricultural implements to establish the forage crops and maintain levees (Louisiana Crawfish Production Manual, 2007).

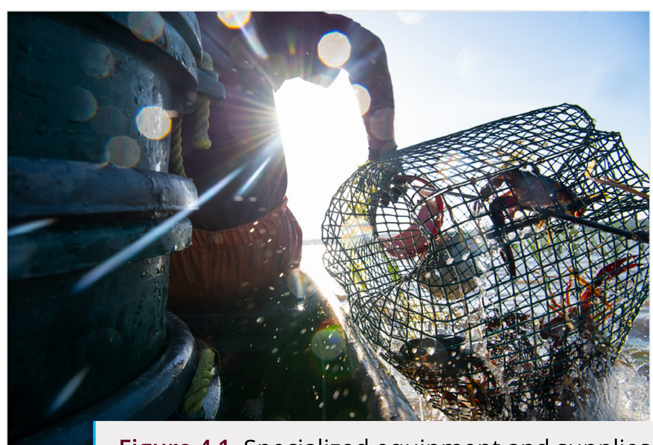

Figure 4.1. Specialized equipment and supplies are essential for commercial success.
Photo: Alan Gaulding

There are generally two types of systems used, with many different variations in each system that will be discussed in the following sections. These two systems include permanent ponds, or monocropping, and crop rotational ponds.

Monocropping is where the sole crop is crawfish, and crop rotational systems are where rice or soybeans are harvested along with the crawfish.

SELECTION OF BROODSTOCK

Crawfish are stocked during the peak of the harvest season, usually March to June. At this time, the sex ratio is equal, whereas when stocking after the peak of harvest, females may be burrowed underground, resulting in a greater number of males harvested.

Broodstock should have more females than males of adult sexually mature size. When stocking in the summer months, a portion of females should show ovarian development. These signs of egg development point toward a healthy buildup of natural energy reserves for crawfish to bring reproduction upon introduction to the new pond.

Yields of harvestable animals within the harvest depend on broodstock survival for successful reproduction. Since crawfish aquaculture relies heavily on natural production within the system, stocking ponds is commonly only necessary at the beginning of a culture set up or with idle ponds and ponds that have been affected by large-scale events, such as levee reconstruction, natural disasters, and disease. After levee reconstruction, stocking becomes necessary because most mature, harvestable adults have burrowed into levees, and alteration of their burrows prevents emergence after reflooding events. Severe drought conditions can cause high mortality rates, just as heavy rainfall events may flood ponds beyond levees and disperse stock. Rotational ponds are often stocked annually because ponds are often out of production for an extended period (Fig. 4.2). It is important to make sure the crawfish selected for broodstock will acclimate easily to new conditions; therefore, selecting crawfish from the same environment or region is preferable. Producers in Texas may choose to stock only red swamp crawfish due to their resiliency in all climate and flood stages. The sizing of mature broodstock is of little importance when stocking a pond because, with careful and controlled farming practices, the farmer should ensure maturation to harvestable size.

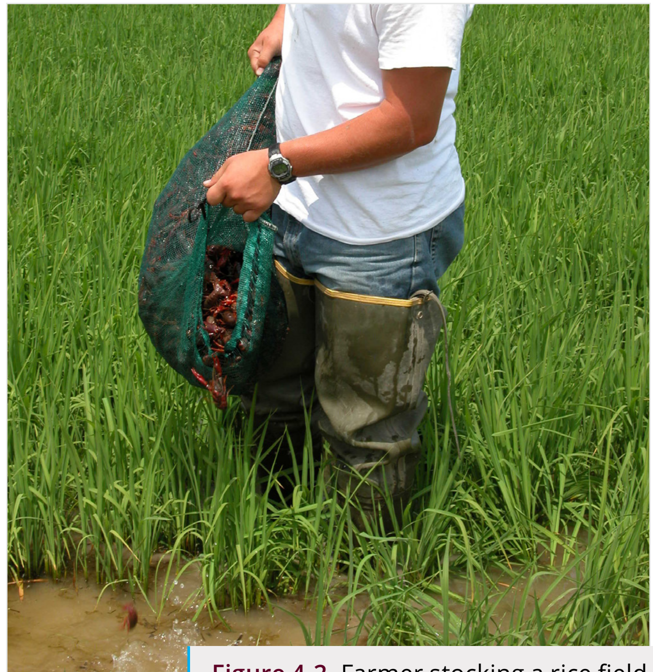

Figure 4.2. Farmer stocking a rice field.
Photo: LSU AgCenter

Some evidence exists that small, mature broodstock may be more economical due to a lower price per pound and the ease at which smaller animals adapt to their environments. The cost of broodstock is an important factor when initial stocking occurs, and prices are usually lower at the end of a harvest season. Broodstock can be obtained from a variety of sources and from a wide array of environmental conditions. Science has not shown a direct link between the habitat where a broodstock was collected and its survival rates. However, it is important to remember that crawfish are sensitive to environmental conditions, such as water temperature, water quality, crowding, and nutrition sources, and all these factors play a part in reproductive success.

Proper care and handling are critical for high survival rates of transported broodstock. Limiting the amount of time and the number of stressors on animals during and after transportation will aid in high success rates. Crawfish should be kept moist at temperatures between 60°F and 80°F. Exposure to high temperatures, direct sunlight, and wind may cause mortality rates to increase during transport. For a more successful transport, keep stock in bags with limited ice as temperature control, transport the stock during dawn and dusk for cooler temperatures and less sun contact, and lay moist burlap across the top of the bags when transporting.

STOCKING

Initial stocking begins with the broodstock generally obtained from a commercial source with an even male-to-female sex ratio. The stock should have been harvested less than 24 hours before stocking in a new pond. When stocking ponds, an appropriate ratio of stock per surface area of water is 40 to 60 pounds of crawfish. Many producers elect to stock up to 80 pounds per acre or more when post-stocking survival is unpredictable (Louisiana Crawfish Production Manual, 2007). The preferred stocking time is in the May timeframe, when broodstock sources contain a higher percentage of sexually mature animals. Restocking ponds is not generally needed but is considered if a pond has a low growth rate directly trending toward mortality. Crop rotational systems may need to be restocked in the early summer months or past planting when crops are large enough to sustain damage from crawfish and when pesticides are low.

Crawfish should be introduced directly into the water. Because of their high mobility, stocking in only one spot will be adequate to ensure dispersal throughout a small pond. If the pond is segmented, crawfish should be stocked in each section. In larger ponds, dispersal may be conducted by hand or boat to ensure equal habitat availability. There is some evidence that reports supplemental feeding of ponds prior to broodstock introduction may be beneficial to reproductive function. However, if given time to acclimate to a new pond, crawfish will gain sufficient energy without supplements. 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 (Louisiana Crawfish Production Manual, 2007).

AFTER STOCKING

Proper environmental conditions in the pond should be maintained to ensure the health and reproductive abilities of newly stocked animals. Water temperature and DO levels should be within a normal range and should be monitored closely.

Water levels are of importance after stock introduction. The water should remain in the field after stocking. The water may need to be exchanged, flushed, or partially flushed to help with DO in the pond (Fig. 4.3). It is important to monitor predators, especially fish and birds, as they have a detrimental effect on broodstock success.

Vegetative cover within the pond being stocked plays an important role in broodstock survival. Cover along the water's edge, such as aquatic vegetation, provides protection from predators like wading birds and raccoons.

Figure 4.3. A local farmer monitoring water with levee tarps in a rice field.
Photo: Nikki Fitzgerald

Stocking guidelines
(Louisiana Crawfish Production Manual, 2007)

- New or idle ponds should be stocked at ~50 to 60 pounds of crawfish per acre
- Stock healthy crawfish
- Stock at least 50 percent females
- Be sure at least 50 percent of females are mature
- Do not use crawfish that were stored in a cooler
- May to June is the preferred stocking time
- Move crawfish as fast as possible to the pond; keep them wet and shaded during transport
- 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

FEEDING

A continual supply of vegetative matter for decomposition is necessary throughout the production season to feed the invertebrate population (Louisiana Crawfish Production Manual, 2007; Fig. 4.4). Planted crops in single-crop ponds or rotational ponds create forage food for crawfish. Planted agronomic crops routinely have been the most effective forage resources for crawfish ponds. Naturally occurring aquatic plants such as alligator weed can provide for some crawfish production, but they generally cannot generate the same yields as rice or sorghum. In cases where natural vegetation is not adequate to provide nutrition to crawfish stocks, hay is often added at the beginning or end of a season before a flooding event to supplement crawfish diets. However, there has been no direct correlation between the supplementation of hay and an increase in crawfish size and abundance. Preliminary evidence suggests 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, are hard to obtain (Louisiana Crawfish Production Manual, 2007). Producers may use pelleted catfish feed or manufactured feeds to supplement ponds with low or no natural nutrition.

PROBLEMS AND CONSTRAINTS

There are a few parasites and diseases that affect crawfish. On occasion, eggs may develop fungal infections, and small, leech-like worms may be visible on adult crawfish.

Crawfish regularly have small insect eggs on the head or back of the shell, which are not permanent nor of any concern to the producers. However, in a large, high-density pond, significant disease problems may occur. In Louisiana, a study reported outbreaks of the bacteria *Vibrio*, which is shown to be sometimes fatal if consumed. Disease outbreaks are often exacerbated by high temperatures and oxygen stress.

Predation is the largest environmental problem that producers face. Fish and other aquatic animals will prey upon crawfish as well as birds, raccoons, and other rodents. Since most wading/wetland birds are protected by federal law, nonlethal scare devices such as those that move or make loud noises have proved useful in deterring predation. Other methods such as placing traps and small mesh wire fences around ponds can help. There are specific control recommendations for nuisance predators, and a call to a licensed trapper or pest control agency can remedy the effects of rodents. Further information on control measures is available from the United States Department of Agriculture (USDA) Wildlife Services.

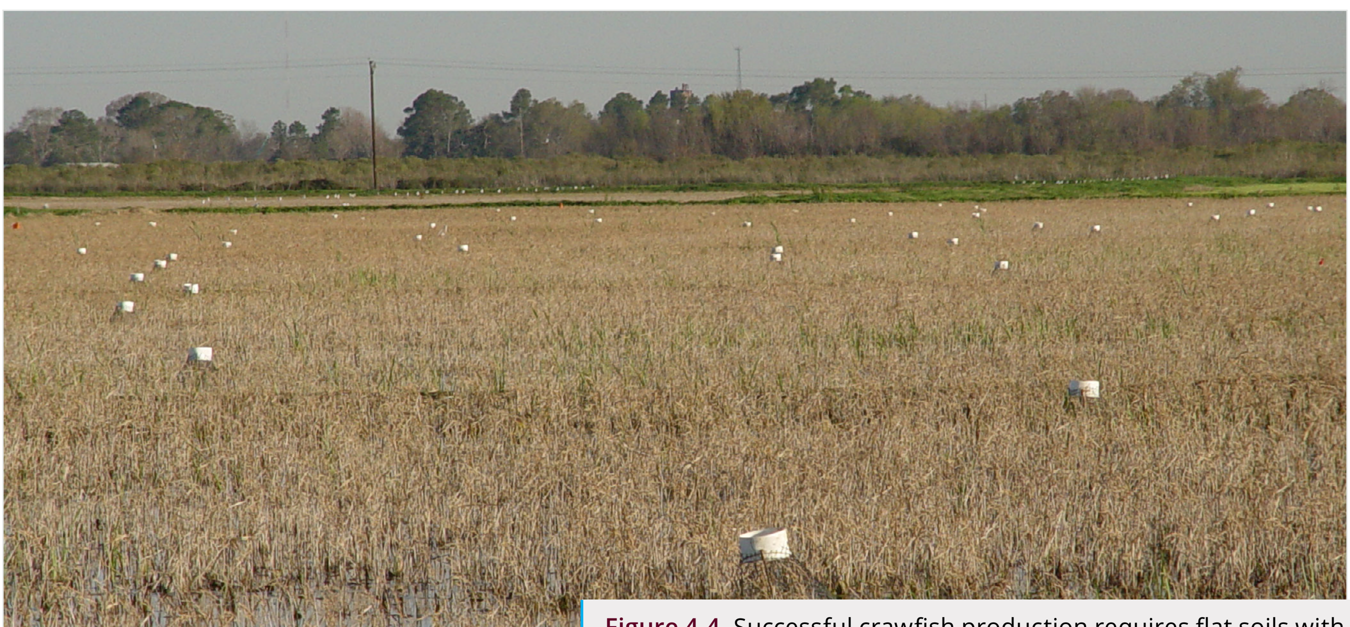

Figure 4.4. Successful crawfish production requires flat soils with sufficient clay—normally land suitable for rice production.

CHAPTER 5: RICE PRODUCTION

Rice (*Oryza sativa*) has become the standard forage crop for the industry. Successful rice production requires timely land preparation. Therefore, fields should be plowed in the summer or early fall. Early land preparation is particularly critical when high-residue crops such as grain sorghum or corn are planted the year before rice. If the land has been out of production and is grown up in weeds and brush, prepare it as early as possible. There are two methods of planting rice: transplanting and direct seeding. Transplanting typically requires enormous amounts of human physical labor or specialized implements used by the rice production industry. For that reason, direct seeding is the most commonly used planting method for crawfish production.

Most varieties mature 105 to 145 days from germination. Rice planting typically begins during the last week of March and continues into early June. Planting after early June will not allow enough growing season for the rice to mature. The typical needs for 1 acre of rice for crawfish production are 100 pounds of rice per acre (or 75 pounds per acre if growing in dry land conditions), 500 pounds of 5-10-10 fertilizer per acre, 200 pounds urea (45-0-0) per acre, and Treflan pre-emergent and 2,4-D post-emergent herbicides.

There are two methods of planting rice: dry planting (Fig. 5.1) and planting on mudflats. When using the dry planting method, start by spreading 500 pounds of 5-10-10 per acre and disk in. To reduce early grass competition, it is a good idea to use a moderate application of Treflan herbicide. Drill the rice at 100 pounds per acre or broadcast 100 pounds per acre and disk in lightly. If planting in dry land conditions, use a seeding rate of 75 pounds per acre rather than 100 pounds. When the rice reaches the fourth leaf stage (about 8 inches), broadcast 200 pounds per acre urea (45-0-0) (Fig. 5.2).

This step is critical to rice production. The rice does best if the field is shallowly flooded or rained on immediately after the application of urea. To ensure this, close water control structures to capture the rain and keep the field wet. However, flooding the field too deep can have adverse effects. The optimal level is 2 inches of water, but since most fields are not perfectly flat, keeping the entire field at one depth may not be possible. Try to avoid flooding any location on the field more than 6 to 12 inches. Rice can still produce well on dry land if there is adequate rainfall but cannot produce in dry or drought conditions. If the rice is threatened by broad-leaf competition, use a spray application of 2,4-D.

Many chemicals applied to rice fields can be harmful to crawfish, so always read labels of pesticides purchased for forage fields before applying.

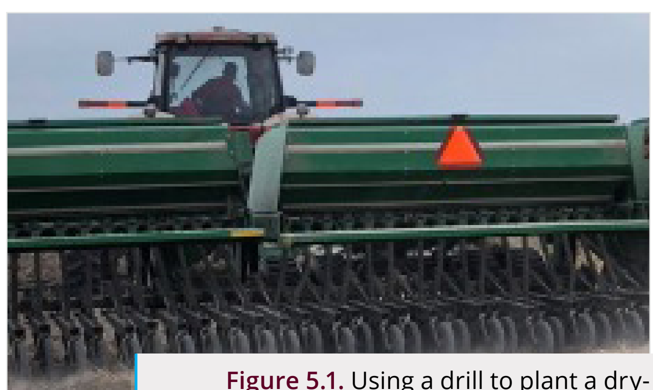

Figure 5.1. Using a drill to plant a dry-seeded rice field in Southeast Texas. The depth of drill-planted seed depends largely on soil type and moisture content.
Photo: Nikki Fitzgerald

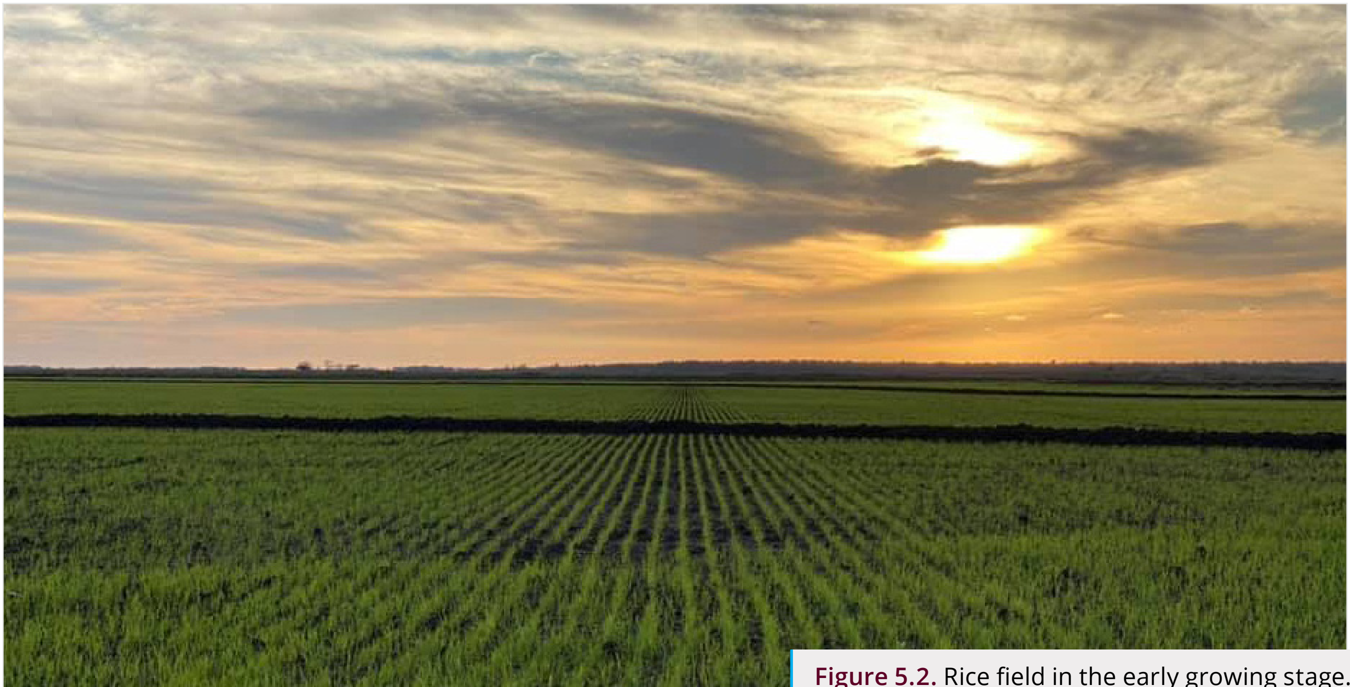

Figure 5.2. Rice field in the early growing stage.
Photo: Nikki Fitzgerald

RICE VARIETIES THAT PAIR WELL WITH CRAWFISH FARMING

Ecrevisse – In 2004, the LSU AgCenter released the first rice culture developed specifically for crawfish monocropping systems. 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.

CL151 – CL151 is a very early maturing semidwarf variety with excellent yield potential and good ratooning ability. It has a strong tolerance to herbicides that are part of the CLEARFIELD production system. It has susceptibility to blast, sheath blight, and straighthead. It is reported to have very good seedling vigor and consistently high head rice yields. It is moderately susceptible to lodging.

Cocodrie – Cocodrie, which was released in 1998, was developed by the LSU AgCenter from a cross of Cypress, L202, and Tebonnet. It is a semidwarf, long-grain variety that matures similar to Presidio. Main crop yields have been excellent, and Cocodrie continues to be a very stable and strong-performing variety, although other varieties may exceed it in ratoon crop yields and milling quality. This variety has improved resistance to blast similar to that of Presidio but is considered moderately susceptible to sheath blight.

Hidalgo – Hidalgo is a long-grain specialty variety that was developed at the Beaumont Center from a cross of Cypress, Pelde, and Jefferson. It is a semidwarf variety similar in height, maturity, and yield potential to Cocodrie. It has a higher milling quality than Cocodrie and cooks soft like Toro. It is like Cypress in susceptibility to blast and is considered moderately resistant to sheath blight.

Neches – Neches is a long-grain, waxy rice developed at the Beaumont Center from a cross of waxy Lebonnet and Bellemont. Neches is very similar to Lemont in height, maturity, and yield. Asian markets want waxy rice as a specialty rice, and it is also used by the ingredients industry as a flour and starch. Its grain is completely opaque, and it is very sticky when cooked because of its waxy (glutinous) properties. It is moderately resistant to blast and very susceptible to sheath blight.

Presidio – Presidio, released in 2005, was developed from a cross of Jefferson, Maybelle, and Rosemont at the Beaumont Center. It is a long-grain variety that is similar in maturity and height to Cocodrie. Its main crop yield is lower than Cocodrie, but its ratoon crop potential averages

35 percent higher than Cocodrie. Presidio has excellent milling quality, similar to or better than Cocodrie. Presidio inherited broad-spectrum blast resistance and moderate susceptibility to sheath blight from Jefferson at a level that is likely to make fungicides unnecessary in most circumstances.

CLEARFIELD XL745 – Released in 2008, this high-yielding, long-grain hybrid is tolerant of herbicides in the CLEARFIELD production system. It is 2 to 3 days earlier than CLEARFIELD XL729 and 1 day later than XL723, with excellent ratoon potential and above-average milling quality. It has improved grain retention characteristics compared to CLEARFIELD XL729 and should be harvested at 18 to 20 percent grain moisture.

Sabine – Sabine was developed at the Beaumont Center from a cross of an experimental line from the LSU AgCenter and Dixiebelle. It has the same superior parboiling and canning quality that is found in Dixiebelle and was developed primarily for these industries. Sabine is about 2 inches taller and has higher yield potential than Dixiebelle. The two are very similar in maturity, milling quality, and susceptibility to blast and sheath blight.

Sierra – Sierra was developed at the Beaumont Center from a cross involving Dellmont, Basmati 370, and Newrex. It is a long-grain rice that possesses the fragrance and cooked kernel elongation characteristics of Basmati-style rice. It has an excellent aroma and cooks dry and flaky. Sierra is very similar to Lemont in height, maturity, yield, disease resistance, and milling quality.

Wells – Wells, which was released in 1999, is a long-grain variety developed by the University of Arkansas from a cross of Newbonnet, Lebonnet, CI9902, and Labelle. Compared to Cocodrie, it matures slightly later and is about 3 inches taller. Wells has a high main crop yield similar to or better than Cocodrie but has a lower ratoon crop yield and milling quality. The blast resistance of Wells is similar to Cypress, which is less than Cocodrie. However, its sheath blight resistance is better than that of Cocodrie.

When planting on mudflats, the first step is to drain the water just prior to planting to expose them. Soak the rice seed in the bag for 8 hours, and then allow them to drain for 4 hours. Once drained, broadcast the rice on mudflats at 100 pounds per acre, and then immediately apply 5-10-10 fertilizer at 250 pounds per acre. After the rice has sprouted about 2 inches, spread 5-10-10 fertilize again at 250 pounds per acre (Fig. 5.3). When rice reaches the fourth leaf stage (about 8 inches), broadcast urea (45-0-0) at 200 pounds per acre (Fig. 5.4). Rice does best if it is flooded shallow or rained on immediately after the urea application, but it will still produce well on dry land if there is adequate rainfall. As with dry planting, broad-leaf competition can be decreased by using a spray application of 2,4-D and grass competition with Stamm. Rice harvest normally starts at the beginning of August and concludes toward the end of October or early November, with crawfish season typically starting in November.

Figure 5.3. Most varieties mature 105 to 145 days from germination.
Photo: Nikki Fitzgerald

Figure 5.4. Flooded rice field in Southeast Texas.
Photo: Nikki Fitzgerald

RICE AND BLACKBIRDS

Blackbirds, primarily red-winged blackbirds, are pests of rice during the planting season, the seedling stage, and the ripening period. The birds consume the seed and seedlings on and under the soil, which can result in inadequate plant stands. In some cases, the fields must be replanted. Reseeding is expensive and delays planting, which may reduce yields and quality and hinder harvesting operations. Also, harvesting the main crop late can make ratoon cropping impractical and increase the chances of blackbird damage on the ripening main and ratoon crops.

Blackbirds also damage the ripening crop by "pinching" grains (squeezing a grain with the beak to force the milky contents into the mouth) in the milk stage, hulling grains in the dough stage and consuming the contents, and breaking panicles by perching and feeding. This type of damage is insignificant in the ripening main crop, according to results of a study in Matagorda County by Texas A&M AgriLife Research and Texas A&M AgriLife Extension Service. However, damage to the ripening ratoon crop was found to be severe, particularly along field margins. Yield losses ranged from about 4 to 15 percent, even in fields that were patrolled using firearms. The cost of control was as high as $46 per acre.

CHAPTER 6:

SITE LOCATION AND POND CONSTRUCTION

Location and design are the most significant physical factors affecting crawfish production. They should be carefully considered to provide the best control over flooding and drainage operations, forage management, water circulation, and harvesting. An Extension agent can offer advice on site location, design, and construction of crawfish operations.

LOCATION

When selecting a site for a crawfish production pond, it is advisable to choose a piece of land with little slope because it is easier to establish forage crops and harvest the crawfish. Though heavy equipment exists to move lots of soil, it is preferable to perform minimal leveling to avoid heavy costs and bad water quality. Most crawfish ponds are about 10 to 20 acres and located near a sufficient water supply, power source, and good road network system to facilitate marketing, distribution, and management of operations. Ideally, the area should have heavy black clay soil with a calcium concentration of more than 500 parts per million (ppm) so that water does not leach out of the pond. Heavy clay soil is also essential to supporting the structure of the burrows, which may collapse in soils with less clay. Clay loams, sandy clay loams, and silty clay loams all have a satisfactory amount of clay. A general rule of thumb is if the soil can be rolled into a ball, it should have enough clay. The price of land varies considerably depending on location and features of the property.

For rice-field ponds, sites are usually existing rice ponds. When selecting which ponds to establish crawfish culture in, it is important to have all-weather access, an accessible water supply, and adequate trapping lanes. Some modifications to existing ponds may be necessary, including the deepening of existing levees and the widening of existing parameter levees. Rice production only requires a holding period of 7 to 9 weeks, whereas crawfish ponds need to be flooded for 6 to 9 months. It is important to note that rice field irrigation is designed to achieve maximum water output and rarely takes into account the oxygenation of the water that enters the pond. High levels of oxygen are of paramount concern in crawfish culture ponds, and existing water input systems should be modified to include aeration screens to improve water quality in crawfish-rice ponds (Fig. 6.1).

Crawfish are often a secondary crop to rice, and for that reason, the best-yielding production rice ponds may be kept solely for rice production, with lower-yield ponds integrating crawfish culture. However, it is important to not place crawfish ponds directly between rice fields that will have pesticide applied because chemicals will hinder the success of a crawfish crop.

Figure 6.1. Aeration screens provide extra oxygen and reduce wild fish into the pond.
Photo: LSU AgCenter

There are several crucial aspects to consider when choosing a site for a crawfish pond. The probability of the area flooding is vital because frequent or heavy floods can bring in predatory fish, allow crawfish to escape, and possibly impede harvesting.

Contamination probability is crucial since crawfish are extremely susceptible to inorganic chemicals and pollutants. Avoid placing a pond too close to predatory bird territories to protect the crawfish from predation. In addition, all-weather access is critical to manage the pond effectively. To avoid theft, the pond should not be easily accessible to the public.

DESIGN AND CONSTRUCTION

When designing the crawfish pond, consider the size, shape, topography, and location of water sources and drainage structures, as well as access points, roads, tree lines, prevailing wind directions, and the natural slope of the land. Pond size needs to be compatible with water availability, which should be sufficient enough to provide a 6-inch flood depth across the entire pond area in a week or less in normal weather conditions. The most efficient and common pond size is about 10 to 20 acres. As previously stated, the pond should be built on a relatively flat area; the maximum slope should be 6 inches or less between levees. Reforming the land may be necessary if the land is not level. A good ratio for the slope of the levees is 3:1 (3 feet of distance for every 1 foot of rise) from the top of the levee to the pond bottom.

Proper construction of both perimeter and baffle levees is critical. Levees serve to keep flood waters from ponds at times when flooding would be detrimental to the crawfish crop. Levees also keep crawfish in the ponds and prevent predators and crawfish burrows from eroding existing levees. Pond levees need to be sound enough to allow for vehicular access to the pond in all weather conditions and for the efficient use of harvesting equipment. Perimeter levees maintain the integrity of the pond's structure and are built with a core of clay to prevent water seepage from the pond. As such, they should be built with a core trench cleared of debris. The base of the perimeter levee should be at least 9 feet wide to allow adequate space for burrowing and 3 feet high to contain the 12- to 18-inch water depth maintained in the pond for production. This leaves a distance of 14 to 18 inches between the level of water and the top of the levee. Interior or baffle levees are constructed to circulate aerated water through the pond to maintain good water quality throughout and prevent stagnant areas (Fig. 6.2).

Figure 6.2. Interior levee being constructed for rice and crawfish farming.
Photo: Nikki Fitzgerald

These levees should be positioned lengthwise to ease harvesting, should be about 6 feet wide at the base, do not need to contain a core trench, and should be high enough to be about 6 inches above the expected water level. For the best water circulation, interior levees should be spaced about 150 to 300 feet apart. Levees should be planted with grass or other vegetation to prevent erosion. It is important to avoid creating wide and deep interior levees, as wide and deep interior levees hinder water circulation and can lead to poor water quality conditions. The size and placement of drains are crucial; drains need to be appropriate for the pond size, pumping capacity, and expected rainfall in the area.

Inadequate drainage systems cause problems because standing water hinders tillage operations, forage establishment, water quality, and harvesting. Drainage ditches should be placed outside the perimeter levees because when on the interior of the pond, they can reduce circulation and water quality and may offer a refuge for predaceous fish. The drains should be able to empty the overflow from heavy rains and allow for complete and rapid drainage without water topping the levees. At the least, two 10-inch drains should be sufficient for a 20-acre pond.

Provisions for recirculation should be made in areas where water quantity or quality is not consistent or where well water is pumped from great depths. A return canal should be constructed outside of the perimeter levee, and a relift pump or paddlewheel aerator will recirculate the water, minimizing effluent and ensuring a more stable water supply and quality.

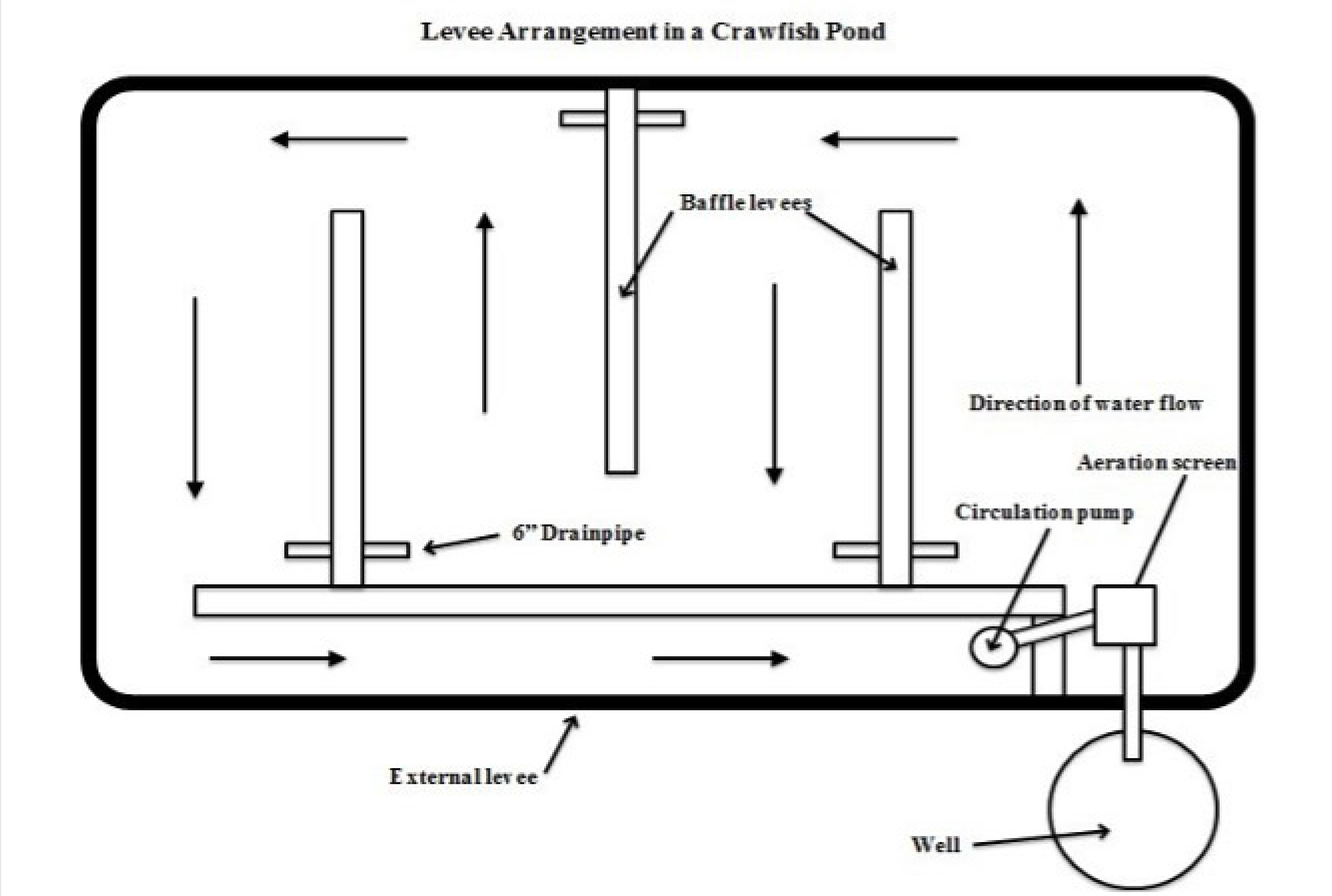

Figure 6.3. Arrangement of baffle levees to allow proper water circulation within the crawfish pond. Baffle levees are often comparable to typical rice field contour levees. The key is to direct the flow of water through the pond to avoid "dead" areas with little or no oxygen (Louisiana Crawfish Production Manual, 2007).

USDA Natural Resources Conservation Service (NRCS) crawfish pond construction suggestions:

USDA Natural Resources Conservation Service (NRCS) has suggestions for crawfish pond construction. These suggestions minimize erosion, reduce the amount of pollution from discharges, and maximize benefits for all wildlife.

Fish pond management: This allows the pond to be utilized not only for crawfish production but to provide a habitat for many forms of wildlife.

Access road: An access road is necessary for transport to and from crawfish ponds and to transport animals for stocking, take vital water quality measurements, harvest, and can aid in siltation control when properly vegetated.

Wells: Well water is recommended over the use of surface water to flood ponds and control water quality.

Wildlife wetland: Crawfish ponds provide manmade wetland habitat to many species of waterfowl, reptiles, and amphibians, and they must be managed as such.

Irrigation water management: Irrigation, flooding, and draining must be planned to manage forage and successful crawfish production.

Wetland development: In most cases, flooded crawfish ponds improve water quality from both input and output events.

Filter strips: Filtration devices reduce contamination and sediment inflow as well as aid in deterring erosion.

Brush management: This may be required in some site locations and can have temporary effects on water turbidity. The use of herbicides is not encouraged unless the specific herbicide is appropriate for wetland use.

Crop residue use: This cover provides habitat and nutrition for crawfish as well as reduces erosion and improves soil moisture.

Channel vegetation: Without vegetation located in interior channels throughout the pond, turbidity may increase and contribute to sedimentation issues.

CHAPTER 7:
WATER MANAGEMENT

WATER MANAGEMENT

Persistent poor water quality is detrimental to crawfish production. The annual hydrological cycles used in crawfish production reflect the environmental conditions in which crawfish evolved. In many systems, the pond is drained and kept dry during the summer; the fall flood coincides with the completion of the reproductive cycle and the emergence of a new generation of crawfish. Temporary dry conditions in the pond allow for aeration of the bottom sediments of the pond, reduce aquatic predators, and support the growth of vegetation that provides food and shelter for crawfish when the pond is reflooded. 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 (Louisiana Crawfish Production Manual, 2007).

WATER SUPPLY

Either surface water or well water can be used in crawfish production. Surface water is cheaper to pump and may be more desirable if it is not polluted and unwanted fish are screened out, but the quantity and quality may not be very reliable. In contrast, well water is predator free but has higher pumping costs, must be oxygenated before use, and usually contains soluble iron and hydrogen sulfide that must be removed. Crawfish prefer water with a temperature of 65 to 85°F; thus, too much cold well water can lower the temperature below the optimal range for crawfish.

Many farmers pump water into a holding reservoir to be warmed by the sun before introducing it to the pond. Generally, groundwater is preferred because it has fewer biological and chemical risks associated with it. If surface water is used, predator fish can be screened out with a 0.5-inch mesh aeration screen; this size mesh allows smaller fish into the pond because they are not a predation problem and should die when the pond is drained in the summer. If any pools or puddles remain in the pond after the water is drained, they should be treated with a fish toxicant to ensure the removal of unwanted nuisance or predator species. The water supply should be sufficient enough to fill ponds to a depth of at least 18 inches within 72 hours and to allow the complete exchange of water in 4 to 5 days.

Figure 7.1. Southeast Texas water gate system to control water flow and levels.
Photo: Nikki Fitzgerald

WHEN TO FLOOD

When flooding a pond for crawfish production, it is very important to take climate conditions into account. The end goal is to time flooding when conditions are ideal for young-of-the-year recruitment. Flooding generally coincides with peak spawning season, and it is seldom healthy to flood a pond before September. At this stage, extreme heat—especially with the undependability of Texas weather—could deplete oxygen levels and cause crawfish mortality. Ideally, temperatures when flooding commences should be in the low 80s at the peak of the day and no lower than the mid-60s at night. Warmer water, but not hot enough to create issues with evaporation or water quality, is conducive to faster growth in crawfish. To combat warm water that leads to oxygen depletion, water exchange is preferable. When dealing with larger ponds or ponds that contain a heavy amount of plant debris, it is beneficial to wait until temperatures are much cooler, usually in October or November.

Flooding can also be timed with the development of a forage crop, such as rice, or volunteer vegetation. If flooded too early, crop growth and yield may suffer, and the breakdown process that tends to exacerbate depleted oxygen conditions may speed up.

A notable occurrence is that of large rainfall events such as hurricanes. While leaving water from these events is tempting because it cuts the economic costs of water pumping, it can have a negative impact on crawfish yield.

When using a rice-crawfish rotation, this rain may be kept without affecting rice or crawfish. Forage management has a direct effect on water quality. Green, new-growth rice requires relatively low oxygen intake to grow, allowing for adequate DO to maintain crawfish stocks. Yet too much rice debris left after a harvest, dense strands of sorghum-sudangrass, and volunteer grass species can cause low levels of DO and high levels of crawfish mortality to occur. When this occurs, it is necessary to pump aerated water into the ponds to mitigate.

It is important to keep in mind that crawfish ponds do not have to be fully flooded to produce a maximum yield, especially when brood crawfish and their young are emerging from burrows. Young crawfish have successfully begun maturation in as little as 6 inches of water, especially when vegetation is present. As always, continuous monitoring of water quality is paramount to the success of crawfish growth.

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 (Louisiana Crawfish Production Manual, 2007).

WATER QUANTITY

Crawfish culture uses more water and discharges more effluent than most other agronomic crops. It requires extensive water quantity to fill ponds, to replace evaporative or seepage loss over the 7- to 9-month season, and to correct low DO levels. The larger ponds may require more pumps. In fact, pumps with sufficient capacity are needed to fill the entire volume of the pond twice weekly. In the spring, sufficient water levels may be higher (18 to 22 inches) than in the fall (8 to 10 inches). Generally, a flow capacity of 70 to 100 gallons per minute per surface acre is recommended for intensive operations. This rate allows for complete water exchange every week. During warmer seasons, plant decay and high demands for oxygen may occur, and when this happens, crawfish mortality may be detrimental to pond yield. It is important that water be recirculated to maintain satisfactory DO levels.

During an average season, it requires about 7.5 feet of water to maintain the pond at near full depth—12 inches—but as much as 22 percent of this can be lost to seepage and minor leaks. If poor-quality water is not recirculated and just discharged, water usage can reach 10 to 16 acre-feet of water per surface acre. A pond with dense vegetation may require seven to nine water exchanges per season to minimize the amount of new water needed. A recirculation canal can be built outside the perimeter levee to allow the reuse of water to minimize the amount of new water needed.

A return channel can also be constructed inside the pond for reusing water before it is disposed of. Recirculation systems can reduce water usage to less than 3 acre-feet per surface acre. It is more beneficial to drain water and then pump oxygenated water in than to have a completely recirculating system. Replacing bad water in the pond with fresh, oxygenated water helps maintain satisfactory water quality. By draining some of the water first and then refilling, oxygenated water will be distributed through the entire pond (Louisiana Crawfish Production Manual, 2007).

Figure 7.2. Well water, while usually free from contaminants, must be vigorously aerated prior to use.
Photo: Nikki Fitzgerald

WATER QUALITY

Important factors affecting water quality are DO, pH, total hardness, total alkalinity, ammonia, nitrite, iron, hydrogen sulfide content, and salinity. DO is the most critical and is influenced by temperature. Warm water cannot hold as much oxygen as cold water, and biological activity increases in warm temperatures, causing oxygen to be consumed at a faster rate. The levels of DO should be maintained at 3 ppm or greater and measured regularly using oxygen test kits. When DO drops too low, crawfish start dying.

Water samples should be taken early in the morning at a median depth in the pond when they are at their lowest. It is vital to check multiple areas of the pond. DO levels can be taken using a DO monitor, but that equipment can be expensive, so many farmers use oxygen test kits because they are inexpensive and easy to use (Fig. 7.3). If DO levels are not high enough, the water should be replaced or recirculated with pumps or mechanical aerators. The pH of the pond should be maintained between 6.5 and 7.5, and total hardness and alkalinity (as calcium carbonate) should range between 50 to 250 ppm. Remedy low pH, alkalinity, or hardness by adding agricultural limestone to increase calcium content.

Ammonia and nitrite are toxic to crawfish at concentrations above 2 and 4 ppm, respectively, but these concentrations are unlikely in crawfish ponds because ammonia is rapidly assimilated.

Iron and hydrogen sulfide are toxic to crawfish at concentrations often found in subsurface well water. When using well water, place a flume ditch or pond between the well and the crawfish pond to allow the iron to precipitate out. It is imperative to place crawfish ponds where salinity levels higher than 5 to 10 parts per thousand (ppt) are unlikely to occur if farming near the coastline. Crawfish

Figure 7.3. DO concentrations should be monitored frequently to protect the crawfish crop and avoid unnecessary pumping and associated increases in production costs.
Photo: Nikki Fitzgerald

tolerance to salinity is directly proportional to crawfish size, but salinity can adversely affect vegetation at low concentrations. Producers should also be wary of farming in industrial or agricultural regions because surface water may be contaminated with pesticides, fertilizers, or other toxic chemicals.

There are very few chemicals that are approved for safe use in aquaculture, and because crawfish are very sensitive to pesticides—particularly insecticides—extreme caution should be taken when using these chemicals near a crawfish pond.

Optimum concentrations

- Dissolved oxygen (DO) – 3 ppm or greater
- pH – Between 6.5 and 7.5
- Calcium carbonate – 50 to 250 ppm
- Ammonium – Below 2 ppm
- Nitrate – Below 4 ppm
- Salinity – Below 10 ppt

CHAPTER 8:
HARVEST

Harvesting is labor intensive and makes up a substantial proportion of production costs. In fact, bait and labor used during harvest are the major expenses in crawfish production. In the southern states such as Louisiana, harvesting begins in mid-November and continues throughout April to June. Crawfish are harvested frequently during the season using a passive system with baited traps. In successful ponds intensively managed for optimum harvest, one third of the crawfish are harvested from November to February, one third from March to April, and the remainder from May to June. In field rotation systems, a bulk harvest often occurs in mid-February.

Although crawfish recruitment is continual over much of the 6- to 9-month growing season, frequent harvests are necessary, as catch is highly variable from day to day. The water temperature and the density of the crawfish population influence catch rates. Some other factors affecting the size of the harvest are water quality, type of forage, weather, crawfish reproduction, growth, and molting patterns. Cooler water temperatures can decrease catch, and warmer waters increase yield. The density of the crawfish pond plays an obvious role in the specific yield of a pond. For example, when there are few crawfish, the catch is lower, usually at the end of harvest season. When vegetation is abundant, catch is usually lower than when vegetation is sparse due in part to trapping success and trap access. Short-duration rain showers and flowing water generally increase catch, as mass molting events decrease it. A full moon is also said to limit catch, along with cold fronts and intense harvesting.

Though genetics may play a role, the size of crawfish at harvest is influenced more by environmental conditions. For example, overpopulation will cause crowding, which reduces growth and causes stunting due to the aggressive and territorial nature of crawfish (Fig. 8.1). The minimum size of crawfish depends on the purpose of the buyer. The larger crawfish are preferable for crawfish boils, and smaller crawfish may be selected for peeled and frozen purposes.

TRAPS

During the early history of crawfish farming, crawfish farmers used many styles and sizes of traps, and all caught crawfish with varying degrees of efficiency. Presently, the "pyramid trap" with three entrance funnels has become the industry standard (Louisiana Crawfish Production Manual, 2007; Fig. 8.2). These traps are the most efficient

Figure 8.1. Larger crawfish intimidate and outcompete smaller individuals, thereby suppressing growth.
Photo: Nikki Fitzgerald

and often yield 1.5 to 3 times more crawfish than stand-up pillow traps with only two entrances. The traps are commonly made from ¾-inch PVC-coated wire; the plastic coating helps increase yield and increases the lifespan of the trap. The average overall dimensions of traps are about 17 inches wide at the base and, with an optional 6-inch cylindrical extension to increase the height, about 26 inches tall. The inside diameter of entrance funnels is about 1¾ to 2 inches with metal supporting the rods to stabilize the trap and prevent toppling.

Most producers do not use bait protection containers like in crab or lobster traps because they may reduce the overall catch. The number of traps needed for harvest depends on the crawfish population in that pond. A new pond or a pond with a light population needs only about 10 to 15 traps per acre. Traps are generally placed in rows to ease harvesting by boats and are most efficient in concentrations of about 20 to 25 traps per acre, with about 40 feet between rows and 50 feet between traps (Fig. 8.3). Traps are baited and emptied 3 to 6 days per week, and they are usually emptied about 24 to 48 hours after being baited.

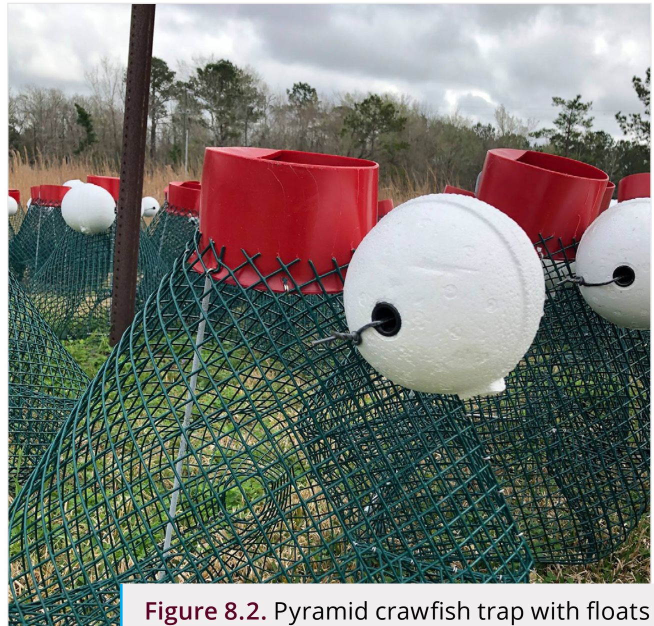

Figure 8.2. Pyramid crawfish trap with floats to help keep the trap from falling over.
Photo: Nikki Fitzgerald

After emptying the traps into the boat, clean off debris and store harvested crawfish out of the direct sun in mesh bags that hold about 40 to 50 pounds of crawfish. Some studies have shown the average size of crawfish may correlate with

Figure 8.3. Spacing of pyramid traps in a commercial crawfish pond.

the amount of time the traps remain in the water because, over time, smaller crawfish are allowed to escape and larger ones move in. If traps are not baited and emptied often enough, the forage will be depleted and suppress the growth and density of the crawfish. However, excessive trapping should be avoided because it can decrease harvest efficiency by removing crawfish before they have had time to grow to their full size.

It is important to correlate how often trapping occurs and the number of traps with crawfish density in the pond being harvested. When yield has begun to slow, some farmers choose to only place 10 to 15 traps per acre. If demand increases, crawfish can be harvested up to 6 days a week.

To deter depletion in one pond, many ponds may be harvested on a rotational basis. If ponds are not being harvested, traps should be removed from the water to discourage incidental mortality. However, if insufficient harvesting occurs, forage depletion and poor quality will follow, having a direct effect on pond yield.

BAIT

Crawfish producers may use natural and manufactured/formulated baits either separately or in combination. Natural baits include a variety of oily fish species such as gizzard shad, menhaden (pogey), herrings (slicker), carp, suckers, and mullet (Fig. 8.4). The heads and viscera of processed fish may also be used.

Manufactured baits are made from fishmeal, fish solubles, cereal grains, and grain by-products scented with attractants and binders with fish oils or other scents to attract crawfish (Fig. 8.5).

They come in cylindrical pellets and are easily stored, last longer in the traps, and are generally more effective than natural baits at temperatures of 60°F or higher. Though natural baits are more effective in cold water, they are disadvantageous because the supply and price are seasonal.

Furthermore, natural baits are more expensive, need freezers to store, and require more labor to cut the bait. Using a combination of fish and formulated bait in approximately equal proportions can increase the catch by as much as one third compared to either bait alone.

Figure 8.4. Gizzard shad; commonly used as crawfish baits.
Photo: LSU AgCenter

Figure 8.5. Manufactured bait better used in warmer temperatures above 75°F.

The traps should be stocked with ¼ to ⅓ pound of fresh bait each trapping day. If any uneaten bait remains in the trap, it should be disposed of outside the pond so that the crawfish will move readily into the baited traps. Producers should pay special attention to bait usage patterns; if a significant amount of bait remains uneaten, reduce the amount used to save costs. The cost of bait varies according to region and seasonal supply but generally ranges from $14 to $27 per 100-pound unit. A producer's bait should account for ~50 percent of total harvest costs and ~20 percent of total direct costs. When using baits, it is important to consider seasonality. Oily fish baits are often more effective in temperatures below 70°F and when used during late winter and early spring trapping. When water temperatures rise above 75°F and forage begins to deplete in ponds, manufactured baits become equally as effective as natural baits.

FACTORS INFLUENCING CATCH AND HARVEST SIZE

Crawfish catch from production ponds can vary from day to day and is influenced by many factors. Many factors like water temperature, water quality, type and quantity of vegetative forage, weather, lunar phase, and crawfish reproduction, growth, and molting patterns all play significant roles in the variation observed in daily catch (Louisiana Crawfish Production Manual, 2007). The size of crawfish is more influenced by environmental factors than genetic factors. The amount or density of crawfish in a pond plays an important role in the size of the crawfish.

Crowding can reduce growth and usually leads to stunting due to crawfish being territorial and aggressive. The larger crawfish will outcompete the smaller crawfish, suppressing their growth. To alleviate overcrowding, harvesting removes larger crawfish from the population, allowing for more space and food resources for smaller crawfish.

HARVESTING MACHINERY

Emptying traps is one of the most time-consuming and labor-intensive practices in crawfish aquaculture. A variety of methods are employed by many types of farms. Smaller ponds can be harvested by hand, sending harvesters into the field with a small non-motorized boat upon which they collect the harvested animals. In larger ponds, a boat becomes necessary to gather traps at longer distances. Small jon boats with low-horsepower motors are often utilized for this purpose, where one person is needed to drive the boat and one person collects traps, empties them, and rebaits them by hand. Some producers choose to use a boat that has been outfitted specifically for the purpose of crawfish harvest (Fig. 8.6). Many of these boats use an air-cooled engine that operates a hydraulic pump and motor to propel a metal wheel located behind the boat. This wheel is operated using foot pedals and leaves the driver's hands free to empty and rebait the traps (Fig. 8.7). This boat system is often employed when a boat must cross levees located either in or between ponds.

Figure 8.6. Crawfish boat outfitted with tables to consolidate harvested crawfish.
Photo: Nikki Fitzgerald

Table 3. Factors influencing catch and harvest size			
Factor	**Catch decrease**	**Catch increase**	**Reason**
Water temperature	Colder	Warmer	Regulates feeding activity
Density	Sparse	Abundant	Regulates amount of harvestable crawfish
Abundance of vegetation	Abundant	Sparse	Abundance of natural foods and bait attractants not easily dispersed
Mass molting	Usually	–	Crawfish do not feed during molting phases
Lunar phase	Full moon	–	Increases the frequency of molting
Cold fronts	Usually	–	Cooler water decreases feeding
Harvesting intensity	Intense harvesting	With less intense harvest or after rest phase	Influences the amount of harvestable crawfish

All of the boats used in harvest are outfitted with tables to consolidate harvested crawfish. The traps are emptied onto the tables and then funneled through a spout at the end of the table into a mesh sack (Fig. 8.8). These mesh sacks can usually hold 35 to 45 pounds of crawfish. Recently, in-boat graders have been used to cull out larger crawfish from smaller-sized crawfish that may not fetch top dollar at market. The smaller crawfish are generally returned to the pond to continue to grow.

Figure 8.7. This wheel is operated using foot pedals and leaves the driver's hands free to empty and rebait the traps.
Photo: Nikki Fitzgerald

Figure 8.8. Harvesting table on the boat to separate crawfish by size.
Photo: Nikki Fitzgerald

PRODUCING AND HARVESTING SOFT-SHELL CRAWFISH

Producing soft-shell crawfish takes extra effort and consideration because it involves harvesting the crawfish during their molting period after they lose their hard shell. Young, well-fed crawfish molt frequently in warm water as they grow. Crawfish over 2 inches should be selected and transported from the pond to be grown in trays inside a building. To avoid the high mortality rates often associated with removing crawfish from ponds, ensure the crawfish have plenty of time to acclimate gradually to their new conditions. Growing trays should be about 3 feet wide, 8 feet long, and filled with 4 to 5 inches of water. Depending on their size, stock the young crawfish about 20 to 35 per square foot. After the crawfish have acclimated, they should be fed daily with a commercially prepared crustacean feed at a rate of 3 to 5 percent body weight for the first few days and then 2 percent.

Watch the crawfish carefully. At the first sign of potential molting, transfer the crawfish to a separate molting tray. Crawfish are extremely vulnerable during the molting process without their shell. If not separated in time, molting crawfish will be attacked and destroyed by the other crawfish in the tray. One indication of an upcoming molt is a change in color; the carapace will become distinctively dark right before molting. Once a crawfish has molted, immediately remove and process it to prevent regrowth of the shell before marketing.

Soft-shell crawfish can be frozen in bags of water or vacuum-packaged with shrink wrap. Soft-shell crawfish are more delicate, and care should be taken to prevent damage to the product.

Table 4. Some of the factors that influence daily and seasonal crawfish catch			
Factor	Catch decrease	Catch increase	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	Influences the amount of harvestable crawfish

CHAPTER 9:
PRODUCT QUALITY

Remember that providing a good-quality product starts with proper management of the crawfish operation. Producers should be sure to provide the necessary food and oxygen, use fresh bait when harvesting, keep sacked crawfish off the bottom of the boat, and make sure conditions are sanitary. Producers should be aware that the quality of crawfish can change according to the season. For example, the first crawfish of the harvest season tend to be the older broodstock crawfish, which are more likely to have hollow tails. Be aware of dark-colored crawfish, which can indicate a hollow tail. Furthermore, providing voluntary quality assurance in one's operation increases consumer confidence and shows the producer values the quality of their product.

GRADING

Grading is the process of sorting crawfish by size and weight as well as separating the dead, diseased, or unsightly crawfish. Before the foreign market expanded, grading was not typical in crawfish aquaculture. In the mid-1980s, the Swedish market demanded a graded product and insisted on purchasing only large, high-quality crawfish, driving the development of a grading system. In fact, standardization in grading is beneficial to crawfish producers, buyers, processors, and consumers because it ensures consistent size and quality no matter where it is purchased. Also, there are five distinct grading devices in use today: a stationary on-board grader, a shaker grader that can be used on board or on shore, and the tumble grader used solely on shore. The other two devices are a converted vegetable grader and a water-based grader developed at the LSU AgCenter.

Table 5. Example of a common grading system

Factor	Catch decrease	Catch increase
Large	1	15 or less/lb
Medium	2	16 to 20/lb
Small	3	21 or more/lb
Field Run	–	Mixed

WASHING AND PURGING

Washing crawfish consists of holding them in water or very humid environments for a few hours to make for a cleaner and more attractive product as well as to remove silt and clay trapped in the gill chambers.

To provide a more appealing product for live markets, a small number of producers have adopted the practice of "purging" crawfish before selling them (Fig. 9.1). The purging process empties the stomach and intestinal tract by confining them without food for 24 to 48 hours. This process cleans the exoskeleton of mud and debris and eliminates or reduces digesta in the intestine that consumers may find unappealing (Louisiana Crawfish Production Manual, 2007).

Figure 9.1. Purging tanks that are aerated and are used to clean the crawfish intestines before selling.
Photo: Nikki Fitzgerald

Crawfish are commonly held in tanks within specific constructed boxes or baskets (Fig. 9.2) that are usually suspended in water to help facilitate the removal of the intestinal contents. The recommended loading rate is about 1.5 pounds of crawfish per square foot of submerged surface area with adequate aeration and water exchange. Just as effective is the use of a water spray system where crawfish are held in shallow pools of water (0.5 inches deep) under a constant spray or mist (Louisiana Crawfish Production Manual, 2007).

These practices were developed as the out-of-state market expanded because the intestinal tract is dark and considered unappealing to some customers. Non-purged crawfish are safe to eat, and it is the consumer's choice whether they like purged versus non-purged crawfish. The cost for purged crawfish is usually 25 percent higher than non-purged crawfish. Some consumers will rinse or soak crawfish with water or a saltwater bath for a short amount of time before cooking. This serves as little more than a rinse and does not clean out the gut or digestive tract.

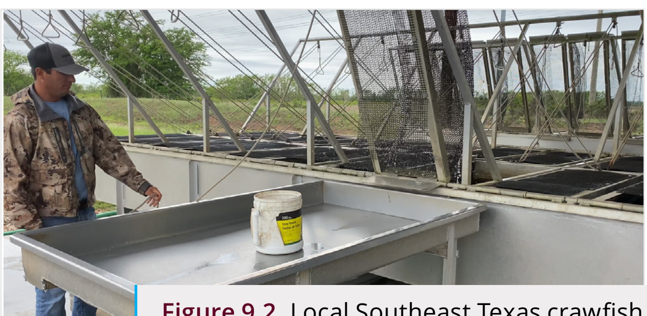

Figure 9.2. Local Southeast Texas crawfish farmer demonstrating how the baskets dump the crawfish from the purging tanks.
Picture of Zac Dishman provided by Nikki Fitzgerald

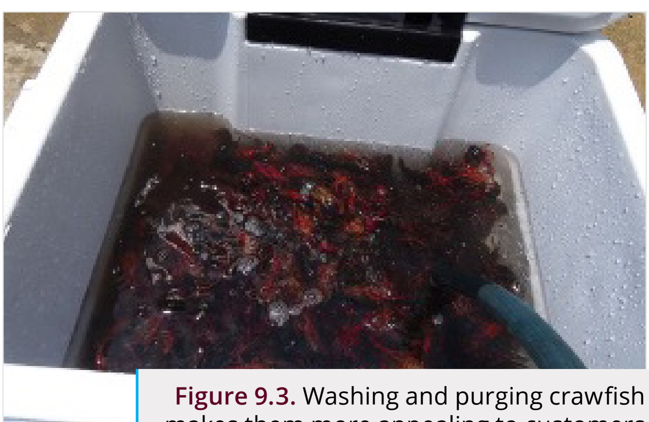

Figure 9.3. Washing and purging crawfish makes them more appealing to customers by removing trapped silt and emptying the intestinal tract.

TRANSPORT AND STORAGE

The common open mesh onion sack is still considered the best method for holding and transporting live crawfish. Keep the bags clean and dirt free, cool and moist, and never exposed to direct, warm sunlight. The crawfish should be packed tight enough to restrict their movement because of their aggressive nature. When transporting, the live crawfish should be kept moist by wetting periodically or by covering them with wet burlap or ice to slow their movement. Crawfish should never be transported in water. Crawfish may be transported in open-bed trucks with ice or in refrigerated trucks and should be moved to coolers or terminal markets as soon as possible after they are harvested (Fig. 9.5). Make sure that the vehicle used is clean and free of petroleum products, pesticides, or other contamination, which may harm crawfish or make for an unsafe product. Within 2 to 3 hours of harvest, crawfish should be stored in 38 to 41°F coolers with high humidity to minimize drying of the gills. The mortality of the crawfish increases as storage time and handling time increases. If shipping crawfish, they should be packaged in insulated seafood shipping bags containing frozen gel packs. In warmer temperatures, crawfish should be cooled overnight prior to shipping.

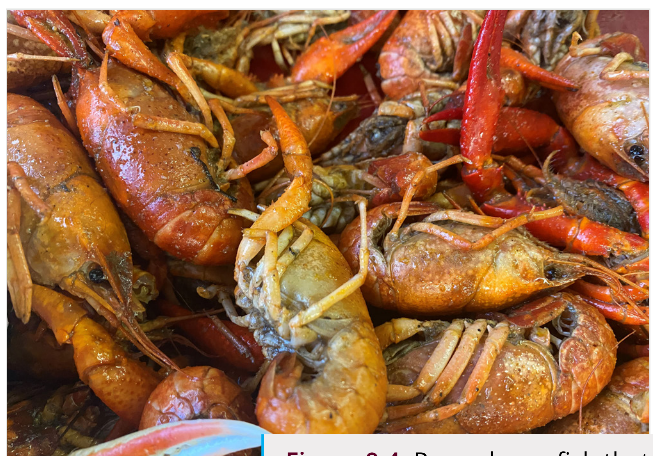

Figure 9.4. Purged crawfish that have been seasoned and boiled.

Figure 9.5. Crawfish transport truck loaded with ice and crawfish.

Figure 9.6. Crawfish held in open mesh onion sacks in a refrigerated room, stacked two high to prevent an increase in mortality.

CHAPTER 10:
ECONOMICS

BUSINESS

Relevant economic factors to consider when developing a business plan for crawfish culture include access to property and equipment, projected cash flows, access to capital and cash reserves, primary and alternative markets, estimated profits, and the labor and resources required in such an investment. Though the profitability of crawfish production varies from year to year because of the unpredictable nature of yields, costs, and market prices, meticulous planning will generally increase the chance of success. Discuss the feasibility of project plans with a Texas A&M AgriLife Extension agent who can provide available data and help develop a business plan that includes production, economic, and marketing data and projections.

MARKETING

When starting in the crawfish industry, the top priority should be to identify and establish markets. Most crawfish are produced, marketed, and consumed in Louisiana—the biggest market for the product—although Texas and many other southern states are secondary markets that are becoming larger as crawfish boils soar in popularity. Crawfish are sold in two forms for several different purposes, including hard-shell (for human food, recreational bait, or as brood crawfish to stock growing ponds) or soft-shell (for human food). Most are marketed to the food industry, but some may be sold as recreational fish baits or promoted to the aquarium trade and to educators.

Most farmers market their products live, either directly to local consumers and businesses or to primary wholesalers or processors who pick up the product from the farmers and distribute it regionally. As markets for live crawfish increase in demand, the number of producers increases, sometimes flooding the market.

When this occurs, larger crawfish are reserved for the live market, and smaller crawfish are shelled for meat. Live crawfish are typically boiled and consumed fresh from the pot. Meat yield is usually 15 percent of live weight and depends on the maturity and size of the individual crawfish. In the beginning months of the harvest season, yields are higher but decline throughout the season.

The development of whole-cooked, frozen crawfish and prepared frozen dishes has increased nationwide consumption and distribution of processed crawfish. The most popular processed products are cooked, hand-peeled, and deveined, but processed crawfish may also appear cooked and whole. The processing companies will generally use smaller crawfish for this market, leaving the larger ones for the more profitable live market. A very small amount of the annual catch—around 5 percent—is sold to European markets.

Supply and demand relationships are reflected in the variability of the crawfish market. Prices are the highest in the winter and early spring when supply is low and then decline significantly in late spring and summer when the supply peaks and the demand for larger crawfish grows. Though the profitability and prices of crawfish production change throughout the season or from year to year, most wholesale buyers pay relatively uniform prices. Loyal or consistent customers may buy crawfish at a premium price. Generally, the wholesale price of tail meat is about 10 to 12 times higher than the wholesale price of live crawfish because of the processing involved.

Producers should be familiar with primary and alternative markets, both wholesale and retail, because the frequent harvest rate of crawfish makes it crucial to have reliable buyers. Sometimes, harvesting schedules must be adjusted to accommodate the available markets. Planning and good communication with potential buyers early in the season can help a producer effectively manage his operation and be competitive in the marketplace.

RECORD KEEPING

Record keeping is crucial in any business to effectively manage the operation and for reporting, evaluation, and planning purposes. In crawfish production, one should keep a record of factors such as pumping time, traps used, type and amount of bait used, water quality, production time in hours and labor, and the results of grading and sales income per acre per day. Financial reports, including income statements, balance sheets, cash flow statements, and enterprise reports, should also be kept. Income statements are records of sales and should include detailed information about when and with whom the sale was negotiated. This statement lists the income generated as well as the expenses that occurred during the accounting period.

Balance sheets show a complete listing of assets and liabilities. They also establish the differences between one's assets and debt to give total net worth or equity. Cash flow statements measure all of the incoming cash and all of the cash going out of a business. This statement is a concise measure of the ability of a business to pay its bills on time.

For successful marketing from the producer to the consumer, heed the following principles:

- Always sell a good product
- Prepare crawfish the way customers want them
- Maintain a mailing list of potential customers
- Advertise in the newspaper, social media, and on the radio
- Establish regular hours for making sales and post these times
- Use signs to identify that crawfish are for sale
- Have a convenient location
- Treat customers with respect
- Evaluate marketing success to determine what worked and returned a profit

Records can be as simple as handwritten notes to record data or as complex as computer data analysis programs. Records can help prove crop losses in times of natural disaster or pollution and can help farmers receive compensation for the losses.

Evaluating records is also critical to make the business more efficient and to keep costs as low as possible. Crawfish production entails a great amount of risk due to the variability and seasonality, and making decisions that affect the financial performance of the operation without accurate and detailed records increases financial risk. Meticulous record keeping is key to building on strengths and recognizing and eliminating potential weaknesses.

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I would especially like to thank Jeffrey Gillespie and Robert Boucher with the Louisiana State University Agricultural Center for allowing the use of their publications, pictures, and their latest publication, *Projected Commodity Costs and Returns for Crawfish Production in Louisiana*, as a reference to this publication. The most current information and publications for the production year can always be found at *https://www.lsuagcenter.com/topics/livestock/aquaculture/crawfish.*

This is an inclusive manual for the production and management of crawfish in Texas. The purpose of this manual is to assist new producers, step-by-step, to enter the crawfish industry within Texas. We strive to educate the producer sufficiently so that they may make informed decisions regarding entry into the industry and manage their crawfish and forage crops to achieve the greatest yields and economic viability. Topics discussed in this manual include crawfish biology, the variety of production systems used to culture crawfish, rice production and other alternative forage crops, site location, pond construction, water management, harvest, product quality, and economics.

As seafood demand increases, there is great potential for Texas to become a large player in the commercial crawfish industry. Texas has a very similar climate and geography to that of the Louisiana swamps, where crawfish are harvested in abundance. The warm climate, swamps, and bayous provide an ideal habitat for raising crops such as rice and soybeans that can be farmed simultaneously with crawfish. With the advances in agricultural technology and the rising demand for year-round crawfish, Texas crawfish are a viable economic prospect for many.

Technical and educational assistance in crawfish production and marketing is provided by the Texas A&M AgriLife Extension Service. From start-up to budgets to marketing strategies, Extension agents are available to discuss feasibility and any questions and concerns you may have.

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