THE COMMERCIAL CRAWFISH INDUSTRY OF SOUTH LOUISIANA

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The Commercial Crawfish Industry in South Louisiana[1]

by

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ABSTRACT

The crawfish enterprise of south Louisiana has expanded as much as eighteen-fold since the 1950's. It was estimated in 1973 that there were about 44,000 acres of managed crawfish ponds. Of the 334 ponds identified and mapped in this report, 231 are classed as open ponds, 45 as rice field ponds, and 58 as swamp ponds. The total Louisiana harvest of crawfish is estimated to be about 11 million pounds annually valued at about $2.2 million.

Future expansion of pond acreage is envisioned but will be limited by availability of physically suitable sites. Increased crawfish production may also result from intensified pond management. Increases in crawfish production and harvest, however, will probably depend upon further research leading to improvement of the crustacean, especially for greater percentage of edible meat; development of markets for crawfish waste; research leading to more efficient processing and longer storage time in retail markets; and a more stable, adequate price to provide the economic incentive.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

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INTRODUCTION

In the cypress swamps and willow-fringed bayous of south Louisiana there lives a crustacean which has been both the delight of the epicure and the fare of the lower classes for more than 200 years. Nowhere else in the country are crawfish (Astacidae) produced and consumed as much as in French-speaking south Louisiana.

Since the 1950's annual commercial production has expanded approximately eighteen-fold, in large part due to increased output from commercially managed crawfish ponds (Gowanloch, 1951; Lyles, 1972) and to a market that has been rarely saturated (LaCaze, 1969).

Currently in south Louisiana there are approximately 44,000 acres of managed ponds used for commercial crawfish culture. Assuming conservatively that 60 percent of this acreage produces crops of crawfish which are commercially feasible to harvest (J. F. Fowler, personal communication), that the yield per acre is 200 pounds per year of live crawfish, and that the price paid to the producer if $0.20 per pound, then the total production from commercially managed ponds may be estimated to be at least 5.28 million pounds per year with a value of $1.06 million. Annual production from unmanaged sources is estimated to total about 6 million pounds (C. G. LaCaze, personal communication); thus, the production for Louisiana is approximately 11 million pounds per year with a value of $2.2 million.

The commercial crawfish production of Louisiana surpasses that of all other states of the United States combined. The second-ranking state is Oregon, which has an annual production that is less than 1 percent of that of Louisiana. Small annual catches have been reported from the Puget Sound of Washington (Lyles, 1965-1973) and the Sacramento River delta of California (Nicola, 1971).

This report presents an overview of the Louisiana crawfish industry as background for persons involved in management and development of living resources in the Louisiana coastal zone, and as a source of information for persons who wish to evaluate the potential for development and exploitation of a crawfish industry elsewhere.

HISTORICAL SURVEY OF CRAWFISH EXPLOITATION

The crawfish was a widely consumed springtime food staple of the early French immigrants of south Louisiana, most of whom settled on Bayou Teche and Bayou Lafourche (Martin, 1882) (see Figure 1).[1] Crawfish of edible size were abundantly available in south Louisiana and were captured by the bait-on-the-string method (Dumont de Montigny, 1753).

Commercial sale of crawfish in Louisiana was reported for the first time in a government publication for 1880 (Penn, 1941). During that year 10,000 pounds were produced with a value to the fishermen of $800. Through the 1920's annual commercial production was probably, at the most, on the order of 100,000 pounds (Collins and Smith, 1893; Townsend, 1900; Alexander, 1905; Sette, 1925). Due to the perishability of crawfish and the poorly developed highway network, sales tended to be local and were comprised of the occasional surpluses of subsistence crawfish fishermen (Security Industrial Insurance Co., 1970). The commercial industry did not come into its own until the 1930's.

The 1930-1949 Period

During the 1930's the problems of crawfish preservation, transportation, and capture that had severely limited growth of the crawfish industry were solved to a large degree (Comeaux, 1972). During that decade, preservation in vehicles and in retail stores by means of packing in insulated cases containing ice or dry ice became commonplace (Dauenhauer, 1934). Meanwhile, transportation between the most important crawfish source area, the Atchafalaya Basin, and the two very significant market cities on the opposite side of the Mississippi River, i.e., New Orleans and Baton Rouge (see Figure 2), was notably improved by highways and bridges built during the 1930's, particularly during the administration of Governor Huey P. Long (1928-1932)[2].

Prior to the early 1930's crawfish were captured by scooping with a dip net. By 1932, use of more efficient creole crawfish nets and crawfish traps became popular (Comeaux, 1972) (see Figure 3). The net

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[1] Approximately 4,000 French Acadians settled in south Louisiana subsequent to their expulsion from Acadia (Nova Scotia) by the British after 1744 (Knipmeyer, 1956).

[2] In Louisiana between 1930 and 1939, the total mileage of state highways increased from 8,145 to 14,176 miles, and the number of surfaced miles increased from 268 to 3,956 miles. Bridges were built across the Mississippi River at New Orleans and Baton Rouge and across the Atchafalaya River at Morgan City and Krotz Springs (C. M. Reeves. personal communication).

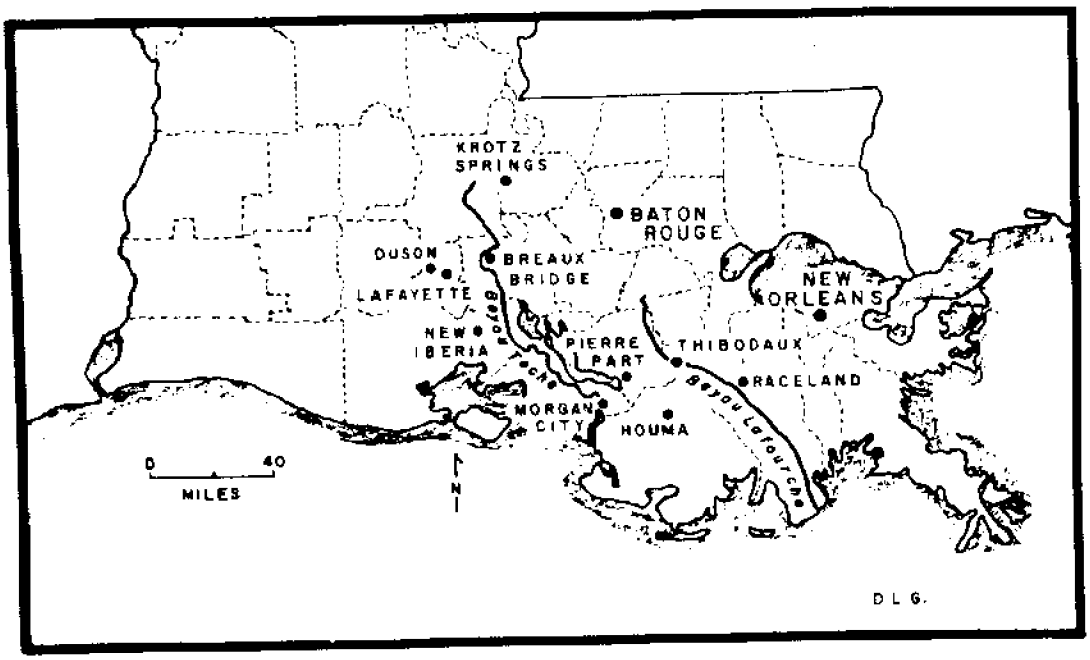

Figure 1. Places important to the crawfish industry.

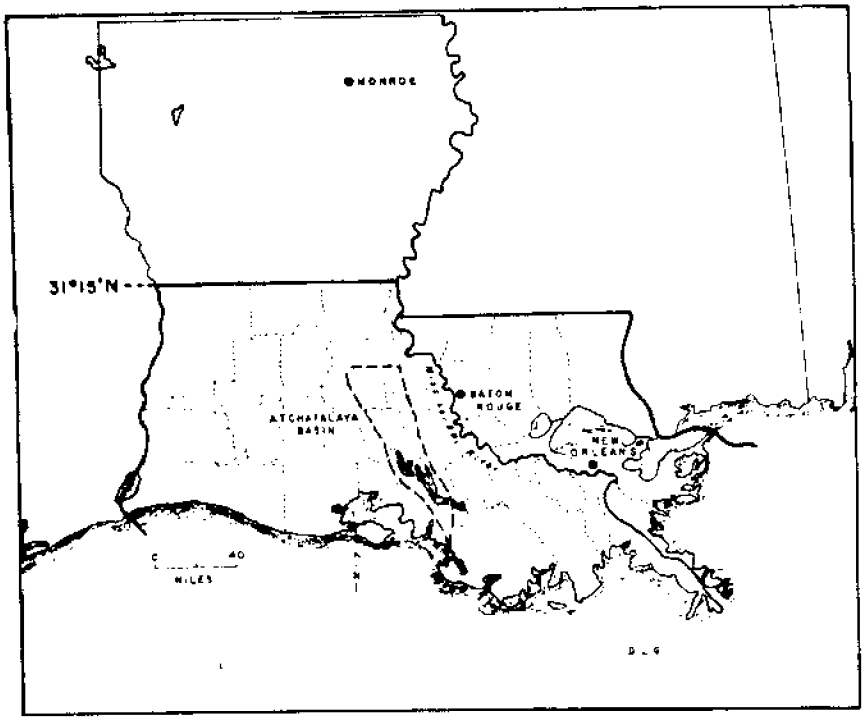

Figure 2. The south Louisiana study area.

Figure 3. The creole crawfish net (left) and the crawfish trap (right).

measures about 14 inches on the side and is suspended from the four corners by two V-shaped wires. The crawfish trap is a cylinder of wire poultry netting with a funnel entrance at one end and a movable flap of wire netting at the other end which can be raised for emptying. The trap has been preferred over the creole crawfish net because it can be left unattended with no chance of escape by captured crawfish, and it is less expensive.

During the 1930's these improvements, and a population increase of 12 percent in south Louisiana (Truesdell, 1941), made possible a marked increase of reported commercial catches. For the first two years of the decade production was less than 300,000 pounds per year. Annual output from 1932 through 1939 ranged between roughly 1,000,000 and 2,500,000 pounds and averaged almost 2,000,000 pounds (Dauenhauer, 1934-1940).

Through World War II and up to 1949, reported annual commercial harvests averaged somewhat less than those of the 1930's. Between 1940 and 1948 catches ranged between approximately 100,000 and 1,000,000 pounds and averaged 601,000 (Dauenhauer, 1942-1944; La. Wild Life and Fisheries Comm., 1946-1950). Though the reported harvests indicate a decline in production during the 1940's, in all probability the catches

were as large as those of the previous decade. The crawfish production data that were gathered in the 1940's are notably incomplete (C. G. LaCaze, personal communication).

The Post-1949 Period

The commercially managed crawfish pond was first contrived in Louisiana by a rice farmer, Voorhies Trahan, in 1949 near Duson. Reflooding of his field after the fall rice harvest through spring made possible rotation of rice and crawfish, i.e., rice was the warm-season crop, and crawfish was the cool-season crop. Soon thereafter wooded swamps, timber harvest impoundments, reclaimed marshland, and other open lands unsuited for cropland or pasture were managed for the purpose of producing commercial crops of crawfish (Viosca, 1966).

Quantitative information regarding year-to-year total crawfish pond acreage is sketchy and conservative; nevertheless, the available information is presented in Table 1.

Table 1. Estimated total pond acreage for various years.

Year	Acreage	Authority
1949	40	Lovell (1968)
1960	2,000	Viosca (1966)
1966	6,000	LaCaze (1966)
1968	10,000	de la Bretonne (1969)
1969	12,000	Perry and LaCaze (1969)
1970	18,000	Perry, Joanen, and McNease (1970)
1971	24,000	Walton and LaCaze (1972)
1973	44,000	Field inventory by Don L. Gary (1973)

From 1949 to the mid-1960's the total acreage of managed ponds was small because crawfish farming was a high-risk endeavor due to insufficient knowledge of the habits and needs of crawfish (LaCaze, 1968). Then, beginning in the mid-1960's, commercial crawfish enterprises increased greatly.

There is no single overriding reason for the increase of pond acreage from approximately 6,000 in 1966 to 44,000 in 1973, but rather there were many factors. Publication of pioneer management research results, promotional activities of the state government, county agents, engineers of the Soil Conservation Service, associations of crawfish farmers and other parties interested in the development of the crawfish industry, and increasing availability of crawfish processing plants helped to make possible a rapid increase.

Widespread distribution of free crawfish farming bulletins by the Louisiana Agricultural Extension Service and Wild Life and Fisheries Commission, such as Hill and Cancienne (1963), LaCaze (1970), and Viosca (1966), removed many doubts regarding the likelihood of high per-acre yields of crawfish. Thus, in time, potential crawfish farmers became more inclined to pursue the activity, and involved government personnel confidently gave positive counsel more often.

The state government has supported the crawfish farming enterprise in several ways. In 1959, $10,000 was appropriated for construction and maintenance of a pilot crawfish farm (Waldo, 1959). That same year the town of Breaux Bridge by legislative decree was proclaimed to be the Crawfish Capital of the World.

Since 1959, the Crawfish Festival Association has sponsored the biennial Crawfish Festival of Breaux Bridge, a gala affair. Tens of thousands of avid crawfish eaters have flocked to this three-day event to enjoy the widely publicized parades, balls, and crawfish eating and racing contests. The 140-member Louisiana Crawfish Farmers Association, founded in 1970, convenes annually, and on these occasions technical reports are given by experts, and ideas are exchanged.

During the 1959's and the 1960's reported crawfish production ranged generally from one to two million pounds and from two to four million pounds respectively (La. Wild Life and Fisheries Comm., 1952–1970). The actual annual catches, however, were probably from two to three times greater than those which were reported (C. G. LaCaze, personal communication). Reported harvest data are always incomplete because the law does not require producers to give an account of quantities of crawfish captured.

Reported production was extraordinarily low in 1959 and exceptionally high in 1965. In the former year only about 300,000 pounds, reportedly, were caught. Failure of the Atchafalaya Basin to dry out during the summer of 1958 permitted fish to survive in unusually large numbers and very likely, predation on the basin crawfish by these fish was responsible for the relatively small harvest of 1959 (Viosca, 1959).

In contrast, during 1965 nearly nine million pounds were reported to have been produced. The Atchafalaya Basin was flooded unexpectedly early by precipitation from Hurricane Hilda in October of 1964. This early flooding allowed a phase of the crawfish life cycle to start several weeks sooner than it would have ordinarily; relatively early maturation of the crustaceans made for an unusually large crawfish crop.

Currently, annual production is probably about a minimum of 11 million pounds. The increases of total annual crawfish production in the past two decades in large measure have been due to harvests from a continually increasing acreage of managed ponds. In recent years pond crawfish have comprised about one-half of the total annual catches (C. G. LaCaze, personal communication).

Finally, the importance of commercial crawfish processing plants deserves to be discussed. During the latter half of the 1960's processing plants were handling almost three million pounds of live crawfish per year (Hudson and Fontenot, 1970), and this amount represents a significant increase over quantities handled in previous years (Lovell, 1968). The number of licensed crawfish peeling and packing plants in operation increased from five in 1959, to 29 in 1966, and to 34 in 1972 (J. A. D'Alfonso, personal communication; Hudson and Fontenot, 1970).

THE CRAWFISH: ITS DISTRIBUTION AND ENVIRONMENT

Distribution of Crawfish

Crawfish are found on every continent except Africa (Andre, 1937), and there are over 300 species in the world (Poole and Avault, 1971) (see Figure 4). Regarding the history of the genera of North America, Astacus evolved during the Eocene epoch in north-central Eurasia. Members of the genus migrated eastward during the Pleistocene Ice Ages across the Bering Strait via the land bridge and established themselves in western North America, as shown in Figure 4 (Andre, 1960). The Procambarus genus of eastern North America originated in Mexico; it eventually spread to the foot of the southern Appalachians, where a secondary center of evolution developed. The more advanced forms of Procambarus that developed in the Appalachian center then dispersed along the Atlantic and Gulf coast plains and farther up the Mississippi valley (Hobbs, 1942).

Two hundred or so species of crawfish are known to exist in North America (Washburn et al., 1953), and 22 are found in Louisiana (Penn, 1959). Of those species inhabiting Louisiana, only two are sufficiently abundant and possess adequate tail meat to warrant commercial capture; they are the swamp crawfish, P. clarki (see Figure 5), and the river crawfish, P. blandingi acutus.

Swamp Crawfish versus River Crawfish

In spite of the common names, swamp crawfish and river crawfish, neither species requires a swamp or river type of environment. Nevertheless, as shown in Figures 6 and 7, the river crawfish favors streams, whereas the swamp crawfish prefers swamps and marshes and is relatively indifferent to streams. The river species is inclined to inhabit streams because of its poor tolerance toward the relatively low oxygen contents of static swamps and marshes (Washburn et al., 1953). The swamp species thrives in swamps and marshes despite the low oxygen levels.

With respect to size and morphology of adults, the two species are strikingly similar and differ mainly regarding the form of pincers and legs. Ordinarily, the color of the swamp crawfish is dark red, and that of the river species is pinkish (Penn, 1959). Anomalous, bright blue swamp crawfish have been discovered near New Orleans (Penn, 1951; Waldo, 1957). The normally translucent outer shells of these specimens were blue, and they obscured the reddish color patterns of the pigment cells below them (Penn, 1951).

Though in a few commercially managed ponds the number of swamp and river crawfish are roughly equal (LaCaze, 1970), 90 percent of the

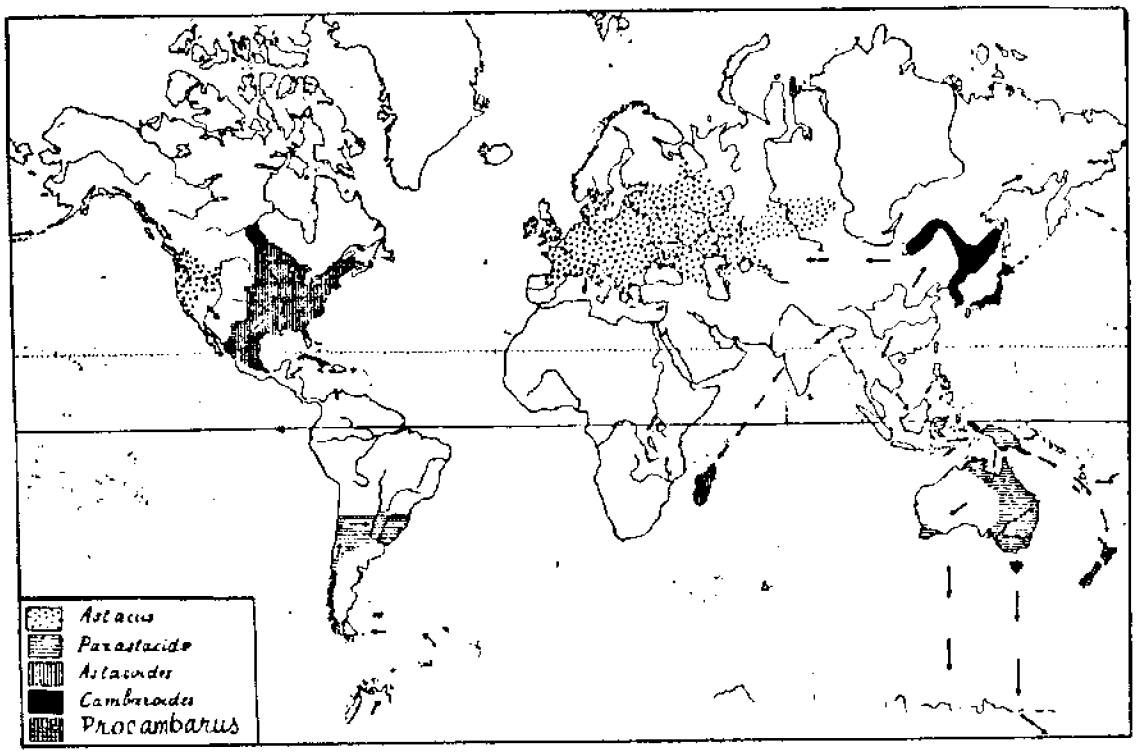

Figure 4. General distribution of the genera of crawfish (from Andre, 1960).

Figure 5. The swamp crawfish.

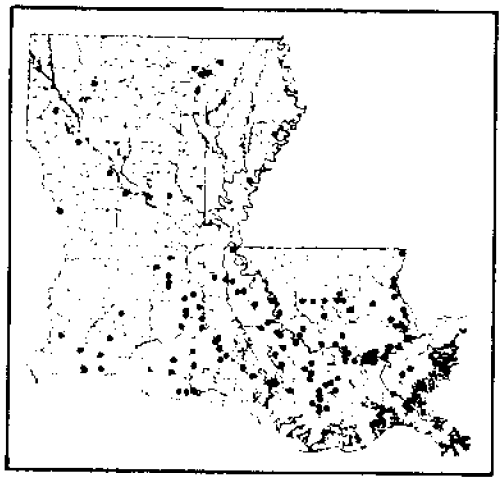

Figure 6. Distribution of the swamp crawfish in Louisiana (from Penn, 1959).

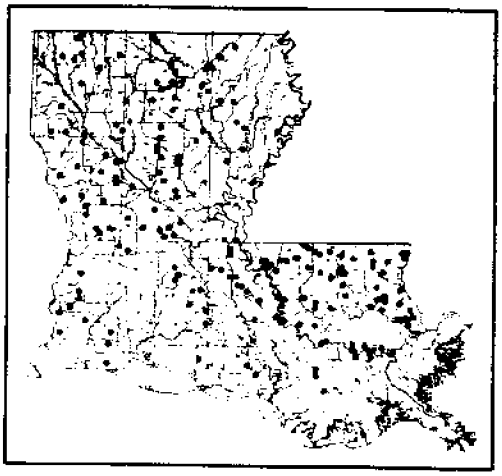

Figure 7. Distribution of the river crawfish in Louisiana (from Penn, 1959).

average commercial catch consists of the swamp species (de la Bretonne et al., 1969). Representative adults of one species have no advantages for marketing purposes over those of the other species (Lovell, 1968). Full-grown swamp and river crawfish are approximately the same size (Penn, 1959), and their tastes are quite similar; in fact, it has been proven that a person eating a mixture of swamp and river crawfish cannot identify the species by taste (Comeaux, 1972).

Life Cycle

The swamp crawfish produces only one brood per year; this occurs between the months of June and October (Hill and Cancienne, 1963).[3] The mating season is from early May through June, and sperm is deposited into a receptacle on the abdomen of the female. Prior to spawning the female digs a burrow down to the water table in drained soil, occasionally at the edge of open water; she retains the sperm for an interval of from 2 to 20 weeks. The eggs are emitted from the oviducts, located on the bases of a set of walking legs, and are fertilized as they pass the opening of the receptacle out of which sperm is extruded. The fertilized eggs are held in place below her abdomen by a viscous substance named glair (LaCaze, 1965). The female swamp crawfish lays from approximately 200 to over 700 eggs (Avault et al., 1970), each about 0.08 inch in diameter (Penn, 1943). The river crawfish lays no more than 400 eggs (Ham, 1971).

The eggs remain attached to the female's abdomen and hatch in about 15 days (Viosca, 1939); the peak of the hatching period is in October (LaCaze, 1970). The young crawfish cling to the swimmeret appendages of her abdomen for a period of from 5 to 27 days. They leave her when they become capable of fending for themselves (Hill and Cancienne, 1963). Within the burrow, problems of crowding and lack of food terminate with evacuation in response to flooding of the habitat area by autumnal showers (Washburn et al., 1953).

For unknown reasons almost all of the sexually mature males make a fall death-migration over land at the time of autumn rains. Penn (1943) collected 750 migrating crawfish; and, of the lot, only a dozen were females. He observed that the condition of the males was very poor, i.e., the gills were clogged with debris, the hepatic glands were an unhealthy dull gray, and the testes were shrunken and degenerate. He speculated that those which did not fall prey to some other animal died natural deaths shortly after commencement of the migration. Viosca (1939) and Chidester (1912) have also observed mass dying of males.

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[3] No detailed study of the life cycle of the river species exists to date. One may assume that it is quite similar to that of the swamp crawfish, excepting that in most respects the river crawfish may mature a little earlier than the swamp species (Broom, 1963).

During the ensuing winter months the omnivorous young feed upon organic materials, particularly aquatic vegetation. As spring approaches and habitat water warms up, crawfish activity, though drastically reduced at water temperatures below 45°F, is moderate between 50° and 60° and optimal in the 70° to 85° range (LaCaze, 1970). Given warm spells and adequate food, the young crawfish grow rapidly and can double their weight each month (Broom, 1963). In open ponds they can attain edible size, 3 inches in length, as early as mid-December (LaCaze, 1970).

This generation makes up the major portion of the crop, which is harvested through mid-May. By the end of May the shells are harder and the meat is tougher than in younger stages, and the delicious "fat" (liver) is resorbed as sexual development takes place (Washburn et al., 1953).

Sexual maturity is reached between March and July, and the cycle is then completed (Hill and Cancienne, 1963). Most of the crawfish of this generation will not survive the coming winter. Though individual crawfish can be raised for a number of years in a laboratory, LaCaze believes that almost all swamp crawfish have a natural life span of up to two years (Morning Advocate, 1965).

Habitats

Habitats of the swamp and river crawfish are aquatic and include streams, marshes, swamps, lagoons, roadside ditches, borrow pits, and crawfish burrows, all widely distributed throughout the study area (see Figure 2). Penn (1956) completed the only detailed, quantitative, statewide study of the habitats of the swamp and river species. An analysis of data on a total of 312 lots of swamp and river crawfish is summarized in Tables 2 and 3.

Partiality of the swamp crawfish for static marshes and swamps and of the river crawfish for creeks, rivers, and ditches that tend to be better aerated is expected and pointed up by the tabulations. The presence of both species in the various types of habitats attests their exceptional adaptability.

Penn's conclusions (1956) concerning the physical and biological factors common to swamp species habitats were summarized in the statement that this crawfish occurs most frequently and in greatest abundance in water which is less than 15 inches deep, permanent, static, and exposed to full sunlight. Most of the habitats had mud bottoms and abundant aquatic vegetation. He remarked that the hydrophytic plants most commonly found in swamp crawfish habitats, in order of frequency of occurrence, were: bulrush (Scirpus spp.), cattail (Typha spp.), aligator weed (Achyranthes philoxeroides), water hyacinth (Eichornia crassipes), water primrose (Jussiaea spp.), smartweed (Polygonum spp.), pickerelweed (Pontederia spp.), arrowhead (Sagittaria spp.), duckweed (Lemna spp.), water fern (Azolla caroliniana), water milfoil (Myriophyllum spp.), water shield (Cabomba sp.), hornwort (Ceratophyllum spp.),

Table 2. Percentage of swamp crawfish population in habitat categories (after Penn, 1956).

Habitat	Estimate of Percent of Population Utilizing Each Habitat (152 Lots)
Marshes and marsh pools	35
Swamps and swamp pools	30
Lakes, ponds, and borrow pits	14
Ditches (mostly roadside)	12
Slow-moving streams (mostly bayous)	8
Pineland sloughs and springs	1

Table 3. Percentage of river crawfish collections in habitat categories (after Penn, 1956).

Habitat	Percent of Total Collections (160 Lots)
Temporary situations:	30.9
Ditches (mostly roadside)	26.2
Pineland sloughs	9.4
Burrows	3.7
On land (migrating ?)	.6
Permanent situations:	60.1
Creeks and rivers	25.0
Ponds and borrow pits	26.3
Swamps and swamp pools	8.8

spike rush (Eleocharis spp.), bog rush (Juncus spp.), figwort (Bramia sp.), water millet (Zizaniopsis miliacea), water pennywort (Hydrocotyl sp.), and naiad (Najas sp.).

Similar sorts of investigations by Penn (1956) of the river crawfish habitats yielded the following conclusions. The river crawfish occurs most frequently in water which is less than 15 inches deep (74 percent), turbid (53 percent), permanent (60 percent), and exposed to full sunlight (60 percent). A majority of the collections were from habitats with mud bottoms (71 percent) and aquatic vegetation present (72 percent). The hydrophytic plants most commonly found in these places, in order of frequency of occurrence, were: smartweed, water primrose, water milfoil, bog rush, alligator weed, spike rush, spiderwort (Tradescantia sp.), pickerelweed, arrowhead, bladderwort (Utricularia spp.), lizard's

tail (Saururus sp.), and iris (Iris spp.).

Burrows and Chimneys

When the surface water of the habitat disappears, both species of crawfish burrow into the ground (Hobbs, 1942). Burrows and chimneys of the swamp and river species are similar, but only those of the swamp crawfish (see Figures 8 and 9) have been studied in detail; observations in the following paragraphs will be confined to burrows and chimneys of that species.

The burrow is an undulating, downward tunnel with a diameter of about 2 inches, and the bottom is enlarged into a chamber which is almost 6 inches in diameter at the base (Jaspers, 1969). Burrow depth generally ranges from 24 to 40 inches, but is always deep enough to contain ground water at least at the bottom (Avault et al., 1970).

After examining 158 burrows near Baton Rouge, Jaspers and Avault (1969) concluded that despite seemingly adverse and foul conditions in these tunnels, the crawfish in them thrived. For burrows near ponds during the burrowing period, they found that water temperature ranged from 48.2° to 93.2°F, turbidity from 320 to 13,500 parts per million, and dissolved oxygen content from 0.2 to 2.8 parts per million. Almost all of the aquatic fauna in the burrows was composed of nematodes (Nematoda), earthworms (Oligochaeta), and planktonic Crustaceae (Copepoda); the benthic fauna was dominated by earthworms and snails (Gastropoda).

A burrowing crawfish can create above the mouth of the hole a vertical mud chimney that is as high as 8 inches, about 4 inches in diameter at the base, and tapered toward the top. The chimney consists of small mud globules (each about 0.4 inch in diameter) which are put into place as the crawfish burrows (Jaspers and Avault, 1969). Though Abbott (1884) held that crawfish build chimneys purposely, the opinions of Tarr (1884) and Jaspers (1969) were to the contrary. After observing that only 24 percent of 158 examined burrows were covered with chimneys, Jaspers concurred with Tarr who concluded earlier that the chimney is nothing but the product of burrowing and is not designed.

Crawfish as Predators and Prey

Crawfish make up a notable part of the food intake of a wide range of sizes and species of wildlife because the crustacean is amphibious and goes through such a range of sizes during its growth (Gowanloch, 1951). Piscine, avian, reptilian, and amphibian types of crawfish predators have been reported on in the literature and are considered in this discussion.

Considered in the piscine predator studies are the food habits of six species of game fish and three species of non-game fish which inhabit the fresh-water bodies of south Louisiana. Excepting the redfin pike

Figure 8. A burrow of a swamp crawfish.

Figure 9. A chimney of a swamp crawfish.

(Esox americanus), all of the studied game fish are sunfish (Centrarchidae).

Viosca (1936) found crawfish remains in one of eight stomachs of rock bass (Ambloplites ariommus). Cahn (1927) stated that about one-third of the food intake of another species of rock bass (A. rupestris) is crawfish, and Gowanloch (1933) was of the opinion that crawfish fill a very large place in the sustenance of this species.

The warmouth bass (Chaenobryttus gulosus) is tolerant of turbid water and, according to Cahn (1927), feeds upon insects, small fish, and to a much less extent upon crawfish. Palmer and Wright (1920) found a mixture of mud and crawfish claws in the stomachs of two specimens.

Lambou (1961) looked into the feeding habits of the largemouth bass (Micropterus salmoides) and spotted bass (M. punctulatus). Though it was claimed by Cahn (1927) that crawfish are a minor part of the diet of the largemouth bass, Lambou found crawfish in 86 percent of 28 stomachs. Half of six inspected stomachs of spotted bass contained food; swamp crawfish was the only food item noted. The only non-sunfish game fish, the redfin pike, is a member of the pike family (Esocidae). Cahn (1927) stated that the food of the young consists of small crawfish.

The three non-game fish species whose diets have been investigated are the bowfin (Amia calva), the bullhead catfish (Ameiurus melas catulus), and the shortnose gar (Lepisosteus platostomus). The bowfin typically frequents sluggish, weedy water, and devours crawfish. Gowanloch (1951) reported that 14.1 percent of the food found in the stomachs of 131 bowfin was crawfish, and Stacy (1967) analyzed the stomach contents of 135 adults. He found that crawfish occurred in 31 percent of them and made up 30.2 percent of the total weight of the food. Cahn (1927) observed that the food of the bowfin varies between fish and crawfish; and, during late summer and fall, crawfish dominates its diet.

Bullhead catfish, which thrive in managed ponds, almost exterminated the crawfish in a study pond which was closely observed by Viosca (1931). According to Penn (1950), crawfish made up 17 percent of the total food volume of the stomachs of 110 shortnose gar.

Investigations of avian predation have been done only for the white ibis (Eudocimus albus), the glossy ibis (Plegadis autumnolis), and game ducks (Anatidae). The white ibis is a permanent resident of south Louisiana (Shaw, 1963) and feeds in shallow marshes along lake borders, and flooded agricultural fields (Palmisano, 1971). Palmisano (1971), Allen (1962), and Baynard (1914) agree that the main diet item of this wading bird is crawfish. Baynard found 602 crawfish in 50 meals which young ibises were forced to disgorge. He observed that the feeding habits of the glossy ibis are similar to those of the white ibis and discovered 47 crawfish in three stomachs of week-old glossy ibises (Baynard, 1913).

It seems that crawfish are not a significant food item of game ducks.

Martin and Uhler (1939) analyzed the food of 17 species of game ducks, all of which are at least part-time residents of south Louisiana. Crawfish composed less than 2 percent of the total volume of the contents of 2,101 stomachs of specimens taken in the Gulf coast region.

Reptilian species which feed upon crawfish include the alligator (Alligator mississippiensis) and the slider turtle (Pseudemys scripta troostii). Crawfish are eaten by alligators of all sizes, however, the crustacean makes up the bulk of the food of the smaller ones (Giles and Childs, 1949). These investigators found, on the average, two crawfish in each of 264 stomachs of larger alligators, and they commented that crawfish were by far the most important crustacean consumed. The crawfish of a study pond were exterminated by introduced alligators (Viosca, 1931).

Minyard (1947) collected from a pond near New Orleans 59 slider turtles with food in their stomachs. Crawfish, the most important animal material consumed, constituted 40 percent of the total volume of food of the stomachs. Viosca (1931) noted that crawfish did not thrive in a study pond that contained slider turtles.

A trio of amphibians which eat crawfish, the three-toed congo eel (Amphiuma means tridactylum), the two-toed congo eel (A. m. means), actually salamanders, and the southern bullfrog (Rana grylio), remain to be discussed. The three-toed congo eel lives in subterranean tunnels, including crawfish burrows, and feeds largely upon crawfish (Viosca, 1962b). Ditches, slough margins, and crawfish burrows are dwelling places of the two-toed congo eel. Its diet is composed of crawfish, salamanders, and small frogs (Carr, 1940). The southern bullfrog is almost wholly aquatic, dwells in shallow water, and is limited in distribution to the southeastern part of south Louisiana. Carr (1940) observed that it feeds extensively on crawfish.

It has been incidentally mentioned in the literature that furbearers, including the mink (Mustela vulgivaga), raccoon (Procyon lotor), and opossum (Didelphis marsupialis), prey upon crawfish (Allen, 1962; Gowanloch, 1951).

The crawfish, on the other hand, are omnivorous, feeding upon living and dead plants and animals, but preferring a diet of fresh meat, if available (Morning Advocate, 1965). Approximately 20 percent of crawfish food intake consists of worms, larvae, and other relatively immobile animal matter, and the remaining 80 percent is made up of vegetation (LaCaze, 1970). Crawfish are cannibalistic and prey upon other freshly molted crawfish, which are vulnerable from three to six times per year (Morning Advocate, 1965).

It appears that young crawfish are attracted to decaying vegetation, which has a high protein content due to the presence of herbivorous microscopic animals. Carotene-containing green vegetation is a necessity of larger crawfish (LaCaze, 1970). Crawfish are fond of Spanish moss

(Tillandsia usenoides) which falls from trees of swamp habitats (Viosca, 1939).

Swamp crawfish devour waterweed (Anacharis sp.) and pondweed (Potamogeton spp.), but they do not attack water milfoil (Martin and Uhler, 1939). Viosca (1931) observed control by crawfish of alligator weed, water primrose, smartweed, and arrowhead in a study pond. Alligator weed and water primrose are high in content of carotene, which makes possible formation of copious, delicious "fat" by crawfish (Ham, 1971).

CRAWFISH PONDS, PROCESSING PLANTS, AND THEIR DISTRIBUTION

Ecological Elements and Pond Management

Managed ponds are generally more consistent in production of crawfish than unmanaged areas because they are less vulnerable to vagaries of nature, such as unreliable flooding and drying. Skilled management of ponds provides controlled timing of flooding and drying so that reproduction, survival, and growth of crawfish are optimized.

The life cycles, habitat preferences, and predator-prey roles of the swamp and river crawfish need to be recognized and considered in crawfish pond management. The calendar periods of the life cycle phases of the swamp crawfish and desirable concurrent managerial procedures (Lacaze, 1970) are presented in Figure 10.

Crawfish are stocked at the rate of 45 pounds per acre in June because females are ready to mate, and adults are least expensive then due to their poor edibility (LaCaze, 1970). Since the swamp and river species can thrive in a properly managed pond, either or both may be used. Swamp crawfish, however, are preferred because they are more tolerant than the river species toward low dissolved oxygen levels that occur particularly in shallower open ponds. Also, since the swamp crawfish female lays more eggs than the river crawfish, fewer of the former species are required for adequate stocking.

The pond remains drained from early summer through fall for several reasons. The female crawfish prefers to spawn in burrows, where, for a few weeks, she and the young are protected from harm by predators. During this period herbicides can be used to eliminate undesirable underbrush, cattails, and water hyacinths, which are too tough for crawfish to forage upon. Growth of duckweed, smartweed, alligator weed, and water primrose can be promoted. These plant species are highly desirable because they thrive despite alternate flooding and draining, provide a protective cover for the crawfish, and, if consumed, improve the quality of the crawfish by increasing their "fat" content. Plant biota provide protective cover for the crawfish and through photosynthesis furnish oxygen for the crawfish to respire.

In addition, predatory fish die as the pond dries out. Fish which remain in isolated depressions that contain water after completion of pumping can be easily exterminated with a two or three parts per million solution of Rotenone (LaCaze, 1970).

Draining is prolonged for a month to allow the crawfish adequate time for burrowing into the parts of the uneven pond floor which become exposed to the air as the pond is emptied. A faster rate of drawing off water would needlessly expose crawfish to predatory birds. Fertilization of pond floors has not yet proven to be economically feasible (J. F. Fowler, personal communication).

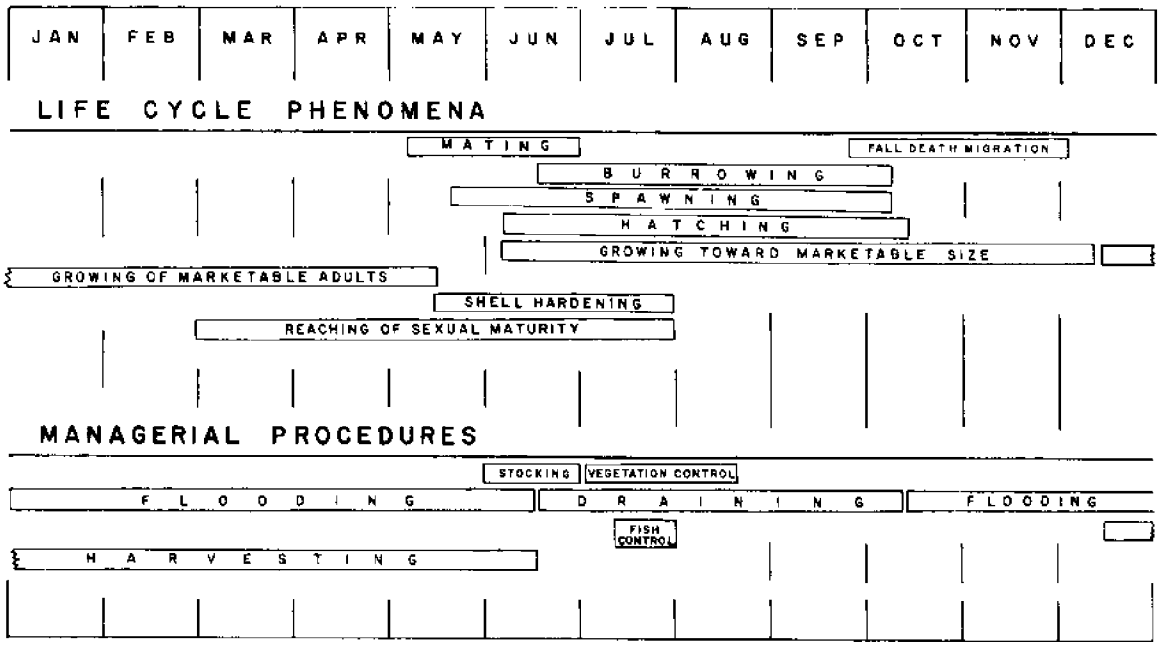

Figure 10. Calendar periods of crawfish life cycle phases and concurrent managerial procedures.

By October the burrows become overcrowded, and females will eat a portion of their broods, if the pond is not flooded to permit the crawfish to evacuate the burrows and enter open water (LaCaze, 1966). The pond remains flooded with from 12 to 30 inches of water through mid-June, and in the meantime young crawfish feed and are protected, to a measure, from avian and terrestrial predators. Crawfish are most active when the water temperature is from 70° to 85°F; however, on some of these occasions it may be necessary to pump aerated water into the pond in order to countervail oxygen depletion due to rapid decay of plant material. This procedure is particularly important if river crawfish, which tolerate low oxygen levels rather poorly, are in the pond. Given adequate food and mild fall temperatures, the young crawfish grow to marketable size by mid-December, at which time harvesting commences (LaCaze, 1970).

Since crawfish prefer fresh animal matter, traps are usually baited with low-priced chunks of trash fish. Oily, widely available fish, such as gizzard shad (Signalosa atchafalayae), are most often recommended by experts (LaCaze, 1970; Ham, 1971). From eight to ten traps per acre are dropped to the pond floor from a skiff boat. Depending upon how numerous the marketable crawfish are, the traps are emptied from every other day to twice a day. Through February, harvesting is interrupted by cool spells which result in water temperatures of less than 45°F, the threshold of crawfish activity (LaCaze, 1970).

Harvesting continues through mid-June, even though by mid-May the crawfish tend to become unsaleable due to their poor edibility qualities. The post-season harvest is necessary to prevent the pond from becoming overpopulated because competition for food by too many young crawfish results in below-average size crawfish in the crop.

Crawfish are generally safe from predation by birds and terrestrial animals while the pond is either fully flooded or dry; when the pond is dry the crawfish are burrowed. Predator fish, however, are a serious problem. A measure of fish control is achieved by filtering the inflow water through a hardware cloth cylinder which is 3 feet in diameter and 12 feet long. Though small fish enter the pond through the one-inch mesh screen, a finer mesh is not used because emptying of the cylinder would be required too often.

The problem that arises most often in crawfish culture is oxygen depletion. A number of factors contribute to it, especially oxidation of biomass and increases of pond temperature. Of particular importance is the large-scale dying of massive, phytoplanktonic blooms which are engendered during several successive days of sunny skies, especially toward summer (Avault, 1968). If several cloudy days succeed the bloom period, the phytoplankton die en masse, and ensuing oxidation of the plant material markedly reduces the oxygen content of the pond. When pond water temperatures are in the high 80's, the oxygen-carrying capacity is often reduced to the point that the crawfish are compelled to break the water surface in order to absorb atmospheric oxygen through their wet gills. Such surfacing is dangerous for crawfish because it exposes them to avian predation.

Pond Distribution

The locations of 334 ponds within the study area are shown in Figure 11. The bulk of the ponds are on back lands of the natural levees of Bayou Teche to the west of the Atchafalaya Basin and of Bayou Lafourche and the Mississippi River to the east of the basin (see Figure 1). Most of the remaining ponds are on prairies west of Bayou Teche. Few ponds are located in the interior of the Atchafalaya Basin, and on coastal marshland they are found only near White Lake. There are few ponds in the northwestern and northeastern portions of the study area. In these two northern quadrants market conditions and topographical realities are unfavorable for crawfish farming.

Since live crawfish are highly perishable, and the maximum pond water depth is ideally 30 inches, nearby consumers and expanses of flat land are prerequisite to profitable crawfish farming. In the northwestern and northeastern quadrants of the study area very few sites provide both conditions adequately to permit a commercial crawfish enterprise.

The French Culture Influence

In general crawfish are eaten mainly by people of French ancestry. Thus, the favorability of market declines as distance from concentrations of French Louisianians increases. There is in the literature an attempt to delimit core areas of French Louisianians (Meigs, 1941) and an arbitrary boundary between French and Anglo-American Louisiana (Knipmeyer, 1956).

Meigs used the occurrence of French names in telephone directories as a basis for mapping the distribution of French Louisianians (see Figure 12). Excepting the areas north of Lake Pontchartrain (above New Orleans) and north of the Atchafalaya Basin, the indicated dearth of French Louisianians in the quadrants is notable. There are two core areas, on opposite sides of the lower Atchafalaya Basin, with the percentage of Louisiana French ranging from 75 to 100. One is along Bayou Teche to the west, and the other is along Bayou Lafourche to the east. Henceforth these areas will be referred to as the Teche and Lafourche French cores, respectively.

Regarding a generalized boundary between French and non-French Louisiana, Knipmeyer subdivided the study area into two culture regions, French and Anglo-American Louisiana, as shown in Figure 11. The location of this line was based on his knowledge of the state and interpretation of culture traits. Of 334 ponds in the study area, only seven are located in Anglo-American Louisiana. In part this is due to dominance of the population by Anglo-Americans, who as a rule have an aversion to eating crawfish.

Limitations of the Anglo-American Region

The topographic relief of the Anglo-American region is generally a

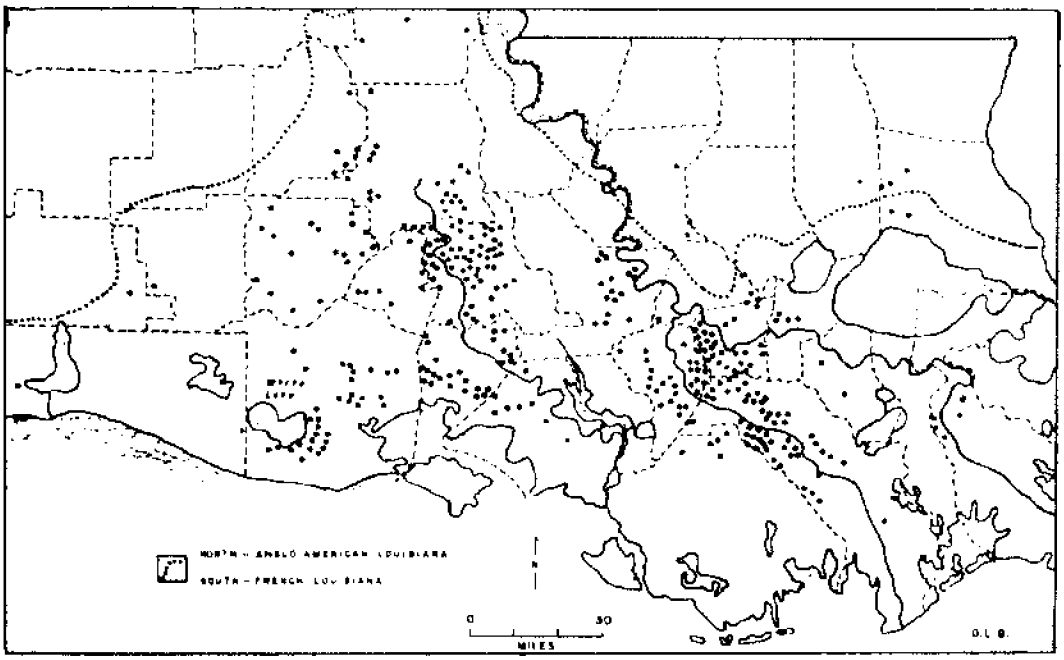

Figure 11. Location of all crawfish ponds (French and Anglo-American boundary, from Knipmeyer, 1956).

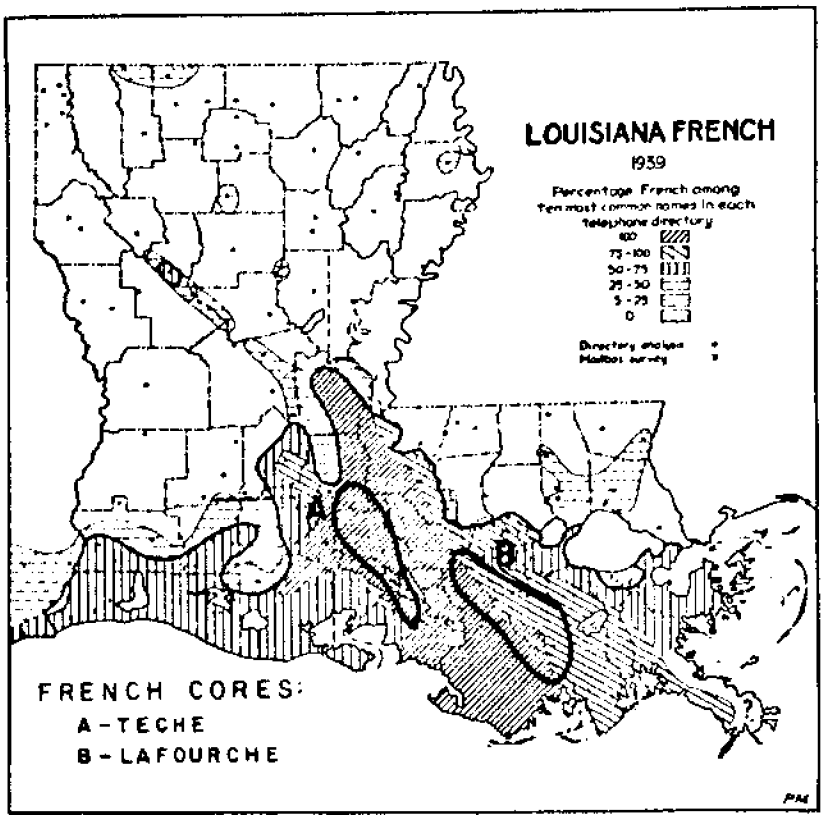

Figure 12. Distribution of Louisiana French (from Meigs, 1941).

very serious hindrance to crawfish farming, except in the small area of relatively flat prairie land toward the southwest (see Figure 13). Local relief of more than a few feet per mile necessitates construction at prohibitive cost of secondary levees within the pond because the water depth should not exceed 30 inches. At depths greater than 30 inches, growth on the pond floor of hydrophytic plants (which are necessary crawfish food) becomes inadequate. In Figure 13 the hill land areas which have maximum relief, the flatwoods with low relief, and the extensive bluff land with moderate to marked relief clearly dominate Anglo-American Louisiana. The topography of crawfish farming is not greatly limited by relief on the prairies and on the few areas of flatwoods and bluff land with relatively low local relief.

Thus, in Anglo-American Louisiana the scarcity of consumers and flat land permits profitable crawfish farming in only a few special places. The seven ponds of Anglo-American Louisiana are small, on relatively flat sites on flatwoods or bluff land, and very near the markets of New Orleans

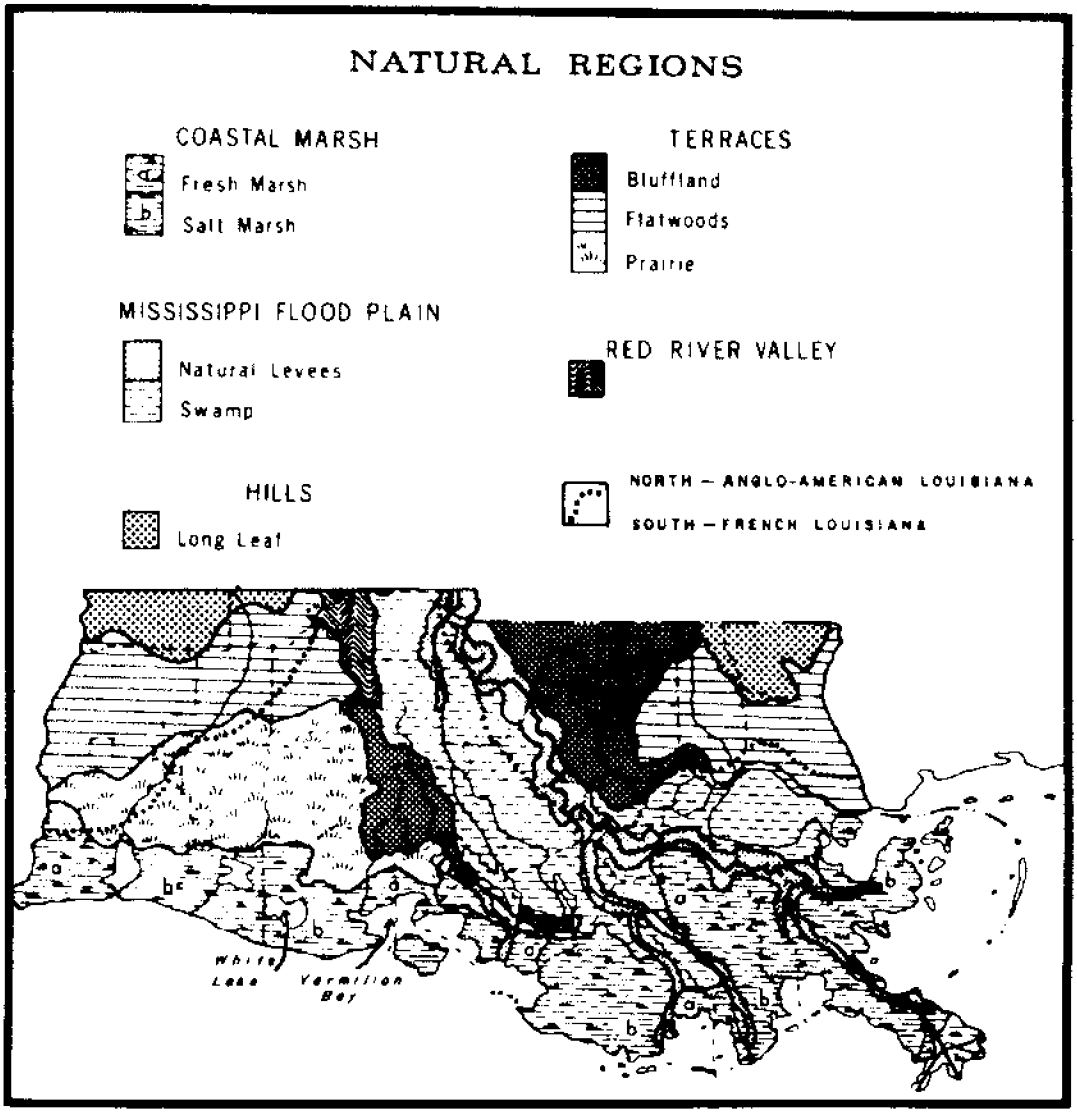

Figure 13. Natural regions of south Louisiana (from Newton, 1972).

or Baton Rouge and the French-Anglo-American Louisiana boundary. Elsewhere in Anglo-American Louisiana crawfish farming is for all practical purposes precluded by market conditions and/or relief, even if some or all other factors were favorable. Therefore, further comments concerning bio-physical and societal-economic factors and pond location are restricted to French Louisiana.

Bio-Physical Factors

The crawfish is particularly sensitive to certain bio-physical conditions of the environment. Pond managers have only recently begun to appreciate the need to simulate the most favorable natural environmental conditions of dissolved oxygen content, flooding and draining, and forage. The impacts of landforms, soil, climate, and vegetation upon pond distribution are of primary concern.

Landforms and Soil

Since leveeing is more expensive on steeper slopes, and good natural drainage at higher elevations makes retention of pond water difficult, landforms and associated relief features are extraordinarily significant. Soil texture is the characteristic of most concern because it determines the water-holding capability of levees. Clayey soils, which are more impervious than coarser silty and/or sandy soils, are best for levee construction. Examined are landforms and soils within the natural regions shown in Figure 13 and their influences upon pond distribution.

The recent alluvium surfaces can be considered in terms of the coastal marshlands and Mississippi and Red River flood plains. In the marshlands, distinct relief features are generally absent, and most of those which are present are only slightly above sea level. Low natural-levee ridges along larger streams are the most conspicuous landforms, but for the most part soil rather than landform limits pond construction. The soils of the marshlands are peats, mucks (partially and well decomposed organic matter, respectively), and fine clays (Chabreck, 1972). Peats and mucks are unsuitable for levee construction because they have a soft, moist consistency. Levees made of these soils shrink in volume as much as 60 percent during the first two years (Perry et al., 1970), and they rapidly subside (Ensminger, 1963). As a consequence of organic matter content in excess of 50 percent for most of the more interior soils (Chabreck, 1972), only one pond is located on the marshland, from just east of Vermilion Bay to the lower Mississippi River.

The 16 ponds west of Vermilion Bay and near White Lake are on older, more clayey soils. These soils are from 15 to 50 percent organic matter and high in clay content (Chabreck, 1972). Levees resting on these clayey soils subside very slowly and, when drying out, they shrink appreciably less than those made from the marshland soils to the east.

Topographic Surfaces

The vast majority of the ponds are located in the Mississippi River

flood plain. Physiographically this is a deltaic area, and everywhere elevations above sea level are low. The higher elevations are at the crests of natural levees of rivers and streams. Crest heights above adjacent back lands are up to 20 feet. Portions of the gently sloping back lands which are roughly 1.5 miles from levee crests are ideal for crawfish ponds in several ways. The relief is slight, and the water table is near or at the surface. The poor drainage minimizes pond water loss by vertical seepage, and the clayey soils are quite suitable for levee construction. Almost all of the back land soils are either clayey Sharkey or slightly coarser Commerce Series soils (Lytle, 1968). Notable exceptions are the clayey Iberia and Baldwin Series soils in the Breaux Bridge area on back lands of the Bayou Teche. The two ponds on the Red River flood plain are on poorly drained, clayey soils of the Buxin Series.

On the terrace surfaces, crawfish ponds are numerous only on the prairies; a lesser number of ponds are on bluff land just to the east of the prairies, and very few are on flatwoods surfaces. Relief on the pairie region of southwestern Louisiana is almost imperceptible, except for low natural levee crests along the larger streams and for numerous residual pimple mounds toward the southern margin. Rice cultivation and crawfish farming take place on back lands. Beneath most of the rice land is a thick hardpan of impermeable clay. Since the hardpan in the crawfish farming area is from 2 to 16 feet thick and from 8 to 12 feet below the surface (Jones et al., 1956), ponds very slowly lose water through vertical seepage. No serious problems are associated with levees, which are usually made out of silty clay Crowley or Midland Series soils.

Within the bluff land west of the Mississippi River is a long, northeastward-facing escarpment. Elevations range from 50 feet at one extreme in northern French Louisiana to near sea level at the southern limit toward the coast. The moderate local relief of the bluff land east and west of the Mississippi and the granular silty Oliver or Calhoun Series soils of the lower areas make crawfish farming very costly. Thus, ponds are absent in the bluff land of eastern French Louisiana and along the higher bluff land north and south of Lafayette.

Finally, there are only a dozen ponds within the two small areas of flatwoods to the northeast and northwest of French Louisiana. These are upland plains with gently rolling surfaces that slope gulfward about 5 feet per mile. In places the land is flat enough to permit pond construction, but the soils of the flatter areas are generally either sandy Caddo or silty Zackary Series soils, which are unsuitable levee materials due to high porosity (Lytle, 1968; U.S. Dept. Agri., 1972).

In summary, ponds are most often located on poorly drained, nearly flat, back lands with clayey soils. The back lands with many ponds are those of Bayou Lafourche, Bayou Teche, and the Mississippi River. Relief and clay content of soil of the prairie region and the marshlands of southwestern Louisiana have presented no serious obstacles to construction

of numerous ponds. In the remaining bluff land, flatwoods, and marshlands, ponds are few in number due to excessive relief and/or soils with inadquate amounts of clay.

Climate

Since the humid subtropical climate of French Louisiana is characterized by a high degree of uniformity, it contributes little to the spatial analysis of crawfish ponds. For example, mean annual precipitation is high in French Louisiana and ranges between approximately 56 inches toward the southwest and 64 inches toward the southeast. Excessive precipitation when ponds should be dry or droughts when ponds should be flooded can ordinarily be easily compensated for by artificial draining and flooding.

Average July temperatures are about 82°F and average January temperatures range from 51° toward the northwest, to 56° toward the passes of the Mississippi River. Thus, growth of the crustacean is interrupted the least in the relatively warm southern area. The only notable consequence of this temperature gradient is that crawfish in the southern portion of French Louisiana can be harvested from 10 to 20 days sooner than those to the north (J. F. Fowler, personal communication). As crawfish prices are highest at the beginning of the harvest season, farmers to the north are at a disadvantage; thus, ponds in northern French Louisiana are fewer than they might otherwise be if harvesting were to begin simultaneously at all latitudes. Unusually cool weather from late fall through spring delays crawfish harvesting for up to several weeks.

Vegetation

Forests of the flatwoods, bluff land, and uncleared back lands of the natural levees of the Mississippi and Red River flood plains are formidable obstacles to profitable land use for crawfish culture. Trees are expensive to clear, but if they remain, they obstruct harvesting, and the leaves reduce pond productivity of crawfish. Shading of the pond by leaves not only slows down water warm-up in spring and, thus, temperature-dependent crawfish growth but also retards growth of aquatic plants upon which crawfish feed. Further, decay of fallen leaves in pond water depletes oxygen that could be utilized by crawfish. Nevertheless, a few tens of managed ponds exist on swamplands of the Mississippi River flood plain and on uncleared bluff land west of the Atchafalaya Basin, approximately at the longitude of Lafayette (see Figure 16).

About 80 percent of the ponds in French Louisiana are either on Mississippi River flood plain back land that had been cleared or on the treeless prairies and marshlands toward the southwest (see Figures 20 and 18). That so many ponds are on these open lands is only in part due to the fact that the per-acre productivity of the pond is higher compared to swampland, and access for harvesting purposes is greater. Profitable crawfish farming can be expected in a specific portion of

French Louisiana only where bio-physical and also societal-economic elements are favorable.

Societal-Economic Factors

The bio-physical conditions are obviously important, but, in addition, the explanation of the location of crawfish ponds requires consideration of societal-economic factors. Market and transportation are particularly important factors.

Market Orientation

Since live crawfish are highly perishable, the ponds of French Louisiana are to a great degree market-oriented, and the French component of the population is the most important market for crawfish and crawfish products. A comparison of the distribution of French Louisianians (see Figure 12) and of ponds (see Figure 11) shows that the vast majority of the ponds are in close proximity to the Teche and Lafourche French cores. Toward the French-Anglo-American boundary where the proportions and absolute numbers of people that are of French ancestry decline, ponds are widely spaced.

Means of Transportation and Accessibility

Because live crawfish are perishable, they must be moved to market and sold rapidly. The highway networks in the Lafourche and Teche French core areas and in the rice region to the west are dense enough in most places to permit easy sale of crawfish within 25 miles of the local ponds (see Figure 14). Usually only large catches are transported more than 25 miles; they are normally brought without much difficulty to New Orleans, Baton Rouge, or to processing plants, particularly in the Breaux Bridge area, for one-stop sales. The lack of highways toward the interior of the Atchafalaya Basin is a significant reason for absence of ponds in this area.

Within the Teche and Lafourche French core areas, there is not only close proximity between an exceptionally large number of producers and consumers but also a social cohesion among the French Louisianians which facilitates establishment of marketing arrangements that improve connectivity.

Urban and Industrial Land Use

Despite the large number of crawfish consumers in the vicinities of the larger cities, such as New Orleans, Baton Rouge, Lafayette, Houma, and New Iberia, crawfish farming within and near these cities for practical purposes is precluded by exceptionally high land values. Ponds are few in number adjacent to the Mississippi River between Baton Rouge and New Orleans in part due to the presence of a large number of industrial plants that occupy sizable tracts of land.

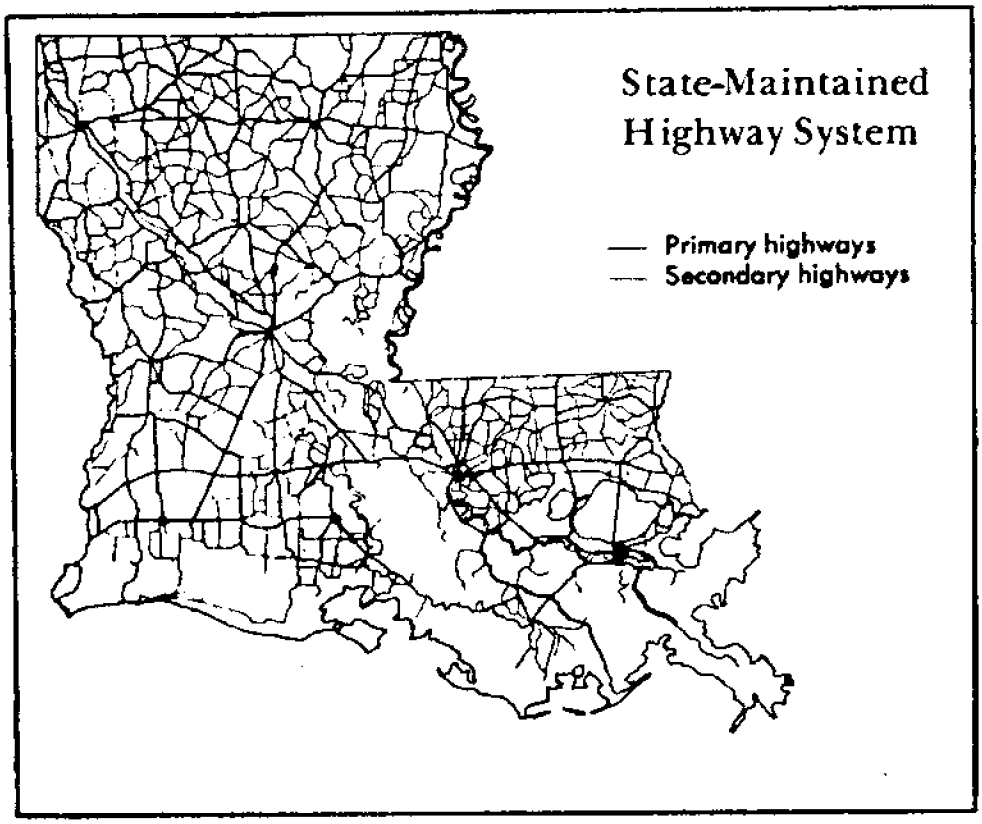

Figure 14. The state-maintained highway network (from Newton, 1972).

Labor

In crawfish farming, harvesting requires by far the greatest amount of labor. As a rule, the smaller ponds are harvested by owners, their families, and in some instances farm hands. In the larger ponds, crawfish are captured by professional fishermen, most of whom are based near the Atchafalaya Basin. The availability of harvest labor varies areally, and is a significant limiting factor of crawfish farming only on the rice region prairies.

In the Teche and Lafourche French core areas the crawfish are harvested by owners, their families, sugar-cane farm hands, and professional fishermen. The services of the professional fishermen are required more frequently in the Teche French core area because, within it, is the greater number of large ponds.

In the rice country to the southwest the bulk of the harvesting often has to be done by the owner and his family. Farm hand laborers

are notably fewer on rice farms than on the sugar-cane farms to the east because rice agriculture is a very highly mechanized operation compared to sugar-cane farming. Further, in the rice region many of the Anglo-American farm hands are reluctant to catch crawfish because they regard crawfish harvesting as degrading "stoop" labor. The Atchafalaya Basin-based commercial fishermen are far to the east and, thus, their services are difficult to engage. Due to the problem of labor shortage in the prairie rice region, the pond density is lower than toward the Teche and Lafourche French cores, where labor does not significantly limit crawfish farming.

State Laws

The extent to which relevant laws circumscribe the actions of the crawfish-farming activity is very limited. Legally there is no closed season for harvesting, and there are no restrictions regarding feasible harvest methods, net or trap mesh size, and quantity or size of crawfish captured. State law, however, requires that the manager possess a $10 Resident Fish Farmer License and a $5 Commercial Fisherman, Bait Seller License (La. Wild Life and Fisheries Comm., 1972). The penalty for violation of either requirement is usually a fine of $25 plus $12 in court costs (R. Montet, personal communication).

Pond Types and Their Distribution

Louisiana crawfish ponds may be grouped into three types: open, swamp, and rice field. The open pond floor is treeless, while there are trees on that of the swamp pond (see Figure 15). The rice field is open, and crawfish and rice are either rotated or grown in the same annual cycle. In the study area there are 334 ponds of which 231 (69 percent) are open, 58 (17 percent) are swamp, and 45 (14 percent) are rice field. The advantages and disadvantage of each are considered in the following separate discussions.

Swamp Ponds

Almost all of the 58 swamp ponds are located on natural-levee back lands of the Mississippi River, Bayou Lafourche, and Bayou Teche and toward the eastern and western margins of the Atchafalaya Basin (see Figure 16). In the main, there are more ponds to the west of the Atchafalaya than to the east, because in the former area the history of crawfish farming is the longer. The characteristic trees of the swamp are bald cypress (Taxodium distichum), a deciduous conifer, and deciduous hardwoods, including tupelo (Nyssa aquatica), red maple (Acer rubrum), and green ash (Fraxinus pennsylvanica) (Brown, 1945). This pond type is absent, of course, in the treeless marshland and prairie regions.

A comparison of average per-acre crawfish yields of productive ponds shows that the swamp pond productivity is about 200 pounds less than the 500 pound figure for the open or rice field pond. The per-acre yield of the swamp pond is lower because quantity of aquatic vegetation

Figure 15. An open pond near Thibodaux.

and oxygen and magnitude of average temperature are less and, therefore, minimally conducive to crawfish growth. An advantage of the swamp pond is that an initial expenditure of from 30 to 100 dollars per acre for complete clearing is not required (LaCaze, 1970). Nevertheless, if trees are closely spaced, some clearing is necessary to permit access for harvesting.

The bar graph of number of swamp ponds versus size shows that the ponds are more or less uniformly distributed above the pond size axis, i.e., not more than 11 percent of the ponds are of a single size (see Figure 17). The evenness of distribution is probably due to the fact that the ponds are often on oddly shaped tracts with the length of one or more sides predetermined by existing ridges of dirt excavated from a drainage canal or ditch. Also indicated by the graph is a notable number of large ponds. Since they are not intensively harvested, and yields per acre are low, the ponds must be generally large in order to permit a minimum amount of crawfish production to pay for initial and recurring costs. The extremely large ponds that are greater than 1,500 acres are located near the Mississippi River about half way between Baton Rouge and New Orleans and are cooperatively owned and managed. In one pond, bald cypress are commercially grown and benefit from the periodic flooding and draining required for crawfish culture.

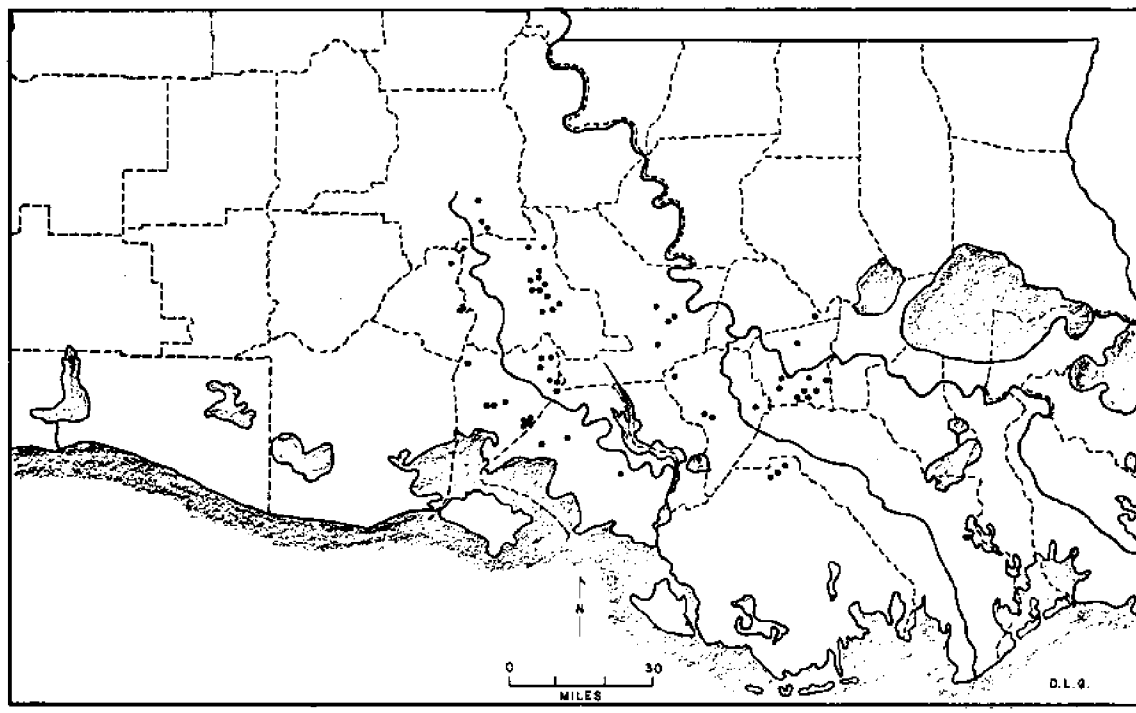

Figure 16. Location of swamp ponds.

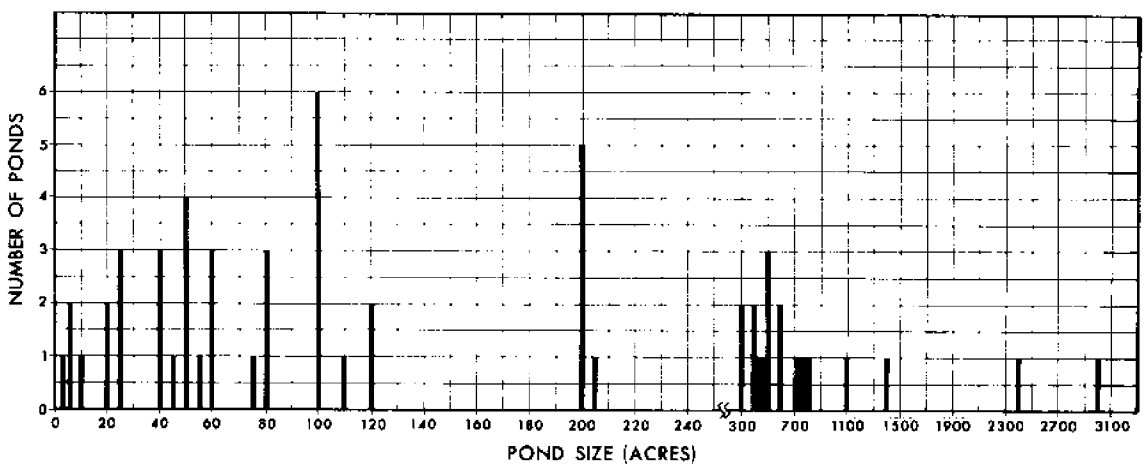

Figure 17. Swamp pond number versus size.

Rice Field Ponds

Forty-five rice field ponds are located on the prairies and the marshland northwest of Vermilion Bay (see Figure 18). Toward the French-Anglo-American culture boundary to the west and northwest, in contrast to the east and southeast, ponds are absent probably because of inadequacy of numbers of French Louisianians and, thus, of market and labor. Further, in those directions general increases in per-acre yield of rice and also of oil royalty income lessen the need for earning supplemental income through crawfish farming.

Almost half the rice field ponds are approximately 100 acres in size (see Figure 19). This is a popular size because with prevailing relief two or three secondary interior levees that run the length and/or the width of the rice field pond are required for water depth control. A small number of secondary levees are highly desirable because they provide convenient access to the pond for harvest. The second greatest number of ponds are 60 acres, the average size of French-owned farmsteads on the prairies (Taylor, 1956). The extremely large ponds are on marshland northwest of Vermilion Bay. These larger sizes are possible because marshland is less expensive than prairie land, and the per-acre cost of leveeing a pond is lower than on the prairies; since relief is relatively low on the marshland, an excessive number of secondary contour ridges for water depth control is never required.

If market and labor conditions are favorable, crawfish farming is a valuable adjunct to rice farming. Levee, water, and pumping are not initial costs of crawfish farming on established rice fields, and the crustacean can be raised on land where rice is rotated. Though crawfish feed on young rice shoots, damage to a rice crop is minimal because when shoots are young, the crawfish are in burrows. Because crawfish feed on weeds, application of widely used 2,4-D herbicide to fields producing rice and crawfish is usually not necessary.

The main disadvantages of crawfish farming in rice fields involve levee heights and use of pesticides. Rice cultivation requires levees that hold only about six inches of water. As a result, rice straw must be returned to the field to provide protective cover for crawfish because avian predation is a serious problem at this water depth.

Spraying of fields with Furadan and planting of Aldrin-treated rice seeds are two widely employed measures for controlling the rice water weevil (Lissorhoptrus oryzophilus), which eats rice seedlings. Application of Furadan to a rice field used for crawfish production should be made only when the rice shoots are young and require lesser amounts. According to Hendrick (1965), use of rice seeds treated with Aldrin at recommended rates does not adversely affect per-acre yield of crawfish; however, residue build-up in crawfish may, in time, jeopardize the edibility of the meat (J. F. Fowler, personal communication), and the use of such seeds is not recommended.

If the crawfish are raised on land off which rice has been rotated,

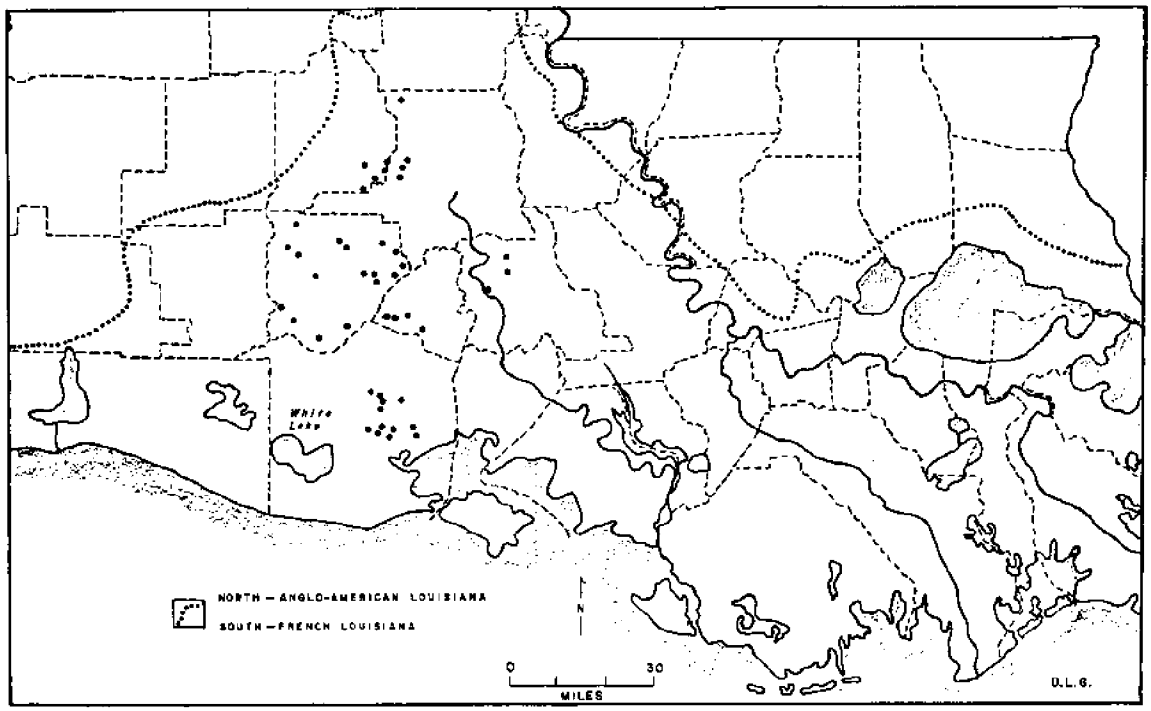

Figure 18. Location of rice-field ponds.

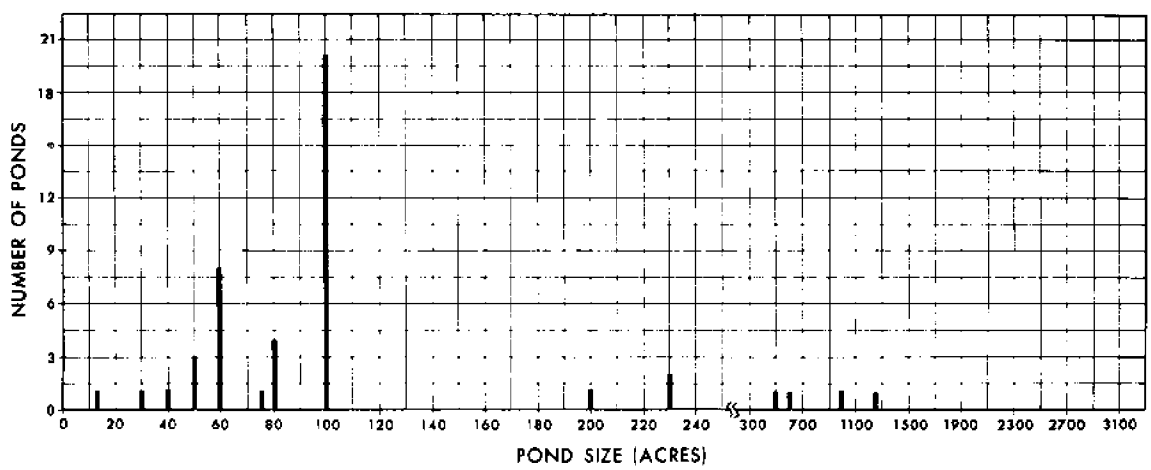

Figure 19. Rice-field pond number versus size.

the managerial procedures, as outlined in Figure 10, are followed. Adjustment of the procedures is necessary, however, if crawfish and rice are farmed during the annual cycle on a field. With rice, fall flooding occurs a few weeks earlier, and spring draining takes place sooner (Thomas, 1962). Thus, there is less time in fall for fish and vegetation control, and harvesting of saleable crawfish during spring ends about seven weeks earlier.

Open Ponds

Most of the 231 open ponds are within and near the Teche and Lafourche French core areas and on back lands of the natural levees of Bayou Teche, Bayou Lafourche, and the Mississippi River (see Figure 20). At these sites the bio-physical and societal-economic factors are favorable. There are three noteworthy clusters of ponds at some distance from the French core areas. Production from the half-dozen ponds north of Lake Pontchartrain, above New Orleans, and from the five ponds near the Mississippi River below New Orleans is for the nearby New Orleans market.

Near White Lake to the southwest is an unusual group of 15 ponds on marshland. Brackish water from this lake with a mean salinity of 0.5 parts per thousand (Chabreck, 1972) is used to flood these ponds, but salinity fluctuations in ponds due to evaporation can cause difficulties. In a nearby experimental pond Perry and LaCaze (1969), for two years, observed crawfish growth with a salinity range of from 3.1 to 8 parts per thousand. They considered that under these conditions a per-acre production of 272 pounds is minimal and could be as high as 1,525 pounds. Their findings are in agreement with Loyocano (1967), who after experimentation stated that 10 parts per thousand may be the highest salinity that crawfish can tolerate. Evaporation, during drought or after an inundation of the ponds by saline Gulf water, can result in dangerously high salinities (J. S. Lynch, personal communication).

The distribution of open ponds, differentiated with respect to size, is illustrated in Figures 21, 22, and 23. The ponds are categorized as small, medium, or large, with labor arrangement and proportion of catch sold serving as criteria for the size ranges. The small ponds, up to 34.9 acres, are in general family-type operations. The family manages and harvests the pond; up to 50 percent of the production may be consumed at home; and the balance is sold. Ponds with sizes ranging from 35 to 99.9 acres are classified as medium. As a rule they are owned and managed by a family, and harvest is by the family with the aid of one or two commercial fishermen. The proportion of the production consumed at home is much lower than that of the small pond. Large ponds are at least 100 acres in size, and on the whole these ponds are harvested only by professional commercial fishermen, usually one to two per 100 acres. Often the significantly large ponds are owned and managed cooperatively.

As indicated in Figures 24, 59 percent of the open ponds are small, and approximately half of them are from 10 to 20 acres in size. Since there is a limit to the amount of crawfish a family can consume, then as

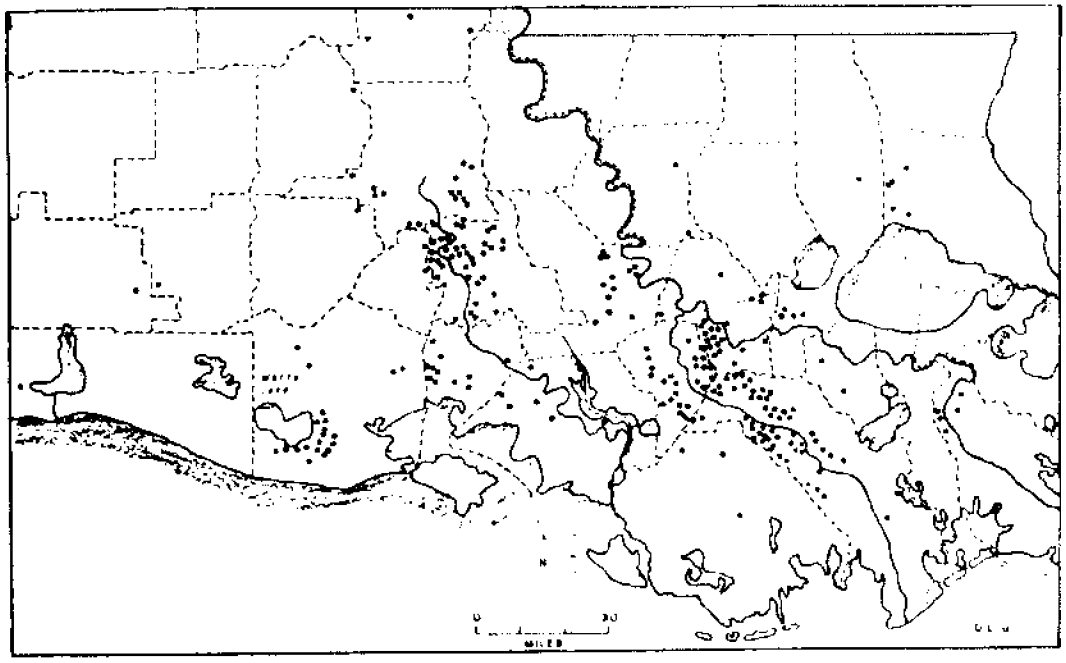

Figure 20. Location of open ponds.

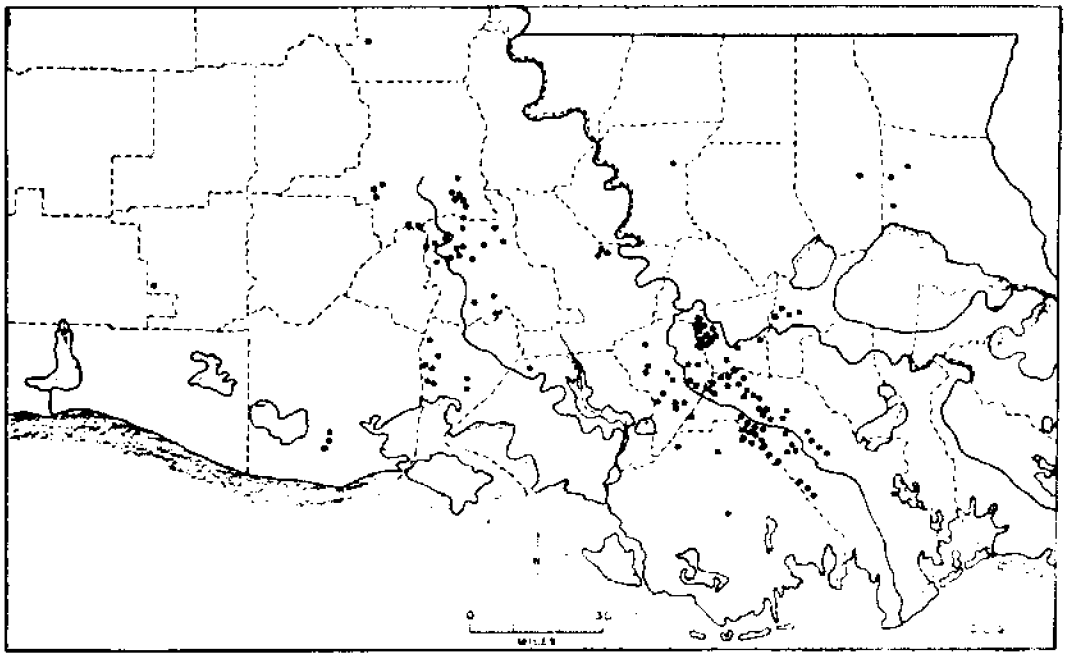

Figure 21. Location of small open ponds.

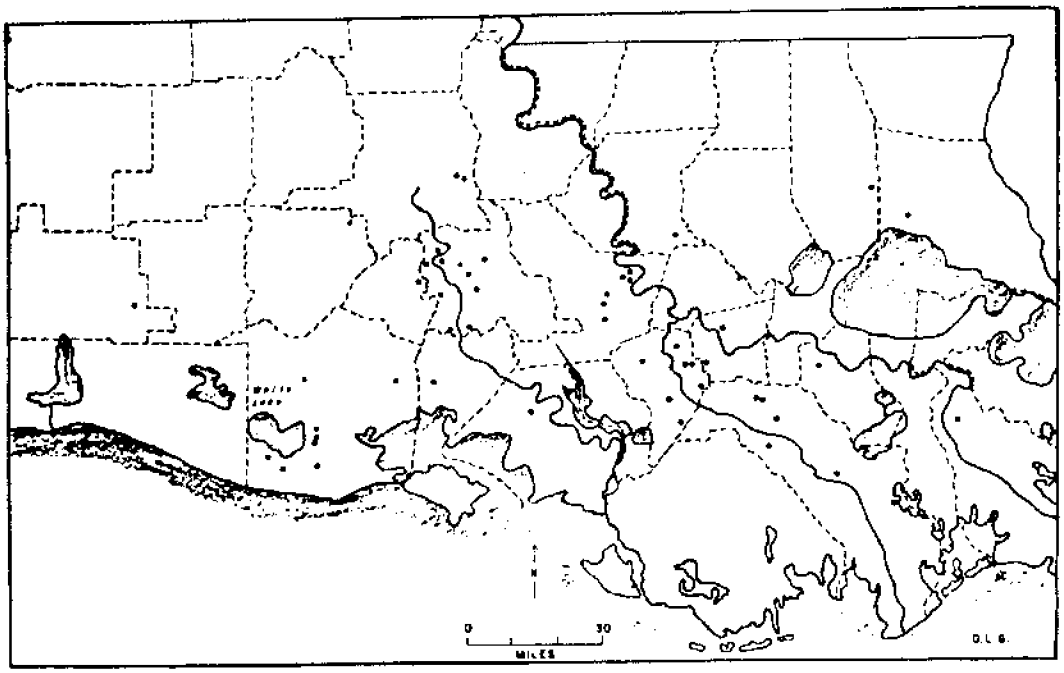

Figure 22. Location of medium open ponds.

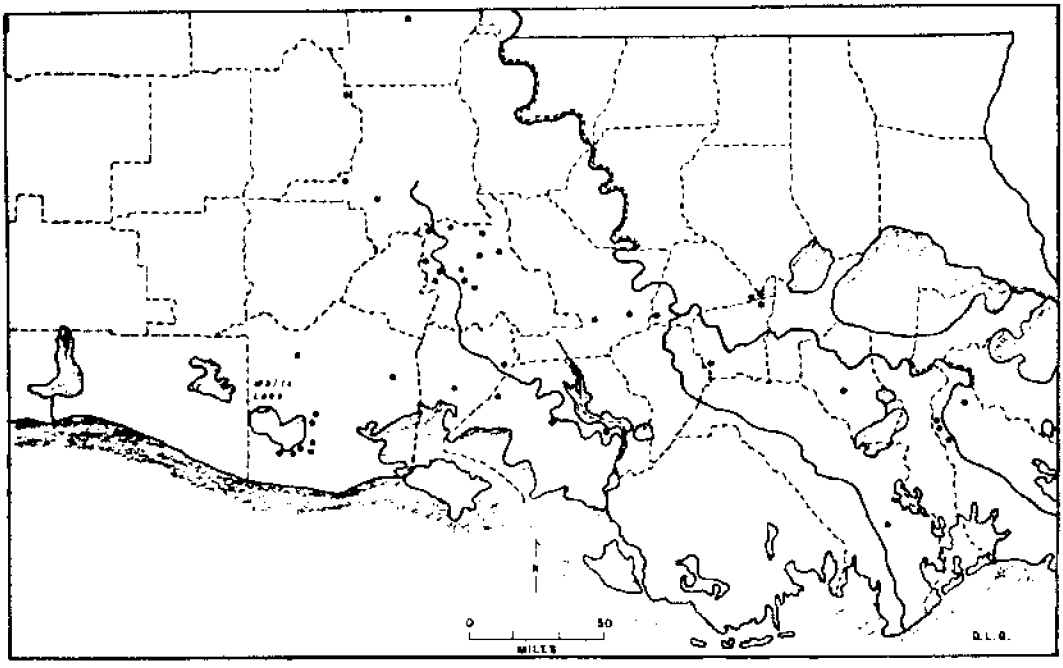

Figure 23. Location of large open ponds.

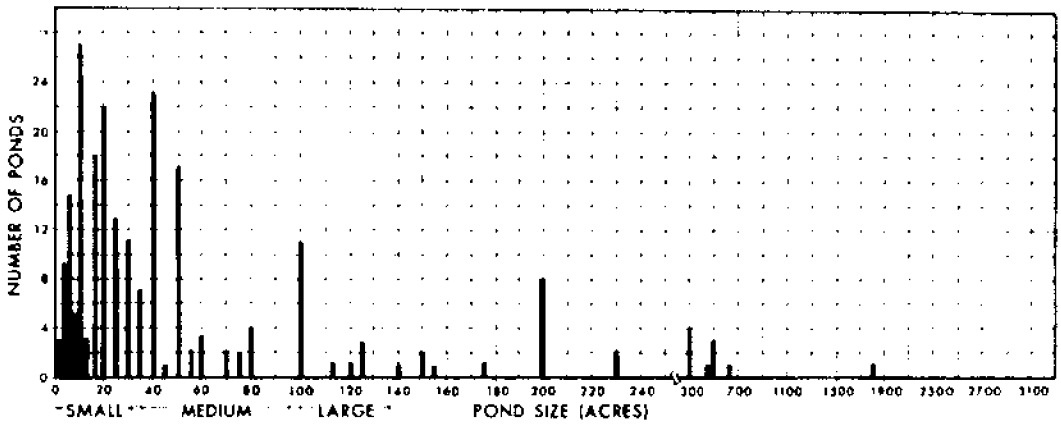

Figure 24. Open pond number versus size.

size of the pond increases, the proportion of the catch that is sold increases. Field inquiry revealed that most families with small ponds are satisfied with the income from the 10 to 20 acre pond.

A majority of the small ponds are located in the Lafourche French core area (see Figure 21). The small pond is prevalent in this area because sugar-cane farms on which they are located tend also to be small (due to a long tradition of multiple inheritance) and because crawfish farming is relatively new; there were only five ponds east of the Atchafalaya Basin in 1961 (Viosca, 1962a). Because crawfish farming is so novel to this area, in contrast to the Teche French core, there has been inadequate time for many of the small ponds to be proven successful; until they are, most crawfish farmers will be reluctant to invest in larger ponds.

About 23 percent of the open ponds are medium-size ponds, and almost three-fourths of them are from 40 to 60 acres in size (see Figure 24). That such a high proportion of the medium ponds are in this range is due to size recommendations made during the past eight years by the experts of the Cooperative Extension Service and the Louisiana Wild Life and Fisheries Commission. They regard a size of approximately 50 acres as the one which provides maximum profit per dollar invested.

The medium-size ponds are located on the eastern and western margins of the Atchafalaya Basin, on both sides of, but some distance from, Bayou Lafourche and the Mississippi River, and near White Lake (see Figure 22). There are almost as many ponds to the east of the Atchafalaya River as to the west. A majority of the ponds are located within the zone where Meigs (1941) found 100 percent French population and in close proximity to the needed Atchafalaya Basin supply of commercial fishermen. In contrast to the small-pond market situation, large volume buyers are important because the medium pond output is greater than that of small ponds. In that regard, production of the medium-size ponds east of the Atchafalaya Basin is marketed largely in New Orleans, while that from ponds west of the basin is sold primarily to nearby processing plants.

Finally, there are 51 large ponds, 18 percent of the total number of open ponds. About three-fourths of the ponds are 200 acres or less in size, and all but one of the remaining ponds is less than 700 acres (see Figure 24). The sizable large ponds are relatively few in number because returns rapidly diminish for larger ponds; construction, water, and pumping costs are relatively high, while intensive harvest of the entire area of a larger pond is rarely, if ever, accomplished.

Approximately two-thirds of the ponds are west of the Atchafalaya Basin, probably due to the longer history and greater confidence regarding crawfish farming (see Figure 23). Furthermore, in the Breaux Bridge area and to the south, the ponds are numerous because of nearby processing plant markets and availability of commercial fishermen and large poorly drained tracts on the margin of the Atchafalaya Basin.

Near White Lake the seven ponds are on inexpensive, nearly flat marshland and connected to the Breaux Bridge market area by a highway.

Those ponds east of the Atchafalaya Basin are located on cleared back land except for the southernmost one, which is a marshland pond. Being extensive in size, the ponds are more remote from settled bayou sides and towns than the small- and medium-size ponds. All of the captured crawfish are sold to New Orleans buyers except those from four ponds. The catches from the three ponds west of Bayou Lafourche are sold to nearby wholesale seafood dealers on the eastern margin of the Atchafalaya Basin, and that from the southernmost pond is sold locally.

Processing Plants and Their Distribution

In the study area there are 33 plants that are licensed by the Louisiana State Board of Health to process crawfish (see Figures 25 and 26). Most plants are family enterprises with the husband and wife composing the management. Since all peeling is done by hand, persons to carry out this task are invariably hired. In the 1966-1967 season individual plants handled from 2,000 to 450,000 pounds of live crawfish and processed from 101 to 15,750 pounds of meat (Hudson and Fontenot, 1970). About 57 percent of the plant owners are proprietors of restuarants, grocery stores, or fish markets that serve as outlets for the sale of live and processed crawfish (Hudson and Fontenot, 1971).

During the past decade, due to increases in supply, and the resulting need to process the surplus which cannot be sold live, and to meet the rising market demand for processed crawfish products, these plants have become numerous and important markets for pond crawfish.

Crawfish Salvaging and Prepared Products

Live crawfish make up about 65 percent of the total volume of crawfish marketed by plant managers, and the market life of these crawfish, which are usually stored in shaded, damp onion sacks, is about five days (Fontenot, 1969). When marketable crawfish become plentiful, often beginning toward the middle of the harvest season due to marketing of catches from the Atchafalaya Basin, or when the price of live crawfish is at a maximum in the beginning of the harvest season, the selling of live crawfish by plant managers becomes difficult. Thus, the need often arises to extend the market life of unsaleable live crawfish through processing them into prepared products for which there is a demand.

Processed crawfish are marketed as peeled tails, precooked preparations, such as bisque (stuffed crawfish heads in gravy with a roux) and étouffée (tails in a gravy with or without a roux), patties, or boiled. These products are particularly convenient to serve because the household or restaurant chef is not required to peel the tails. About 75 percent of the processed crawfish is sold as fresh tail meat; the remainder is more or less equally divided between boiled crawfish and other products (Cox, 1968). Peeled tail meat with containers of "fat" is the most popular

Figure 25. A processing plant near Pierre Part.

prepared product because it permits the chef the greatest degree of freedom to be creative in the final preparation. The shelf lives are as follows: frozen washed tail meat (one year), refrigerated washed tail meat (seven days), frozen, pasteurized "fat" (three months), refrigerated, pasteurized "fat" (two days), frozen tail meat patties (six to eight months), canned, precooked étoufée or bisque (one to two years) (J. E. Rutledge, personal communication), and refrigerated boiled crawfish (a minimum of four weeks) (Lovell, 1968).

Only pioneer research on preparation of crawfish by-products for marketing has been done, and it concerns channel catfish (Ictalurus punctatus) feed. This use of by-products was investigated because roughly 85 percent of a crawfish is waste, and 26 percent of the waste meal is nutritious non-chitinous protein of value in feed (Lafleur, 1967). It was found that although reasonably good growth was produced by the feeding of pelleted waste, a widely-used commercial ration gave a better growth rate (Walker, 1967). Nevertheless, in the foreseeable future crawfish wastes may be processed into pelleted catfish feed near Breaux Bridge, i.e., close to large supplies of waste. The demand for the product should increase as costs of conventional feeds continue to rise, and as catfish culture continues to grow in the state (Kilburn, 1972). In Louisiana there are already approximately 7,200 acres of managed catfish ponds, most of which are located toward the northeast on land formerly used for cultivating soybeans (R. H. Kilgen, personal communication).

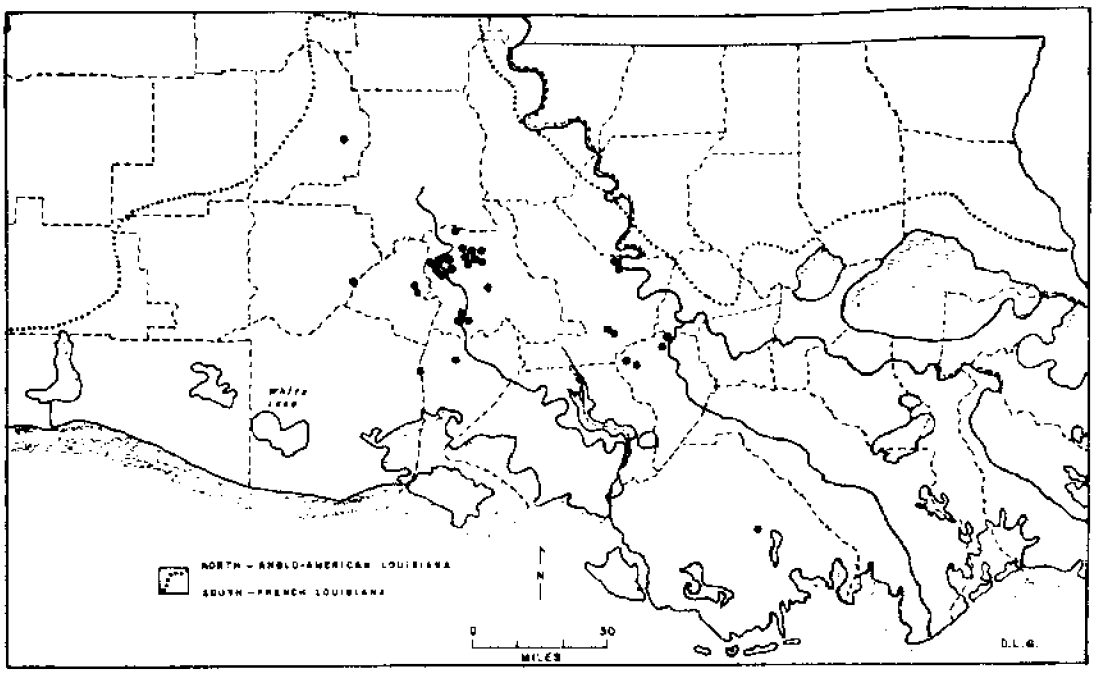

Figure 26. Location of licensed processing plants.

Market Relationships

Processing plants are markets for live crawfish from ponds and unmanaged sources. Twenty-one percent of the plant owners collectively have 1,611 acres of ponds (Hudson and Fontenot, 1971). Processing plant managers purchase approximately 80 percent of the pond production in the Breaux Bridge area (M. A. Andrepont, personal communication), but less than 10 percent of the pond production in the area to the east of the Atchafalaya Basin, where there are only eight plants (J. F. Fowler, personal communication). Plants are attractive markets for pond crawfish, because managers buy large volume lots from suppliers and often all that regular sellers have to offer.

Although the market for crawfish is largely confined to the study area, there is a limited out-of-state demand that is chiefly in the larger cities of eastern Texas where there are many people who were originally from south Louisiana. An average of 1,125 pounds of live crawfish and 600 pounds of peeled tails are shipped out-of-state by each of the processing plants (Hudson and Fontenot, 1971).

Except for occasional trips to markets in New Orleans and Baton Rouge, the delivery radius of a plant within the study area ordinarily is from 50 to 70 miles, or a half-day drive. Almost 90 percent of the live crawfish are sold to fish markets or directly to the general public. The most important type of market for peeled tails is the restaurant (59 percent of the peeled tails). The other kinds of markets for this product are: grocery stores (14 percent), general public serviced from peeling plants (14 percent), and fish markets (13 percent). Finally, boiled crawfish are, as a rule, sold only to the general public (53 percent) and to restaurants (Hudson and Fontenot, 1971).

Plant Distribution

As shown in Figure 26, 24 of the 33 plants are located to the west of the Atchafalaya River, mainly in and near Breaux Bridge, and most of the remaining nine are close to the eastern margin of the Atchafalaya Basin. Only two of nine medium plants, which handle annually from about 1,000 to 9,000 pounds of live crawfish, and one of seven large plants, handling annually 10,000 to 450,000 pounds, is located outside of the Breaux Bridge area (Hudson and Fontenot, 1970). Differences on western and eastern sides of the Atchafalaya Basin of labor supply for peeling, pond crawfish supply, and need for salvaging account for the concentration of plants in the Breaux Bridge area.

In the more populous Breaux Bridge area, labor for peeling is easier to engage than in the smaller communities just east of the Atchafalaya Basin, and the total pond acreage is much greater. East of the basin the need for salvaging through processing is not nearly so great as in the Breaux Bridge area because the lucrative live crawfish markets in New Orleans and Baton Rouge are relatively close and well connected. In addition, since the ponds are newer east of the basin, the crawfish are

of higher quality and command a wholesale price in terms of cents per pound that is generally 30 percent greater than that recieved for live crawfish from the Breaux Bridge area. Thus, east of the basin there is greater incentive for potential plant owners to sell live crawfish, rather than to process the crawfish into a product for lower profit.

Analysis of a Hypothetical Crawfish Farm

Assume a 500-pound per acre yield from a 50-acre pond and a price of $0.34 per pound which is paid by a local buyer, yielding a gross income of $8,500.

The cost of crawfish farming are computed assuming the following:

1. The land, near Raceland, is owned by the manager, and, thus, no land rent payments are involved.

2. The pond floor was completely cleared of trees at the time of pond construction, less than 20 years ago.

3. The only cost associated with removing water from the nearby canal is that of pumping.

4. A professional fisherman captures 65 percent of the crawfish and is paid when the manager sells the catches.

5. The cultural procedures which have been indicated are followed.

The costs for producing crawfish, totaling $4,396.50 per year, are tabulated in Table 4. Examination of the table reveals that the expenses of harvesting, pumping, and stocking account for almost 90 percent of the total. The most important item is that for harvesting; therefore, the labor arrangement with the professional fisherman has a significant impact upon net return to the manager.

The total annual fixed cost is $674.00 and less than one-sixth of the expenses for producing crawfish (see Table 5). Pond and equipment maintenance costs are very minor relative to those of amortizement of loans that were acquired to pay for clearing, pond construction, and purchase of equipment. The initial costs of these three items are as follows. The cost of clearing the pond floor was $3,500, and pond construction required $1,950. The levees were built with a bulldozer which was rented at a cost of $150 per day for 13 days. The equipment cost $1,100 of which $900 was the pump price.

In Table 6 the gross return is compared to the sum of the fixed costs and the costs for producing crawfish, and the net return to the manager is shown. The net return is $68.59 per acre or a total of $3,429.50. Sixty percent of the net return will be invested in the pond operation for the purpose of paying for all of the operating costs of the next farming cycle, except those of recompensing the professional fisherman. The per-acre net return of $68.59 compares favorably with those from other agricultural enterprises in south Louisiana.

Table 4. Approximate per-acre and total annual costs for producing crawfish in a 50-acre open pond.

Item	Approximate Cost	
	Per Acre	50 Acres
Harvesting by the professional fisherman	$55.25	$2,762.50
Pumping (Goodwin, 1970)	12.00	600.00
Stocking	10.35	517.50
Feed and cover plant establishment (Goodwin, 1970)	5.33	266.50
Weed and pest control (Goodwin, 1970)	2.00	100.00
Property tax (H. P. Robichaux, pers. communication)	1.50	75.00
Telephone and misc. (Goodwin, 1970)	1.50	75.00
Total	$87.93	$4,396.50

Table 5. Approximate per-acre and total annual fixed costs for constructing, equipping, and maintaining a 50-acre open pond.

Item	Approximate Cost	
	Per Acre	50 Acres
Clearing - amortized for 20 yrs @ 8%	$ 7.03	$351.50
Pond construction - amortized for 20 yrs @ 8%	3.82	191.00
Equipment, including pumps, valves, pipes, etc., - amortized for 20 yrs @ 8%	2.21	110.50
Equipment maintenance (Goodwin, 1970)	.37	18.50
Pond maintenance (Goodwin, 1970)	.05	2.50
Total	$13.48	$674.00

Table 6. Annual return from producing crawfish in a 50-acre open pond.

Item	Per Acre	50 Acres
Gross return	$170.00	$8,500.00
Costs for producing crawfish, and fixed costs	101.41	5,070.50
Net return to manager	$ 68.59	$3,429.50

SUMMARY

Crawfish farming, which has made a tremendous expansion in recent decades, has been demonstrated to be a profitable use of poorly drained wasteland. In south Louisiana an abundance of suitable sites for raising the species and an almost insatiable demand for crawfish, particularly by French Louisianians, are in large measure responsible for exploitation of the crustacean through crawfish culture.

Most of the ponds are located on back lands of the natural levees of the Mississippi River and of the bayous on opposite sides of the Atchafalaya Basin. The bulk of the remaining ponds are on rice fields in the western portion of the study area. Ponds are either absent or few in number toward the interior of the Atchafalaya Basin, on marshland except near White Lake, and in the northeastern and northwestern portions of the study area. The paucity of ponds in the northern quadrants of the study area is in part due to lack of essential flat land and of local markets for the highly perishable crawfish. Inaccessibility and dominance of peaty soil, which is unsuitable for levee building, make crawfish farming difficult, if not impossible, toward the interior of the Atchafalaya Basin and on coastal marshland, respectively.

All of the rice field ponds and most of the swamp ponds are located to the west of the Atchafalaya Basin. Rice cultivation and crawfish culture can take place simultaneously in leveed rice fields of southwestern Louisiana. The advantages of using rice fields for crawfish farming are twofold. First, the initial investment for levee construction is not required, and second, the rice fields are underlain by a hardpan which makes for efficient flooding. Nevertheless, labor shortage and lack of demand for crawfish are notable obstacles to crawfish culture toward the western and northwestern parts of the rice region.

The swamp ponds are located on the eastern and western margins of the Atchafalaya Basin and on back lands of Bayou Teche, Bayou Lafourche, and the Mississippi River. The longer history of crawfish farming west of the Atchafalaya Basin is the main reason for concentration of ponds on that side. Though yield per acre of crawfish is lower than that for open or rice field ponds, costly complete clearing is not an initial expense of crawfish farming in swamp ponds.

The bulk of the open ponds are on cleared back lands of Bayou Teche, Bayou Lafourche, and the Mississippi River. In these areas bio-physical factors are favorable, and the proportions of the populations that are of French descent are relatively high; French Louisianians make up the most important market for crawfish.

That the small open ponds are more numerous east of the Atchafalaya, and the large open ponds are concentrated west of the basin is in the main due to the fact that crawfish farming is relatively new east of the basin.

Thus, along Bayou Lafourche and the Mississippi, in contrast to west of the basin, crawfish culture is still more or less experimental, and crawfish farmers are understandably reluctant to invest in large ponds.

In contrast, the number of medium-size open ponds located east and west of the Atchafalaya Basin are roughly equal. Processing plants, which are most numerous in the Breaux Bridge area, are the most important market for medium-size pond output west of the basin, while to the east along Bayou Lafourche and the Mississippi River, local buyers, who ultimately sell to markets in populous Baton Rouge and New Orleans, are the prime markets. More than half of the medium-size ponds are from 40 to 60 acres in area because it is the consensus of experts that a size of roughly 50 acres maximizes the profit per dollar invested. For ponds smaller than 50 acres the ratio of pond area to total levee length is relatively small, and thus, the per-acre construction cost tends to be relatively high. It is difficult to harvest crawfish thoroughly from ponds larger than 50 acres in size.

The number of commercially managed ponds increased from 2,000 acres in 1960, to 18,000 in 1970, and to about 44,000 acres in 1973. The recent rapid increase in total pond acreage is due to many factors: diffusion of information concerning improvement of crawfish management techniques, support of the industry by state government, county agents, engineers of the Soil Conservation Service, the Louisiana Crawfish Farmers Association, and other concerned parties, and expansion of the processing plant market.

Despite the high rate of growth of crawfish farming in recent years, in the foreseeable future the annual pond acreage increment will more than likely level off. There are several limitations to future expansion of pond acreage. The majority of the areas in south Louisiana with the more favorable site and situation factors are already used for crawfish culture, excepting marshland with clayey soil located in southwestern Louisiana. According to C. G. LaCaze (personal communication), outside of the marshland of southwestern Louisiana, perhaps only 10,000 to 12,000 acres can be added over the next five years.

The market situation continues to present serious problems. Until a crawfish peeling machine that is feasible to use is invented, new processing plants are not likely to be built. Labor is the greatest operating expense of a peeling plant, and unless this cost is reduced, newly constructed plants probably cannot compete with existing ones (Hudson and Fontenot, 1970). Further, crawfish producers have little or no collective bargaining power. Although mutual agreement by all pond crawfish farmers to seek a minimum price for their product would be advantageous, there continues to be vigorous competition that drives the price of pond-produced crawfish downward. It appears that a peeling machine that would permit expansion of the processing activity, a sufficient minimum price for pond-produced crawfish, and full-time personnel hired by the Louisiana Crawfish Farmers Association to establish market contacts and to co-ordinate marketing would increase the incentive to expand pond acreage.

Research is needed to improve the crustacean and to help assure the viability of the crawfish harvest. C. G. LaCaze (personal communication) believes that pond harvests would be greatly increased by development and utilization of a high protein supplemental feed. If supplemental feed were applied to ponds for one or two weeks during October, the survival and growth rate of young crawfish and the per-acre yield of marketable crawfish very likely would be greatly increased. Breeding of crawfish for larger tails would almost certainly improve the profitability of crawfish culture.

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