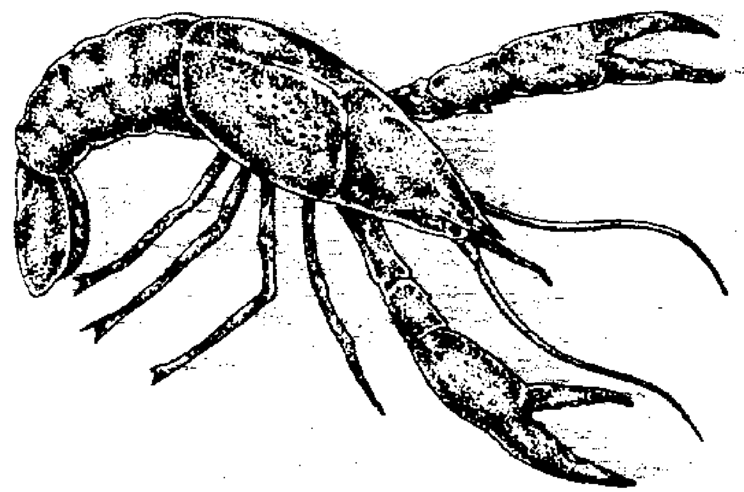
A Production Manual



Culture of the Louisiana Soft Crawfish

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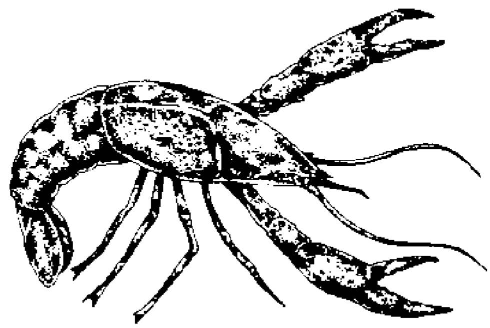

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Introduction

Consumer interest in the Louisiana red swamp crawfish (*Procambarus clarkii*) as a high-quality fishery product is rapidly expanding both nationally and internationally. Approximately 135,000 acres of crawfish ponds were in operation in 1987. In addition, Louisiana has another 750,000 acres in natural swamps that produce an abundance of crawfish.

The technology for the commercial production of soft-shelled crawfish (commonly referred to as soft crawfish) became generally available in 1985. Soft crawfish are produced by holding and feeding large numbers of immature, hard (intermolt) red swamp crawfish in culture trays until they molt. During the 1985-86 production season, seven commercial producers introduced the product to restaurants in Louisiana. By 1986-87, 35 producers were active and, in the 1987-88 season, an estimated 150 producers were in operation. Most of the systems are in Louisiana, but others also exist in Mississippi, Texas, Florida, North Carolina, South Carolina, and Georgia.

The first manual for the commercial production of soft crawfish (Producing Soft Crawfish, Louisiana Sea Grant, 1985) rapidly became outdated as producers quickly incorporated existing technology and modified their culture systems as new research produced new technology. This manual is an update of research since the 1985 publication, and includes a considerable amount of information obtained by working closely with commercial producers.

The following sections discuss pertinent aspects of the crawfish life cycle and pond management, current technology for the selection and collection of immature crawfish, types of facilities in use, the procedures for producing and packaging soft crawfish in a high-density culture system, and a guide for undertaking an economic analysis. Each section covers the latest technology developed by the end of the 1988-89 season (July).

The Crawfish Life Cycle and Pond Management

Young crawfish are produced during every month of the year that ponds are flooded in south Louisiana. Egg production peaks in September and October, and there is a minor peak throughout February and March. To take advantage of the major production period, ponds are flooded in September or October. Three distinct populations of crawfish appear in the ponds after flooding: these are the fall breeders (usually very large) and their young and a small but edible immature crawfish. This immature crawfish is a holdover from the previous season, and was probably produced in the February-March breeding season. It failed to reach maturity in May or June when the ponds were drained. Being forced to burrow, the crawfish remains underground until the ponds are flooded in October. The young-of-the-year crawfish produced in October are too small to catch in November and December, unless temperatures remain warm so they can grow rapidly.

As the season progresses, these three populations change. The breeders disappear through trapping and winter mortality. The old immature crawfish become mature, burrow, and normally produce eggs and young in December or February-March. When they emerge from the burrows, the percentage of mature crawfish in the traps may temporarily rise, but these spring breeders soon disappear. The crawfish that were produced in October reach trapping size in the late winter (February) and became the dominant catch through May when most ponds are drained. By late May many mature and burrow. They become the breeders when ponds are again flooded in the fall.

To complicate the matter, the young crawfish produced in February and March grow rapidly and can be trapped in late April and May. Frequently by May, ponds are depleted of food and the crawfish show signs of stunting. Thus, because of their small size, the spring-produced crawfish frequently cannot be used for producing soft crawfish. The pond owner normally drains the ponds in late May or June in order to plant a summer crop of rice. The rice is harvested in September, and the ponds are flooded for the next crawfish season to begin the cycle once again.

The production of soft crawfish follows this annual cycle. If the season is long (November-June), soft crawfish may be produced for seven months. However, if the fall, winter, and spring are unusually cool, the soft crawfish season may extend only from February through June. To reduce this fluctuation, several different stocking schedules are now underway to produce a summer crop of crawfish (May-September). Ponds are stocked in November with spring breeders and then slowly drained to force them to burrow. A winter or spring forage is planted, the ponds are flooded in April or May to flush the young from the burrows, and trapping begins in June. So far, the results of this schedule have been mixed, as some ponds produce good crops of crawfish and others produce few. In other research, ponds are being flooded as early as August in an effort to get an earlier crop of fall crawfish. The most successful schedule involves stocking mature crawfish with advanced egg development and small immature crawfish in May after a spring crop of rice has been produced. These crawfish attain marketable size in June or July and can be trapped into September. For the summer ponds, there has been a high variability in the percent of mature and immature crawfish. At least 50 percent of the population must be immature to support the soft crawfish industry.

The Molt Cycle

Commercial production of soft crawfish focuses on the molt cycle. Red swamp crawfish undergo several molts (Figure 1) in their life cycle. Molting is more frequent in young crawfish, in warm water. Rapidly growing young crawfish may molt every five to ten days, while older (but still immature) crawfish usually molt within 30 days.

Molting is required for growth. As the crawfish consumes food, the space under its shell is filled. Once filled, no more growth can occur until the old shell is discarded. Toward the end of the growth phase, a soft membrane forms beneath the shell and gradually thickens. It is destined to become the new exoskeleton, but at this stage it lacks calcium (the main substance that gives the shell its hardness).

Calcium is extracted from the old shell through a series of chemical processes and stored as hemispherical stones, or gastroliths, in two pouches on opposite sides of the stomach. This process weakens the shell, allowing the crawfish to escape. Water is absorbed by

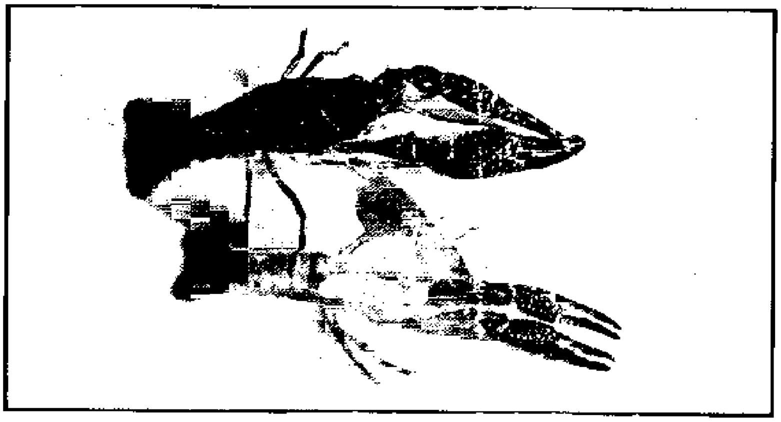


FIGURE 1

The actual molting process occurs very quickly. The carapace (section covering the head and body) slowly begins to slip upward as the crawfish retracts its legs and claws from the old exoskeleton. Once its appendages are free, the crawfish flexes the upper portion of its body backward, and the carapace pops open. The crawfish usually rests a few seconds and then, by simply flipping its tail, frees its body.

At 80, the crawfish is very soft and of prime quality for eating if collected within three hours. Within 12 hours, the new skin becomes somewhat leathery, acceptable for frying but less desirable for other methods of preparation unless the carapace is removed. The tail and legs do not harden as rapidly as the carapace, and, thus, with the carapace removed, the animal can be cooked in a variety of ways. Collecting the crawfish within three hours will guarantee a product of highest quality.

the crawfish after molting, causing the new exoskeleton to expand and creating room for new tissue before it hardens.

Calcium, which hardens the soft exoskeleton, is obtained from the dissolving gastroliths, the hepatopancreas (liver and pancreas), and the blood (called hemolymph). Calcium is also taken from water and food when feeding resumes. Hardening is essentially complete in 72 hours. To obtain the best quality for consumption, soft crawfish must be collected within two to eight hours, depending on water temperature. At 80F the soft crawfish must be collected within two hours, but at 68-70F collection can be delayed up to about eight hours.

In summary there are four recognizable phases to the crawfish molt cycle: (1) intermolt, or hard-shelled crawfish; (2) premolt, the stage preceding the molt, in which the shell is still hard but becoming brittle; (3) molt, loss of the old shell; and (4) post-molt, one to five days following the molt when the shell is hardening.

Selection and Collection of Crawfish

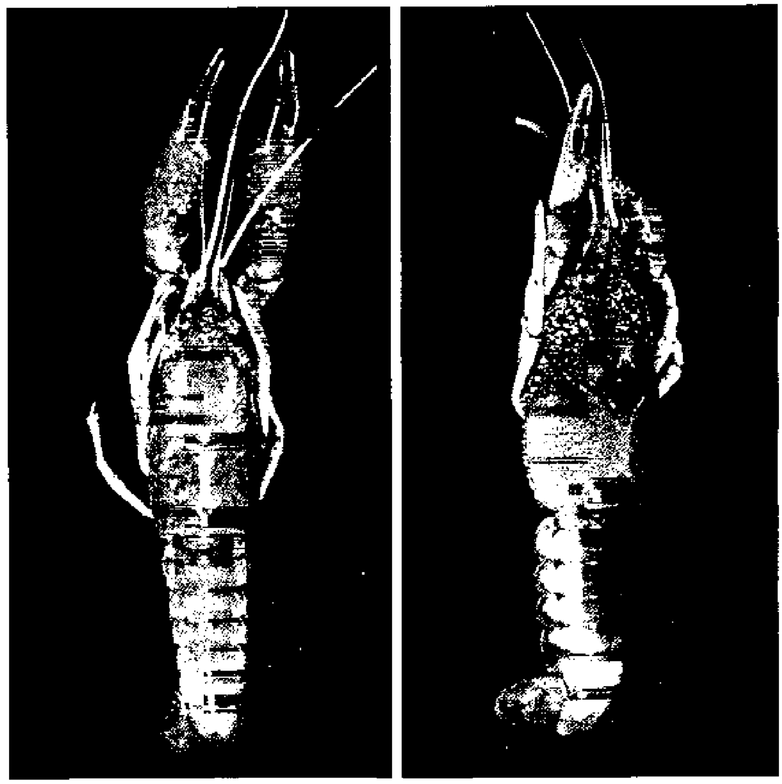
A reliable source of immature red swamp crawfish from commercial ponds or natural habitats is essential for the successful production of soft crawfish. Access to more than one source is desirable because the population may change quickly within a given location. Populations can rapidly mature or begin stunting at a small size if most of the forage is consumed. Locating a reliable source of hard crawfish is most important but is only the first step necessary to ensure successful transfer to and survival in the culture system. The following sections deal with points that must be addressed by a soft crawfish producer to assure a supply of appropriate immature intermolt crawfish.

Selection of Species

In Louisiana there are two species of crawfish of suitable size for soft crawfish systems. The red swamp crawfish (*Procambarus clarkii*) is the preferable animal, as the white river crawfish (*Procambarus acutus acutus*) has not responded to intensive culture very well and the molting rate is too low for commercial production. In a recent study, it was also shown that when red swamp and white river craw-

FIGURE 2

This is the typical appearance of the red swamp (left) and white river (right) crawfish.



fish were placed in the same tank, the molting rate was lower than when the two species were separated. Apparently, some form of antagonism develops. Therefore, it is necessary for the soft crawfish producer to distinguish between these two species (Figure 2).

World-wide, there are many species that might be suitable for producing soft crawfish, but they may not respond to the culture system used for the red swamp crawfish.

Recognizing Immature Crawfish

Because all crawfish of a species cannot be used to produce soft crawfish, the key to success is knowing which crawfish to select. Sexually mature red swamp and white river crawfish in Louisiana molt infrequently, while immature crawfish molt readily when given proper care. In Minnesota, however, Sea Grant researchers found that mature crawfish (*Orcenectes* sp.) molt readily, thus crawfish selection follows a different pattern from in Louisiana.

Some immature crawfish collected from traps are near the molting phase and molt without additional feeding. Others require feeding before they molt. Recognizing immature and mature male and female crawfish is critical to success. The reproductive structures can be seen easily with the naked eye and are accurate indicators for determining whether a crawfish is mature or not. In addition, mature crawfish normally have very large claws and a more intense red and black coloration. The experienced culturist learns to depend on claw size and coloration rather than reproductive structures to identify mature and immature crawfish, and selection is quite rapid.

PREMOLT CRAWFISH. Crawfish within a few days of molting do not feed and seldom go into traps. For example, out of 100 pounds of crawfish collected from traps, 1 pound may be late premolts (within two to five days of molting). These crawfish are identified by their dark color (Figure 3). Most of these premolt crawfish cannot withstand the shock of handling and transporting and will die during the molt process. Fortunately, few of these crawfish are caught in commercial traps

POSTMOLT CRAWFISH. After a crawfish molts in a pond, the exoskeleton rapidly begins to harden. When water temperature is 70F,

FIGURE 3

There are three recognizable stages in the development of red swamp crawfish in the early and late premolt periods.

The crawfish at the bottom still requires feeding and is 10 to 15 days from molting.

The crawfish in the center is committed to molting, does not have to be fed, and will probably molt in three to five days. Note its darker coloration and gray patch.

The dark crawfish at the top is in the late premolt stage and molting will occur in less than 12 hours. The coloration becomes evident within two to three days of molting. The shell becomes brittle and easily breaks if squeezed. The dark color is not actually from the shell but from the new, underlying skin that is highly pigmented.

the hardening process is essentially complete in three to four days, but at lower temperatures, the hardening process may extend to seven days. The exoskeleton remains thin and flexible, and the gills can be seen through the carapace.

Newly molted crawfish are active feeders and will enter baited traps. Although no quantitative information is available, it appears that these crawfish are very sensitive to handling, perhaps as long as one week after they have hardened. When these crawfish are trapped, survival has been poor, most dying within 48 hours after collection.

Expect many losses when the traps contain a high percentage of new molts. However, there appears to be a critical point in development in which, even though the gills can be seen through the carapace, the shell has hardened sufficiently, and the crawfish can handle the stress associated with collection, transporting, and acclimation in the shedding facility. Experience is required to determine whether a postmolt crawfish will survive if collected. If a thin exoskeleton is evident, somewhat flexible along the lower half of the carapace, it is best not to place the crawfish in the culture system. A pond with more than 20 percent new postmolts should be avoided for five to seven days, or the postmolts should be culled out.

Influence of Season on Crawfish Development

Early in the season (late November), crawfish ponds contain a large number of old, immature crawfish and the larger breeders that produced young when the ponds were flooded in October. The immature crawfish are holdovers from the previous season and will molt. The breeders may or may not molt and thus should not be collected. By late February, old immature crawfish reach maturity. The pond catch is replaced by immature crawfish that were produced in October and have obtained marketable size by February. By early May these younger crawfish begin to reach maturity and the percentage of immature crawfish declines rapidly throughout May and June.

In general, if recommended pond crawfish production techniques are followed, a high percentage of the population--about 80 to 100 percent--will be immature from late November through April. In

FIGURE 4

Color is often a quick way to select immature crawfish, which are commonly referred to as "green" crawfish. A crawfish from muddy water, however, does not develop the intense color seen here on the mature red crawfish. Also, if a crawfish is red, it may still be immature, so additional characteristics must be examined. For example, in mature crawfish, the claw size is much larger in proportion to the body. In this figure, the immature red swamp crawfish exhibits the identifying green color. Immature white river crawfish, however, do not display intense coloration, and one must rely on sex-related structures to distinguish the immature crawfish from the mature ones.

May and June the population may contain from 60 to 100 percent mature crawfish.

STUNTED CRAWFISH. A small crawfish is not necessarily immature. Stunted mature crawfish may appear to be immature because of their small size and small claws. Stunted crawfish are common in overpopulated ponds or in ponds with little food (often in May and June). Thus, one must rely on the characteristics shown in Figures 3 through 10, or obtain expert advice until sufficient experience has been achieved to detect these subtle differences.

OLD VERSUS YOUNG IMMATURE CRAWFISH. In Louisiana two groups of immature crawfish are present in ponds. Early in the season (November), many immature crawfish of edible size are present. These crawfish (referred to as old immature crawfish) are holdovers from the previous season and were forced to burrow into the pond bottom when it was drained in May. They emerge in October when the ponds are flooded and appear in the traps in late November. For some unknown reason, they molt very slowly in a water temperature of 70F. Temperatures above 80F are required to give a molting rate that is commercially acceptable.

Later in the season (February) young immature crawfish that were produced in October reach a marketable size. These crawfish molt rapidly in water temperatures of 70-72F. The soft crawfish culturist must learn to recognize the two age groups and make appropriate temperature adjustments to maximize the molting rate. In general, old immature crawfish are available from late November through February. Young immature crawfish begin appearing in the traps in February and become the dominant form through May. Keep in mind, however, that every crawfish pond is different and the population structure can deviate from the general pattern.

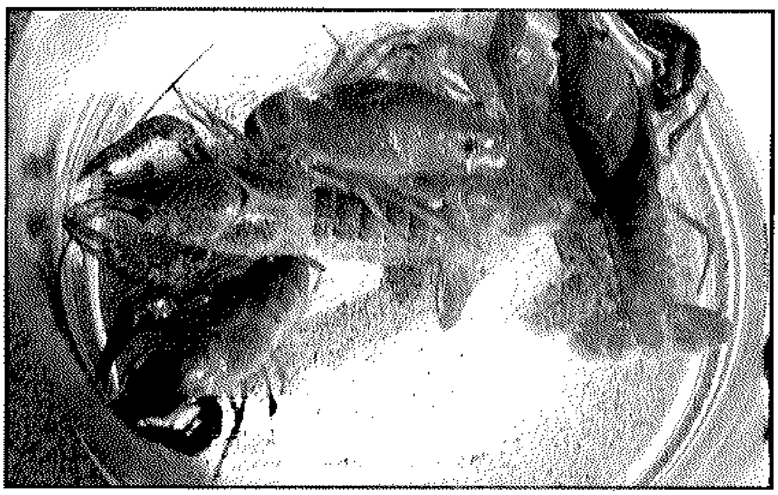


FIGURE 5

This is the typical appearance of a mature female red swamp crawfish. Normally, the annulus ventralis is rust-colored in the central area, but because of frequent mating the rust color may be scraped off.

FIGURE 6

This is a close view of the annulus ventralis of a mature female red swamp crawfish, as seen by the naked eye. The grooving can normally be seen without the aid of a magnifying glass. There is a distinct V-shaped notch on the top edge of the annulus.

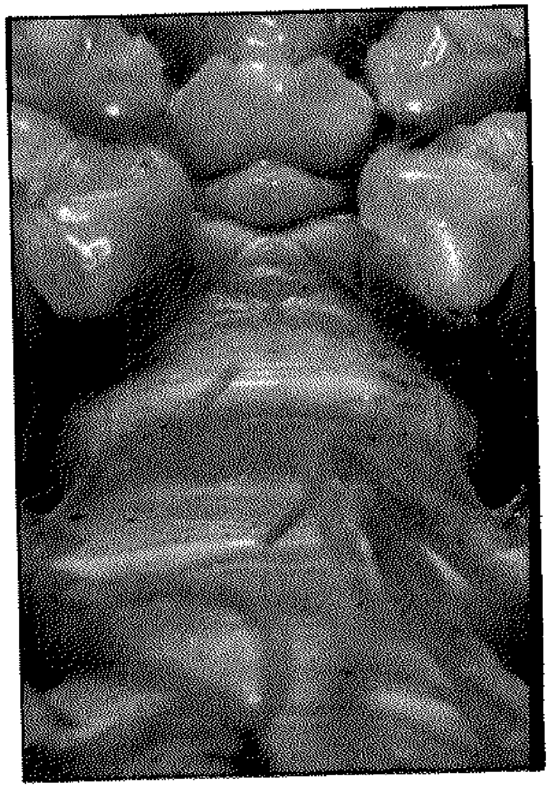


FIGURE 7

In the immature female red swamp crawfish, the annulus ventralis shows only faint grooving and, to the naked eye, the grooves are often not evident. The surface is smooth and cream-colored, and somewhat oval. During the intermolt phase prior to the last molt, a slight groove and V-shaped notch may be evident.

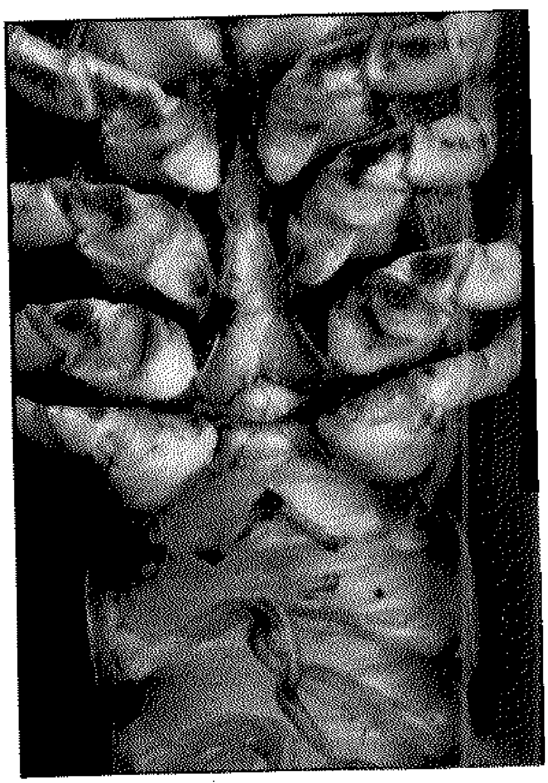


FIGURE 8

In the mature female white river crawfish, the annulus ventralis groove is more pronounced than in the immature stage, but it is not as easily seen as in the mature female red swamp crawfish. The slight bulge that is barely evident in the immature white river crawfish can be clearly seen in the mature specimen. In addition to the expanded bulge, the surface of the mature annulus ventralis is very irregular and loses the smooth, pearl-like quality seen in the immature female.

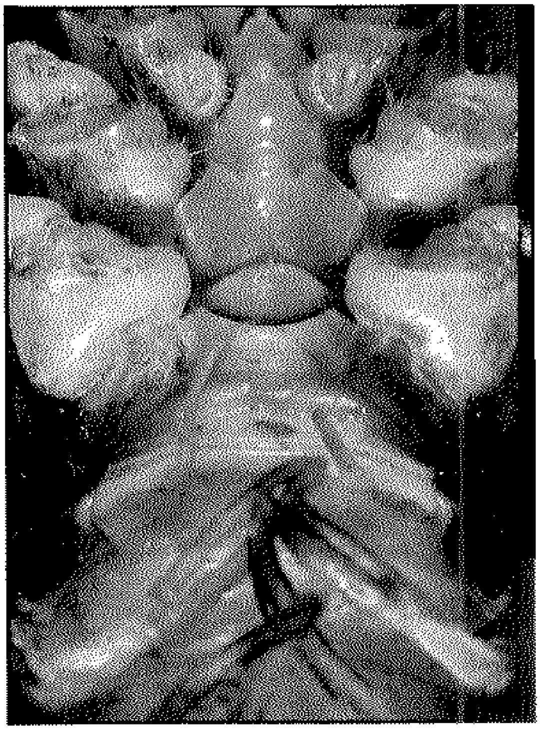


FIGURE 9

In the immature female white river crawfish, the annulus ventralis shows no clear grooving and a slight bulge (upper right section) is often visible. To the naked eye, the surface appears smooth, oval, and cream- or pearl-colored. This is the last stage before maturity. At the next molt, the female will normally be mature.

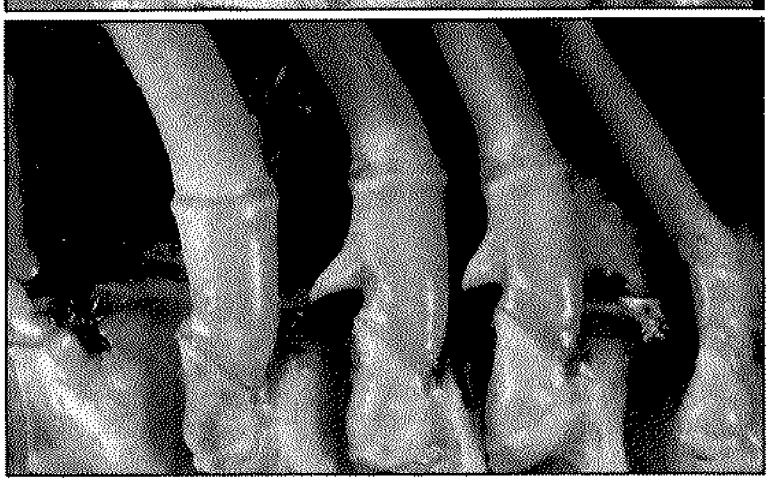


FIGURE 10-A, B, and C

These figures show the hooks on the leg exoskeleton of the male red swamp crawfish. Size is not a factor in a male's reaching maturity. A very small crawfish (two inches) can be mature and show hook development. This is common in ponds where little food is available.

A. The hooks in the mature male crawfish are used to clasp the female during mating. The appearance of the male red swamp and white river crawfish is quite similar, but the shape of the hooks varies somewhat.

B. This male red swamp crawfish will molt once more before maturing.

C. This male crawfish will molt twice before maturing.

Collection of Immature Crawfish

Pond Ownership and Location

Ideally, soft crawfish producers should own or have control of harvesting operations in ponds where the crawfish are to be collected. Lack of control increases the risk of loss. In most cases, such arrangements are not possible, and the culturist depends on a trapper to supply the crawfish. It is essential that the trapper understand exactly how the crawfish are to be selected, collected, and packed. For these services the soft crawfish producer should be prepared to pay a fair price. In return, the producer should expect a high-quality product that has been handled according to specification.

If a pond is close to the culture facility, less time is required in transporting the crawfish. Consequently, crawfish losses are reduced if reasonable precautions are taken.

Trapping, Packing, and Holding Crawfish

If possible, the soft crawfish culturist should run the traps and select the desired crawfish. If this is not possible, avoid taking crawfish from trappers who do not observe the following recommended procedures.

Traps should be lifted carefully and the crawfish poured gently onto the sacking table. The trapper should carefully but quickly select the immature crawfish and place them in sacks attached to the sacking table. The bottom of the sack should be resting on a clean surface (no standing water, oil, or diesel fuel). If possible, about one-half of the sack should be resting on this surface to minimize the weight on those crawfish in the bottom of the sack. Place no more than 20 to 22 pounds of crawfish in a sack, since loosely packed crawfish are less likely to be injured.

Sacks should be tied at the top, picked up horizontally to distribute the weight, and placed on their sides. Place the sacks in a shaded spot, or cover them to protect the crawfish from the sun, wind, or extreme cold. Do not stack the sacks and when transferring them to shore, place them in a location that is not exposed to extreme environmental changes.

Improper Collection Methods

Current trapping and handling techniques for the hard-shelled crawfish industry are not designed to keep crawfish alive for more than a few days. The soft crawfish producer must be able to keep crawfish alive for up to 50 days, and therefore crawfish must be trapped and handled carefully. The following practices, common in the hard crawfish industry, should be viewed with caution.

1. Placing trapped crawfish in washtubs often results in the death of the animals in the bottom of the tub. Whether or not water accumulates in the tub, the crawfish in the bottom layer often die from lack of oxygen. When crawfish are transferred from the tub to a sack or box, mortality usually increases, often occurring several days after the crawfish are placed in culture trays. In general, the more times the crawfish are moved, the greater the chance that they will die.

2. Placing crawfish in covered boxes has been associated with high losses if ventilation is restricted. Frequently the bottom layer of crawfish will die, particularly if the crawfish are layered more than 4 or 5 inches deep.

3. In cool weather there appears to be no problem in baiting traps in the afternoon and then running the traps the next morning. However, as temperatures increase it is safer to bait and run the traps

the same day. When a large catch appears in a trap (2 to 3 pounds), a low level of dissolved oxygen (less than 1.0 ppm) can result in water within the trap. If high temperatures (above 80F) are also present, sufficient stress may be placed on the crawfish to cause mortality within a few days after the animals are placed in culture trays. If pond yield is high when temperatures are above 80F, the dissolved oxygen in the pond and traps should be at least 2 ppm.

4. Standup traps are always preferable to submerged traps because they allow the crawfish to surface if dissolved oxygen is low.

5. Survival of refrigerated crawfish is often poor. It is best to avoid purchasing crawfish that have been refrigerated.

Transporting Techniques

Transportation is stressful to crawfish. Factors contributing to stress include temperature, ventilation, vibrations, time out of water, and condition of the crawfish. In general, the longer the time between trapping the crawfish and placing them in the culture system, the greater the chance of mortality. If possible, avoid transporting crawfish over one or two hours. At the LSU aquaculture research farm, the loss of crawfish is minimal. Ponds are less than five minutes from the culture facility, and this factor may be partly responsible for the low mortality. However, great care is taken in all aspects of handling the crawfish.

During transportation, the sacks should not be stacked. There should be some ventilation, but no obvious wind that could dry out the crawfish gills. All efforts should be made to protect the crawfish from rapid or extreme temperature changes. Ideally, the crawfish should be transported in a van or covered truck. If you have to stop, park the vehicle in the shade. Gradual temperature changes (over two to three hours) are most desirable. We observed a high mortality rate in one instance when sacks of crawfish were placed in the open bed of a truck that had been parked in the sun. Occasionally, some crawfish in a catch will develop orange spots over their shells several days after they have been placed in the culture system. The cause is not known, but it appears to be related to excessive ventilation and perhaps rapid dehydration. Whether the condition contributes to mortality has not been clearly confirmed.

Crawfish can be held out of water for many hours, but survival rates are much higher if the time is minimal. Transportation time should be less than two hours if possible. Some culturists will periodically spray the sacks with water in an effort to prevent dehydration. The value of this practice is unknown, and it could be harmful, particularly if there is a great difference between the temperature of the water and the body temperature of the crawfish. As a general rule, the crawfish should not be suddenly exposed to a temperature difference greater than 5F of its body temperature.

There is much interest in transporting crawfish in trays of water, usually from the pond where the crawfish are trapped. Apparently some success has been achieved by this technique, but the procedure is quite involved, requiring aeration and possibly removal of ammonia. The results do not appear to be any better than those achieved by transporting the crawfish in properly handled sacks. If sacks are used with care, crawfish loss can be held below 5 percent.

Acclimation of Crawfish

Most commercial operators place new crawfish in culture trays for acclimation, a successful practice when proper procedures are followed. However, holding trays, such as those used at the LSU facility, can also work well. A description of holding tray techniques is given at the end of this section.

Acclimation in Culture Trays

Empty culture trays must be used to receive incoming crawfish. When new crawfish are brought into the facility, crawfish from several culture trays are usually combined to make a tray available for the new crawfish. Several trays are temporarily taken out of production, and mortality always increases when current stocks of crawfish are netted and moved to another tray.

When crawfish are transferred from a vehicle and placed in the culture trays, they are once again under stress from movement, the new environment, and increased density. Successful acclimating techniques vary, but even with variation common practices are observed. (1) After the crawfish are placed in the culture trays they are not disturbed for several hours. (2) Exposing the crawfish to a gradual temperature change often takes several hours. (3) The crawfish are not placed directly into water because chemical differences between pond water and culture water can be great. If the animals are not given a chance to acclimate slowly to the new environment, deaths may increase. The following procedures are practiced by most culturists.

1. Carefully transport the crawfish into the culture facility and gently empty the sacks into dry culture trays.

2. Immediately cover the trays with an insulated top (most owners use 3/4-inch styrofoam insulation covered by aluminum). Leave the crawfish undisturbed for at least two hours.

3. Drip (do not flow) water into the tray until 1/4 inch covers the bottom. Turn the water off and leave crawfish for at least six hours (even overnight is acceptable). This water will become very dirty and high in total ammonia content. The pH will usually be less than 8.

4. Add water once again, very slowly, to a depth of 3/4 inch. Then increase the flow rate slightly for another two hours. Thereafter the flow should be turned up to about one-half the full flow rate for two hours, then to a full flow rate.

The temperature of the air and culture water should be similar to the temperature of the new crawfish (within 5F). In a greenhouse the air temperature often exceeds 90F, while the body temperature of the crawfish may be less than 60F in the winter months. By covering the crawfish, the air space within the tray is isolated from the air temperature in the building; thus, the crawfish will gradually warm up and less stress results. The slow flow rate of water (which should be at 80-82F) allows the crawfish to adjust slowly to any differences in temperature as well as water chemistry. It is most important to exercise patience in the acclimation period; 24 hours is not unreasonable.

Another technique that has worked very well was developed by a commercial producer and involves a modification of steps 3 and 4. As in step 3, the water is slowly dripped into the tray. However, it is not allowed to accumulate and the drip rate is maintained overnight, or at least for 12 hours. The water flow is increased the next morning to a very slow flow. After several more hours the rate is increased again and maintained overnight. The second morning the flow is increased to one-half the full rate, and continues for several hours before the water is increased to full rate. A standpipe is added to raise the water level to about 3/4 to 1 inch several hours after full flow is initiated. This technique is becoming more popular.

After 24 hours, feed is provided in small amounts two or three times a day. It is not uncommon for crawfish to consume 3 to 5 percent of their body weight for several days after acclimating, but the rate will soon decline to about 1 percent per day.

Acclimation in Holding Trays

Holding trays are identical to culture trays, but they serve a different function and are managed differently. Basically, holding trays receive incoming crawfish for acclimation, thus allowing all culture trays to remain in full production. By stockpiling crawfish in the holding trays (up to 4 pounds per square foot), daily replacement of crawfish in the culture trays is possible. Over a season, a greater number of molts will be obtained if the culture trays are filled to capacity at all times.

The most effective way to manage the holding tray is to spray a continuous mist over the crawfish, but do not allow water to accumulate in the trays. During the initial acclimation period, handle the crawfish according to recommended acclimation techniques in steps 1 and 2 for culture trays. Drip water into the tray as in step 3 but do not allow it to accumulate. After six to eight hours, increase the flow and hold for about four hours. Increase the flow again to about one-half the full spray for four hours. Over the final four hours, the spray system is turned on gradually until full spray is achieved. Water flow should be about 1.5-2 gallons per minute for each pound of crawfish per square foot, i.e., 4 pounds per square foot requires 6 to 8 gallons of water per minute in a 3 x 8 foot tray. Water used in the holding trays should be the same as in the culture trays.

Dead crawfish are removed each day, and feed is added about three times per week. Crawfish are transferred from the holding trays to replace the dead and premolt crawfish taken from the culture trays. The holding trays can be refilled on a weekly basis. For example, if a producer generates 100 pounds of soft crawfish a week, then only one or two holding trays will be required. Approximately 130 pounds of crawfish would be purchased and split between the two trays. The extra 30 pounds compensate for crawfish mortality during the week.

Operating Procedures

Following acclimation, management activities become less intense, but a daily routine must be followed. Feed is provided daily. Dead crawfish are removed and replacement crawfish added to the trays. Premolt crawfish (within two days of molting), identified by a color change (Figure 3), are removed from the culture tray once each day. They are placed in a molting tray where molting occurs. After collection, molted crawfish are immediately refrigerated, then packaged and frozen the same day. Details of these steps are covered in the following sections.

Culture Tray Management

All culture trays should be maintained at full crawfish density (1 pound per square foot, about 25-30 animals). Premolt and dead crawfish are removed once each day and replacement crawfish are then added to the trays. Most attendants replace premolt and dead crawfish once a week, but daily replacement is preferable. All crawfish should have both claws. Crawfish with only one or no claws are difficult to market.

Once the culture trays have been serviced, they should not be disturbed again, except when the crawfish are fed. Many producers maintain covers on the trays to reduce heat loss from the water. This is a good practice, as the covers probably reduce disturbance. The tops fit loosely so that light will enter the trays, exposing the crawfish to a normal photoperiod (10-12 hours of light).

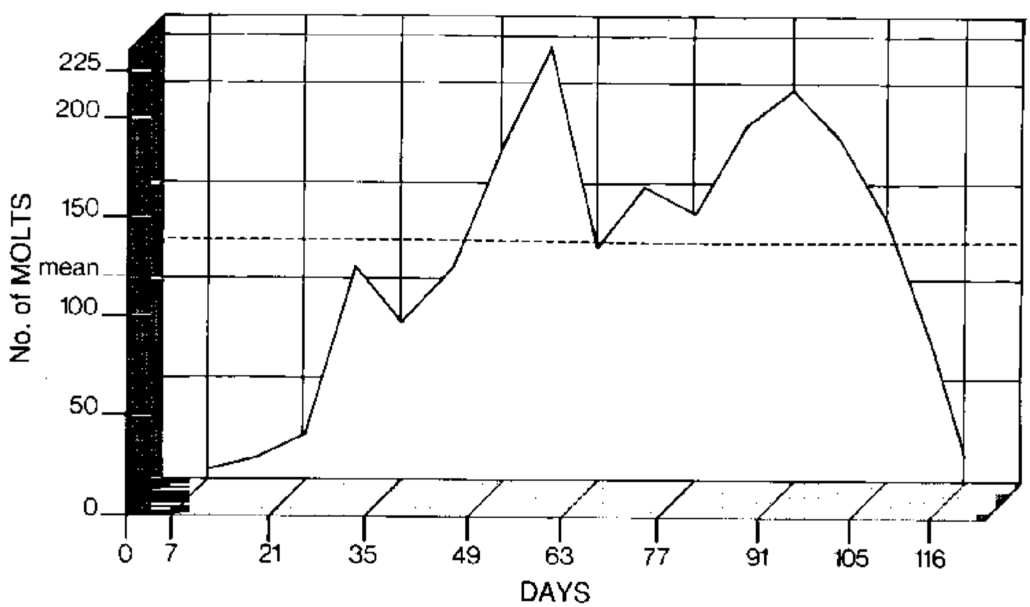
Crawfish under crowded conditions are not seriously cannibalistic if well fed, but if a crawfish molts in a tank with intermolt crawfish, it is usually eaten. Mortality is greatest if crawfish are received in poor condition. If the crawfish are not injured or under stress, mortality should not exceed 1.0 percent per day in the culture trays and 0.3 percent per day in the molting trays.

INITIAL STOCKING AND ACCLIMATION. Assuming that the crawfish have been acclimated properly and survive the first few days, they must still undergo subtle physiological adjustments. Physiologically, the animal has been stressed and its inner chemical systems must settle into a new equilibrium. The animal may resume feeding but few animals quickly enter the premolt condition, and there is little evidence of growth. Complete acclimation may take as few as 28 days or as many as 42 days.

Figure 11 shows the results of a study in which the molting rate of the entire population did not reach the average molting rate until day 42, and Figure 12 shows the average molting rate occurring on day 28 (dotted line). This delay often causes concern for the producer, as it appears that the system is not functioning correctly, but such time lags are consistent with all tests that we have conducted.

FIGURE 11

The weekly molt pattern of crawfish in a soft crawfish facility over 116 days. The dotted line represents the average number of daily molts.



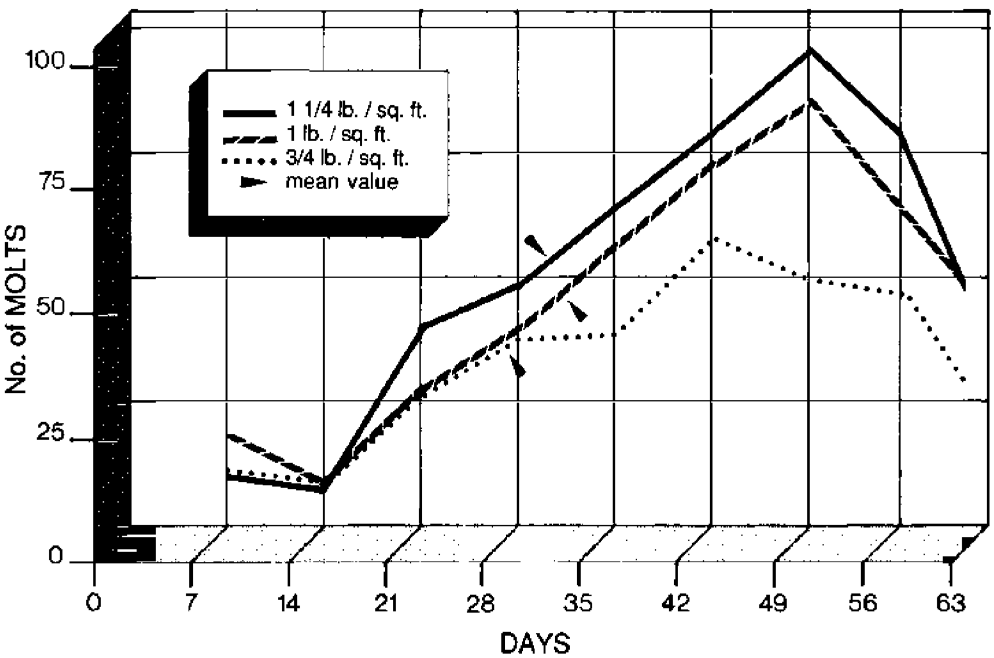
If the crawfish acclimate quickly, the number of crawfish entering the premolt stage will be more evenly distributed over the next 20-30 days. If 30 days are required for acclimation, the increase in premolts can be quite dramatic. Daily fluctuations in the number of premolts can be very large, and the entire population in a tray can enter premolt condition in fewer than 20 days. By adding new crawfish to the trays each day, the daily number of premolt fluctuations will not be as great as when the crawfish are added once a week.

STOCKING DENSITY AND GROWTH. Density affects the growth of crawfish, and thus the number of premolts. Little difference in the percentage of premolts in the culture trays was noted between stocking densities of 3/4 pound and 1 pound of crawfish per square foot (Figure 12). Increasing the density to 1 pound per square foot represents a 33 percent increase, and the number of molts increases by 34 percent. If 2 percent of the crawfish enter the premolt condition each day at a density of 3/4 pound per square foot, the same will occur at the 1-pound density, but more premolt crawfish will be collected. For example, if four trays have a total of 100 pounds of crawfish stocked at 1 pound per square foot, and if 2 percent of the crawfish enter the premolt condition each day, then 2 pounds of premolt crawfish should be collected. At the 3/4 pound density, 1.5 pounds will be collected.

As shown in Figure 12, when the density was increased from 1 pound to 1.25 pounds per square foot (a 25 percent density increase) the production increased only 16 percent rather than the expected 25 percent. Using the example above with 125 pounds of crawfish, the molting rate will decrease from 2 percent to 1.86 percent and yield 2.32 pounds of premolts. The higher density provides little advantage over that of 1 pound per square foot. Mortality at the higher density slightly increases and it is more difficult to pick premolts from the trays.

FIGURE 12

The effects of density on crawfish molting. Each arrow denotes the day that the average number of molts per day was achieved at each density.



The best yield of premolts will be achieved by daily replacing the crawfish that have been removed (premolts and dead). This is not practical unless ponds are near the facility or holding trays are installed. Replacement once or twice a week is reasonable, but yields will not be quite as high as when crawfish are replaced daily.

Maintaining accurate densities is not possible without keeping records on each tray. Record-keeping is time consuming, but it pays off. Most commercial operations estimate the density by visual inspection. Variations of 5 pounds or more per tray are fairly common. At the LSU facility, daily replacement is the rule and records are maintained. Best estimates indicate that the production at LSU is 20 to 30 percent better than most commercial systems that are not having serious problems. Part of the higher production may be related to better management made possible by accurate record-keeping and daily replacement.

FEEDING. The most common practice is to feed the crawfish once a day, but this often results in overfeeding and loss of feed. Feed loss affects the filter system and can result in an increase in total ammonia, nitrite (very toxic), and organic matter. Foam may also appear in the culture tray where water is spraying. This foam is a sign that the filter system is having difficulty breaking down waste materials and excess feed. Thus, maintaining a proper feeding rate is important.

When crawfish are placed in the culture trays they may consume up to 5 percent of their body weight per day for several days (1.2 pounds of feed for 24 pounds of crawfish). However, they will soon settle down to a feeding rate of about 1 percent per day. Multiple feedings (at least two) are preferable to feeding once a day. For example, in a full tray with 24 pounds of crawfish and a 1 percent feeding rate, 0.24 pounds of feed should be added daily, half in the morning and half in the afternoon. If the proper amount is added, it should disappear within 10-15 minutes. If it is not all consumed within one hour, reduce the feed a little at the next feeding. If the feed disappears within about five minutes, increase the rate at the next feeding.

Even though feed is added at an average rate of 1 percent, there will be variation in consumption and each tray must be fed differently. Underfeeding slows the growth rate and reduces the number of premolts from day to day. Crawfish in each tray develop a feeding pattern, and the more efficient attendants vary the feeding rates according to requirements.

The number of premolts produced in a culture tray is a function of proper feeding, temperature, crawfish density, condition of the crawfish, and probably several other factors. Obviously the culturist wants to get the maximum number of premolts at all times. In an effort to stimulate growth, some culturists use a high-protein feed (over 40 percent), but research has clearly shown that this makes little difference in the number of premolts produced (Table 1). High-protein feeds cost more than low-protein feeds. There is no need to use a feed with more than 28-30 percent protein, and feeds having only 25 percent protein have produced a very good molt response.

Table 1. Average number of live molts, dead molts, and dead intermolt red swamp crawfish per day fed five diets containing different protein levels over 60 days.

Diet % Protein	Live Molts	Dead Molts	Dead Intermolts
25	10.8	.33	2.1
32	11.5	.30	1.9
32	11.3	.25	2.0
35	11.5	.30	1.7
43	11.8	.37	1.8

Duobinis-Gray and D. Culley. 1989. Crawfish Tales 8(1,2): 15-16, 27.

High-protein feeds present problems in water treatment. Crawfish consuming these feeds excrete more ammonia and thus the filter must work harder to convert the ammonia to a nontoxic form. Feed with a lower protein content is recommended not only because it is less expensive, but because it puts less stress on the filter system. With the use of high-protein feeds, it is necessary to increase flow rates to remove the additional total ammonia that is excreted.

Three commercial crawfish feeds have been tested at LSU.

The producers are E.I. Dupont, Orange, Texas 76731; Zeigler Bros., Gardners, Pennsylvania 17324; and Burris Feeds, Franklinton, Louisiana 70438. These feeds are reasonably water-stable. By controlling the feeding rate, feed loss and breakdown should be minimal with any of these feeds.

PREMOLT DEVELOPMENT. As the intermolt crawfish approach the premolt condition, a color change is evident along with brittleness of the exoskeleton. The crawfish become much darker, usually turning dark brown with a grayish tint (Figure 3). The reddish color along the sides disappears. The following steps and times describe the general color pattern for crawfish held at about 80F.

1. The dorsal (top) area of the carapace begins to darken, turning grayish brown to brown (seven to ten days before molting).
2. The dark coloration begins to migrate down the sides of the carapace, but the lower edges of the carapace (immediately above the leg attachments) are still firm when squeezed (five to seven days).
3. The sides of the carapace continue to darken, and the lower edges of the carapace are still firm (three to five days).
4. The carapace is uniformly dark and lower edges begin to weaken, becoming flexible when pressed (two days).
5. The lower edges of the carapace begin to slip upward, exposing the new underlying soft skin (less than one day). The molt usually occurs within 24 hours.

This premolt color pattern can vary in intensity according to the source of the crawfish. For example, crawfish from a swamp are much darker than pond crawfish. The reddish color is subdued in swamp crawfish by a dominant brown to black coloration. The same pattern of color change occurs with swamp crawfish but it is more difficult to detect. The attendant will learn to depend more on the flexibility of the lower edges of the carapace rather than the color pattern (step 4 above). However, the attendant will handle many more crawfish, and the inspection time will take longer. With experience, selection of premolt swamp crawfish should take no more than five minutes per tray.

The tray attendant has real problems if the swamp and pond crawfish are mixed in the same culture tray. Most of the time is spent picking up the darker swamp crawfish as they appear to be in the premolt condition. The darker swamp crawfish should always be kept in separate trays. The swamp crawfish will have a less evident color change as they approach the premolt condition, and it is easier to learn this color pattern if they are not mixed with the lighter-colored pond crawfish.

In poorly shaded greenhouses (less than a 92 percent shade cover) top trays without covers will often contain crawfish that turn a grayish blue because of the penetrating sunrays. The color pattern is subdued and carapace flexibility becomes important in selecting premolts. Placement of insulated covers on the trays will block the sun, prevent the color change, and preserve the molting pattern.

Postmolt crawfish have a color pattern similar to that of premolt crawfish, except that the grayish color is not evident in the postmolts. They are more glossy than premolt crawfish, and the lower edges of the carapace are still flexible but not brittle (the shell will break on a premolt crawfish). Postmolt crawfish, if placed in the molting tray, will attack a new molt. They must be removed.

There is one sure way of confirming the premolt condition. If you carefully snap off the tip of one claw (about 1/8 inch) and gently pull the broken tip away from the claw, you will see the flexible underlying skin if the crawfish is a premolt. If it is not, the tip will break away cleanly and no soft tip will be evident.

CARE OF PREMOLTS. When new crawfish are brought to the facility and placed in the culture trays, a few crawfish will be in the premolt condition. They require no feed since they are committed to molting and they should be placed immediately in molting trays. Premolts are very sensitive to stress and handling and transporting can result in their death within a few days, often while molting. It is not unusual to have over 60 percent mortality with these premolts, but the loss can be reduced if extreme care is taken during capture and transporting. Fortunately, these premolts form only a small percentage of the new crawfish, so their loss is relatively minor and the producer should not be alarmed. If a high mortality continues for the next two weeks, however, then something has gone wrong and the producer should seek help.

Within the LSU system, loss of molting crawfish rarely exceeds 0.1-0.3 percent per day. In commercial systems the loss probably averages 3 to 5 percent per day, and in many systems, loss exceeds 20 percent. Many factors contribute to molt death (see water chemistry section), but there are three major differences between the LSU system and commercial systems that may contribute to a lower mortality in the LSU system. These differences involve the handling of new crawfish and premolts.

First, the ponds are less than five minutes from the culture system. Stress related to collecting and transporting is short-term. Second, holding trays are used at the facility. The mortality in the holding trays is low, and even less in the culture trays. The third difference involves handling the premolts. Premolts are collected from a single tray and placed directly into the molting tray within two minutes. In commercial systems it is quite common for premolt crawfish to be collected from as many as 10 trays before they are placed in the molting tray. They are placed in a container without water and often stacked 3 to 4 inches deep. Premolt crawfish are probably under great stress when out of water for up to 20 minutes, stacked on top of each other, and confined to a container that is picked up and moved from tray to tray.

Until more information is available, the premolts should not be held out of water more than two or three minutes. In a large system, the time required for picking up premolts increases. This time loss can be reduced by scattering the molting trays throughout the culture system. This technique is inconvenient, but until a better system is developed it may be better than current practices.

TEMPERATURE. Current recommendations are for maintaining the culture tray temperature between 80 and 82F. At this temperature old immature crawfish will have an acceptable molting rate (Figure 13), and young immature crawfish an even higher rate. Young immature crawfish will molt quite well even at 70-72F. Temperatures above 90F will stimulate more rapid premolt development, but mortality also increases. Current recommendations are to maintain the temperatures above 80F at least from November through February when the dominant catch will be made up of old immature crawfish. Most facilities operate at 80F and higher throughout the season.

FLOW RATES. Flow rates in commercial systems vary from .5 to 2 gallons per minute in a 3 x 8 foot tray. Under full density (24 pounds) water quality is marginal at 1 gallon per minute (gpm). Thus it is advisable to plan for a flow of 2 gpm, particularly in recirculating systems. The higher flow rate is necessary to keep the filter functioning properly and to remove the total ammonia excreted by the crawfish.

MORTALITY. Crawfish loss can be substantial if the animals are mishandled or if water quality is not optimum. A full culture tray (3 x 8 feet) will have 700-800 crawfish. The loss of crawfish should average about 1 percent per day (seven or eight crawfish daily). In well-managed systems, a 0.5 percent daily loss of crawfish is not unreasonable. Most commercial systems probably have a loss of 1-3 percent per day.

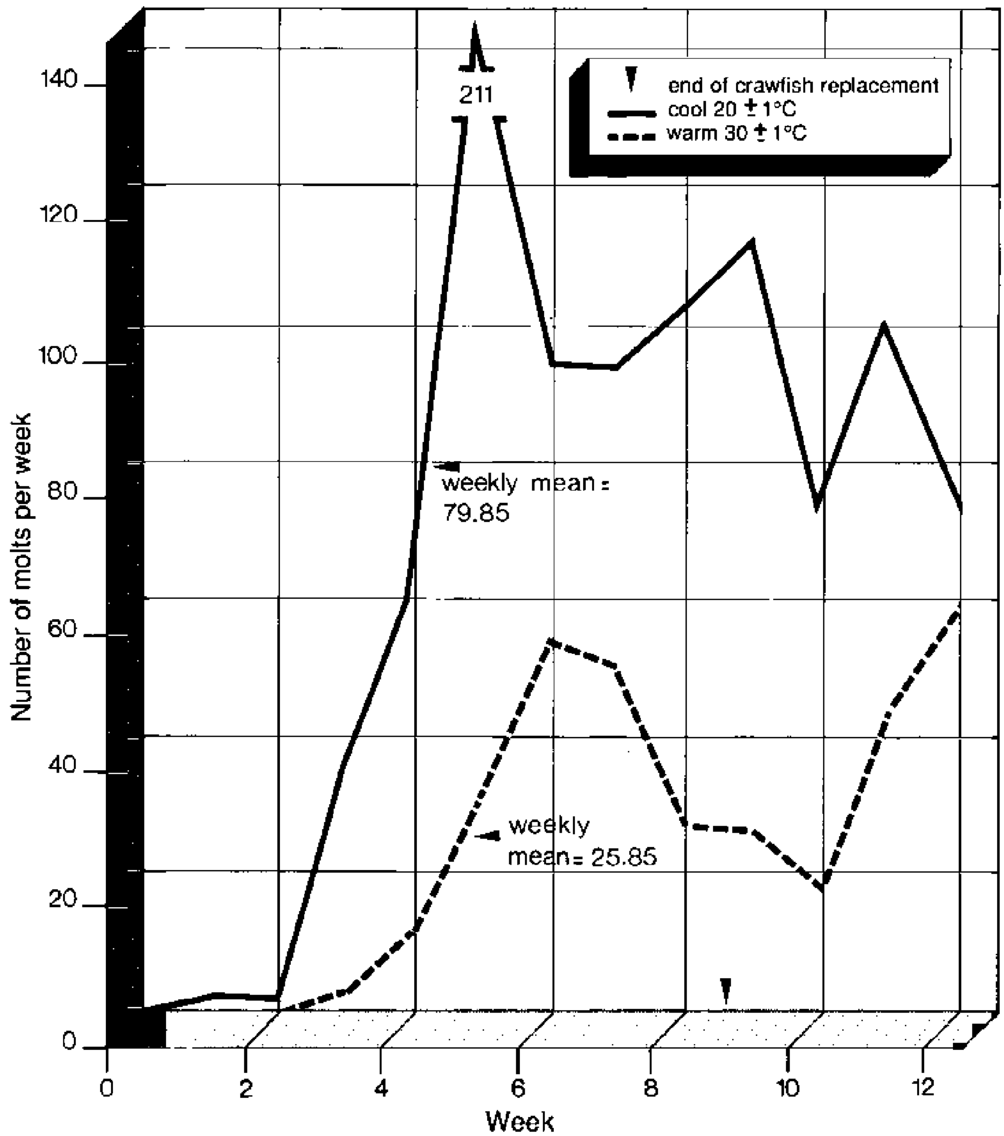


FIGURE 13

The effects of temperature on molting rate of old immature red swamp crawfish.

Molting Tray Management

In general, one molting tray is required for every 10 culture trays when the system is at full capacity. The effect of density in the molting tray on molt mortality is not known. Until more information is available, the density in the molting tray should not exceed the density used for the culture trays, and a lower density may be desirable.

MOLTING TRAY TEMPERATURES. The molting tray temperature is usually the same as that of the culture trays (80-82F). Molts must be picked up in less than three hours at this temperature to be of prime softness for marketing. At 68-70F softness is retained for 8-10 hours, but molts should be picked up within six hours. A temperature difference between the culture and molting trays should not exceed 5-6F.

24-HOUR MOLTING PATTERN. Figure 14 shows the molting pattern over a 24-hour period. Approximately 90 percent of the molts occur in the day, with most occurring between 10 a.m. and 3 p.m., though this pattern varies somewhat throughout the season. Early in the season, molting may be evenly spread over most of the day (9 a.m. to 6 p.m.), but as the season progresses, more molting takes place around the midday hours. Approximately 10 percent of the molts occur at night, and half of these occur in the early morning hours. If attendants collect these night molts about 8 a.m., they are still in a marketable condition. The 5 percent that molt earlier in the night may be too tough for marketing as a sauteed or broiled product, but acceptable as a fried product.

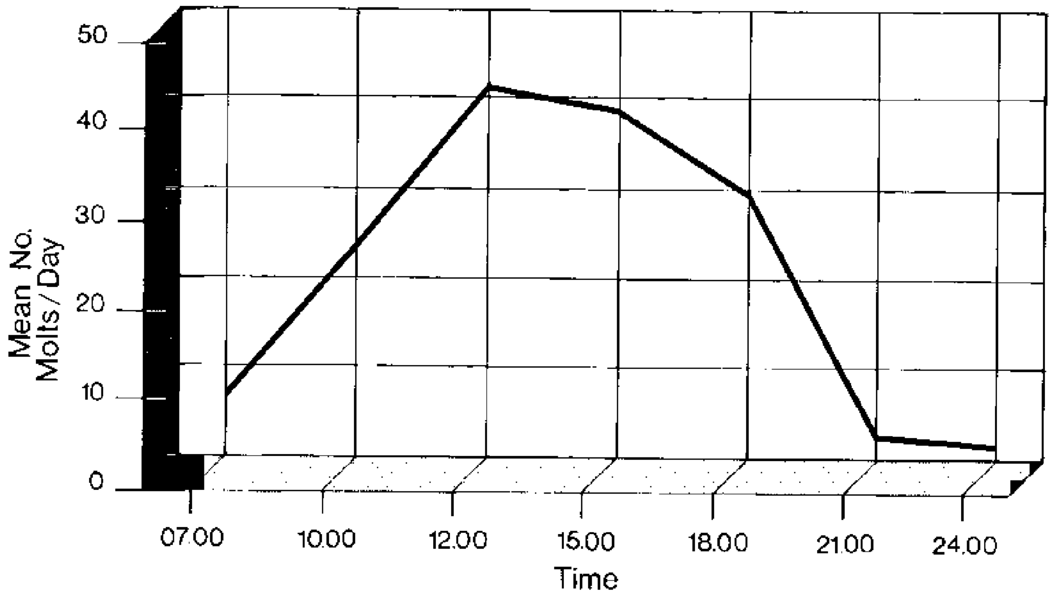


FIGURE 14

The molting pattern of the red swamp crawfish over a 24-hour period.

In large systems, 5 percent night molts can be economically significant. By lowering the water temperature at night to about 70F, the night molts will remain soft enough to market, as the lower temperature extends the softness for about 8-10 hours because the crawfish's metabolism slows down. When the temperature is lowered at night, daytime molting takes place several hours later, even though the temperature is increased to 80F in the morning. The dominant molting interval may shift to a time that is more or less desirable, depending on the producer's particular situation.

The simplest way to manipulate the temperature is to keep the tray covered during the day and remove the cover at night. Because of the large water surface area, shallow depth, and cool night temperatures, the temperature in the molting trays will drop when the cover is removed at night. This technique is not precise but functions reasonably well in cool months. In warmer months it may be necessary to attach a chiller and small treatment system to the molting tray. The chiller is activated only at night. In facilities where the source water is around 70F, it can be used to cool the water in the molting tray.

COLLECTING AND HANDLING MOLTS. When the molting trays are full of crawfish and 100-200 molts are being produced, attendants sometimes miss two or three molts. These crawfish will continue to harden and within 24 hours begin eating new molts. The best method for collecting molts is to remove and count the empty exoskeletons and then pick up the molts. This technique requires only a few minutes and is well worth the effort.

The soft crawfish, when collected, should be placed in a container without water, and not stacked more than three or four inches deep to minimize damage. After collection, the molts are placed in refrigerated water (less than 40F). The cool water greatly slows the hardening process, giving the attendant all day to collect the molts before packaging the product. If left overnight, some crawfish may harden to the point that they cannot be marketed as prime animals but are still edible.

MOLT RATE VARIATION. There has been much discussion about the daily molting rate. How does one figure the correct rate? For calculation purposes the daily molting rate is the number (or pounds) of actual molts each day out of the total number or weight of crawfish in the system expressed in percent. The correct molting rate can only be determined if accurate numbers or weights are known. In commercial systems, maintaining accurate information is very difficult. Under laboratory conditions accurate records have been maintained. To arrive at the molting rate the following formula is used:

$$\frac{\text{Total number (or weight) of molts in one day}}{\text{Total number (or weight) of crawfish in the system}} \times 100 = \frac{\text{molting rate (total molts expressed as a}}{\text{percentage of the total crawfish}}$$

For example, if 20 pounds of molts are obtained in one day from a system that has 1000 pounds of crawfish, then the molting rate is 2 percent:

$$\frac{20}{10000} \times 100 = .02 \times 100 = 2\%$$

If the 20 pounds are not replaced, then the rate will be different if the second day also yields 20 pounds of molts.

$$\frac{20}{1000\text{-}20} \times 100 = \frac{20}{908} \times 100 = 2.04\%$$

If 20 pounds of molts are produced each day, then there is a reduction of 140 pounds in the system after one week. The molting rate on the eighth day would be

$$\frac{20}{860} \times 100 = 2.3\%.$$

Adding 140 pounds to the system restores the tray to full density. Thus, only by daily replacement can an accurate estimate be determined, and this daily replacement must include premolts and any mature or dead crawfish removed.

There are other complicating factors. Some crawfish acclimate quickly (15-20 days) when placed in the system and begin to molt. The next shipment may not acclimate for 30 days and may not contribute much to the number of molts. Fluctuations in the molting rate occur from day to day. There are days when the molting rate may not exceed 0.5 percent (5 pounds per 1000 pounds) and other days when the molting rate may go as high as 8 percent. However, on the average, over the entire season (from the first to the last day) the molting rate ranges from about 1.5 to 3 percent.

For economic purposes, people interested in getting into soft crawfish production must look at the rate over the entire period. In Figures 11 and 12, notice that after the tests were started, it was 28-42 days before the molting rate approached the average rate over the entire study. Only after the systems were running several weeks did the molting rate rise above average. There is a tendency to look at the figures after the system is operating and use the average of these higher rates to estimate production. Use of these higher rates is inaccurate and will produce an unrealistic economic picture.

Length of the season also affects the molting rate. If a system is in operation for 120 days, and for 40 days yields a low number of molts (30 days startup and 10 days at end of the season), then the molting rate is above the season's average only 80 days. But if the system operates 210 days and 40 days are below the average, then 170 days are above the average. Obviously, if 170 days are above the average, the molting rate over 210 days will be higher than that over a 120-day operation if all other factors are equal. Manipulating these figures to look good is quite easy, and can be misleading.

Processing

Removal of Commensal Organisms

A commensal organism is a plant or animal that attaches itself to another plant or animal, receiving some benefit but not affecting its host. Hard crawfish have many commensals attached to their shells. When a crawfish molts, a small worm (*Branchiobdella*) already attached to it then transfers to the soft crawfish.

Branchiobdellids are very tiny but can be seen, and their numbers on crawfish vary greatly. Very few are found in the winter, but as water temperatures rise in the spring, the numbers of these worms increase significantly. Their presence is obvious when the new molts are removed from cold water for packaging, and hundreds can be seen attached to the bottom of the container.

Branchiobdellids are not parasites, so there is no cause for alarm, but market acceptability may be affected, as the worm can be seen in the package. Thus, it is desirable to remove the commensal worms.

Two methods for removal have been worked out. A 0.1 to 0.2 percent salt solution (table salt) will remove the worms in one to two hours, and a 2 percent solution will cause most of them to drop off within 10 minutes. Rinsing the crawfish in fresh water will remove the remaining branchiobdellids. Salt is safe and will not kill the crawfish.

A 50-ppm solution of liquid bleach (sodium hypoclorite) will inactivate the worms in less than 10 minutes. The bleach should not contain any additives. Liquid bleach normally contains 5.25 percent sodium hypoclorite, thus 0.15 ounces (4 ml) added to one gallon of water will give a 50 ppm solution. The crawfish will survive this concentration for at least eight hours. They should be rinsed in tap water before packaging. There are no regulatory restrictions on using this concentration of sodium hypoclorite.

Salt is preferred over sodium hypoclorite because it does not lose its strength in water. Thus, soft crawfish can be added to the solution as they are collected during the day. Liquid bleach will dissipate over time, so crawfish collected late in the day will not be exposed to a solution of full strength and the branchiobdellids on these crawfish may not be killed. If the crawfish are exposed to a sodium hypoclorite concentration overnight, most of them die, but there is an advantage to this. When crawfish are vacuum-packed, the plastic wrapping adheres to the edge of the tray. If the crawfish are alive, legs or antennae frequently protrude over the edge of the tray and the seal is broken. The package loses its vacuum and freezer burn can occur. If the crawfish are already dead, packaging is easier.

Packaging

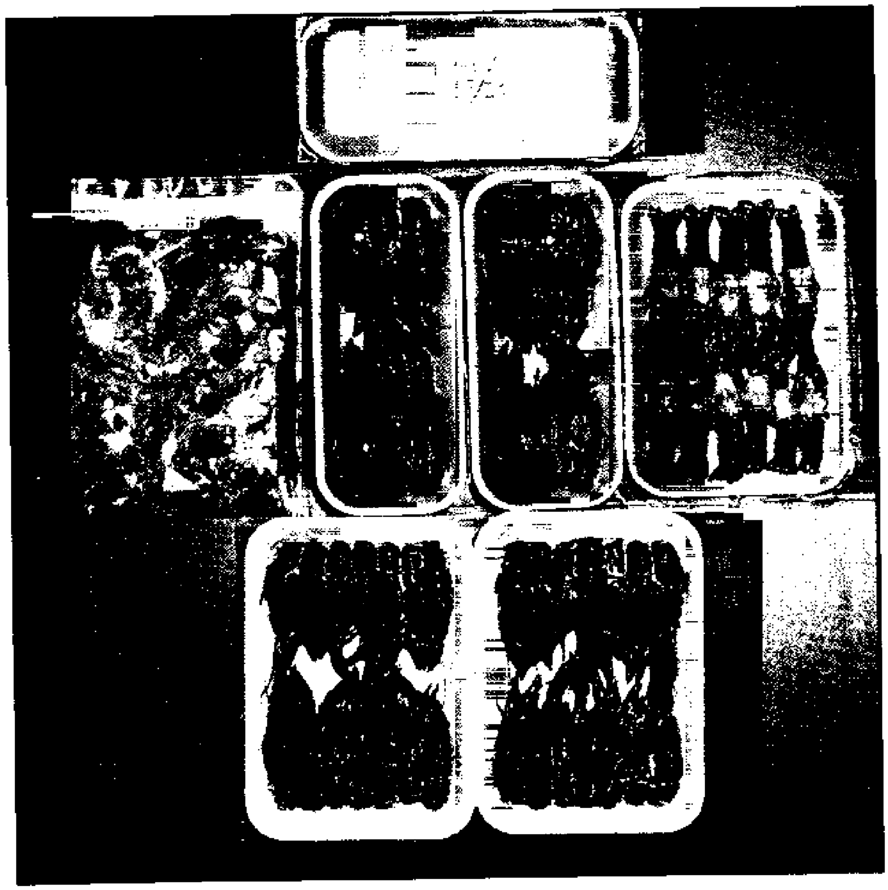
Soft crawfish are rarely marketed as a fresh product, as it is very easy to damage the claws and legs by repeated handling. Almost all the product is collected, held in cold water, graded, and frozen daily. Current packaging practices are changing rapidly and several factors must be considered in developing packaging. (1) Air must be excluded. (2) The product should be visible. (3) The pack should be thin. (4) The package should be tamper-proof. (5) The package must be capable of being frozen quickly. (6) Packages must stack efficiently in storage.

Until recently, most of the product was packed in quart ziplock bags with 1 to 1.5 pounds of crawfish per bag. With this method, sufficient water is placed in the bag to remove all air, and excess water is drained. The plastic bag is flattened and immediately frozen.

The ice prevents freezer burn and provides structural support to prevent the loss of claws and legs. New packaging techniques gaining widespread acceptance involve vacuum-sealing crawfish without the addition of water in shallow trays (Figure 15).

FIGURE 15

Packaging techniques for soft crawfish.



A home freezer is designed to store frozen products rather than to freeze a product. Commercial blast freezing or brine freezing will freeze crawfish faster with better results. When using plastic bags, flattening the bags reduces freezing time. Each package of crawfish should be separated during freezing to allow cold air to completely circulate around the flat package. Never stack or box unfrozen bags of crawfish in the freezer. This practice results in slow freezing and a poor product. Once frozen, the bags of crawfish can be stacked or placed in a master carton for cold storage.

No research data are available on the shelf-life of frozen soft crawfish. However, current restaurant experience indicates that storage for at least six months is not detrimental to product quality and that there is no need for the addition of food preservatives.

Preparation for Use

Because crawfish cease to feed 24-48 hours before molting, the intestine (called vein) is empty and not visible. Its removal is not necessary. However, it is necessary to remove the gastroliths (Figure 16), thus leaving 92 percent of the animal. These two stones (calcium carbonate) are hard and could break a consumer's tooth. The internal organs (called crawfish fat) are rarely removed. These organs include eggs, liver, and the pancreas. Collectively, they are very flavorful, and true Cajun cooking utilizes these products to give distinctive flavors to crawfish dishes. If they are removed, 82 percent of the animal remains. Some restaurants serve stuffed soft crawfish. For this dish, the carapace is peeled off and the crawfish fat removed, leaving 72 percent of edible product. A dressing is molded in the head area, and the product rolled in batter and fried. Covered with a variety of Cajun or oriental sauces, the product is a true delicacy.

FIGURE 16

The processing of soft crawfish is likely to be done by the user. Thus, the crawfish on the far left will simply be collected and delivered on ice or frozen.

In processing, three products can be produced, depending on intended use. The first, second from left, simply requires cutting through the head just behind the eyes, thus exposing two stones (gastroliths) that must be removed. If the carapace is pressed the stones pop out. A deeper cut can be made but another 5 to 7 percent of the product is then lost. With only the stones and the tip of the head removed, about 92 percent of the animal remains.

The second, shown third from left, involves the removal of the stomach and fat (hepatopancreas). When cooked, however, these internal organs add a dimension to the flavor, and are often added to a sauce along with peeled tails. They can be easily removed by squeezing the sides of the carapace. Removal of the head, stones, and internal organs leaves about 82 percent of the animal for marketing.

In the animal on the far right, all internal organs and the carapace are removed. Processing to such a degree is usually done when the crawfish shows some hardening of the carapace (24 hours after molting), making the animal less suitable for consumption as a soft product (except when fried). It is the technique most commonly practiced in preparing and serving stuffed crawfish. Processing to this extent leaves about 72 percent of the animal.

Packaging and Marketing by Weight or Count

Most producers package soft crawfish by fresh weight and count. One-pound packages are commonly used. However, an increasing number of producers are placing a given number of crawfish in a pack (24 or 36, for example), and the fresh weight is then recorded. Most producers are paid by the pound regardless of the method used. If the count technique is used, the weight must be recorded, as it determines the price to the producer. Brokers and restaurants may sell by the count or weight.

Soft crawfish retain water around their gills which adds to the weight, and they must be properly drained before packing. There can be as much as a 20 percent difference in the true weight, with the average being about 10 percent. A 10 percent difference in a 1-pound package means that if all the excess water is drained from the crawfish, then the true weight would be 14.4 ounces (16 - 1.6 = 14.4).

With care this error can be reduced to 5 percent (0.8 ounce per fresh pound). To complicate the matter further, when a pound of frozen crawfish is thawed out, some internal fluids in the crawfish will leak out of the crawfish (drip loss). The drip loss will vary from 5 to 10 percent, depending on how accurate a weight was recorded before freezing. Most buyers will accept an occasional 5 percent weight loss on thawed product, but a consistent weight difference of 10 percent is not acceptable.

Two methods are used to correct weight losses. One is that fresh soft crawfish are removed from water, placed in a perforated container (collander), and allowed to drain about five minutes before weighing. After weighing, the weight is rounded back to the nearest half ounce and then another half ounce is subtracted. For example, if 24 crawfish weigh 16.3 ounces, the weight is rounded back to 16 ounces and another half ounce is subtracted. This gives a final estimated weight of 15.5 ounces. This is a reasonable estimate of the weight if the crawfish are properly drained before weighing. If the weight is exactly 17 ounces, the weight recorded would be 16 ounces.

The second method is to add one or two crawfish to the package rather than subtracting weight. Crawfish are added when the buyer wants a 1-pound package and is not so concerned about the number of crawfish in a pack. For example, if 24 drained crawfish weigh 1 pound (16 ounces) and a 5 percent weight error occurs, the true weight will be 15.2 ounces. The addition of one large crawfish (20-21 count) will bring the weight very close to 16 ounces. If the pack contains 36 crawfish to the pound, then two medium crawfish (30-34 count) will correct the weight loss.

It is important to remember that the weight of the container holding the crawfish must be subtracted. If, for example, heavy-duty zip-lock bags are used, the crawfish must be drained, placed in the bag, and then weighed. The bag will add 1/4 ounce to the total weight (including a full label on the bag). This 1/4 ounce must be subtracted from the weight.

Crawfish have been placed on absorbant pads a few minutes before taking weights, a technique that reduces the weight error about 2 percent. However, it takes longer to weigh out the animals and more claws will be broken off through handling. Crawfish with no claws or only one claw are marketable, but only two or three such crawfish are placed in a pack.

Soft Crawfish Production and Processing Regulations

All seafood processors must be aware of and comply with all regulations and requirements of the Louisiana Seafood Sanitation Unit (LSSU) and the U.S. Food and Drug Administration (FDA). Both have main offices located in New Orleans and agents who work throughout the state. The LSSU regulates all intrastate commerce (products staying within Louisiana borders) while the FDA regulates all interstate commerce (products crossing state lines). Both agencies enforce the same regulations, which fall into three main categories: microbiological guidelines, sanitary processing, and packaging and labeling. Under current regulations, all seafood processors must register and receive a permit from the LSSU. Seafood processors freezing seafood do not have to register with the FDA.

Because soft crawfish packers do not process the crawfish, the LSSU has determined that soft crawfish packers are not considered seafood processors. This action precludes registering with and receiving a permit number from the LSSU. It must be emphasized that at some future time, soft crawfish packers could be designated seafood processors and would then be subject to all applicable regulations, including filing for a seafood processing permit. If the packer cuts or dresses the crawfish in any manner or removes head stones, then the packer would be considered a processor and must apply for a permit.

When soft crawfish packers are not considered processors, they do not need an approved packing and freezing facility. It is permissible to pack the crawfish in any suitable building or room. However, you cannot use any part of your personal living quarters, including your kitchen, to package, freeze, or store the soft crawfish.

All packages of crawfish entering into commerce must meet all food packaging requirements. The requirements for labeling are often complex and your label should be prepared professionally by a firm that has experience in label preparation. It is strongly suggested that, before you have your label printed, you send a copy of the prepared label to the chief of the Louisiana Seafood Sanitation Unit for approval. All labels must include such things as name of the food (whole, frozen soft crawfish), name and address of the packer, and net weight of the crawfish. For further information write or call:

Louisiana Department of Health and
Human Resources
Seafood Sanitation Unit
P.O. Box 60630
New Orleans, LA 70160
(504) 568-5406

Soft crawfish packers offering products for sale must register food labels with the Louisiana Food and Drug Control Unit. There is no cost associated with the registration of your label. To obtain a label registration form, write:

Louisiana Food and Drug Control Unit
P.O. Box 60630
New Orleans, LA 70160

Any company or individual offering seafood for sale in Louisiana must apply for and purchase a wholesale/retail dealer license. Soft crawfish packers fall into this category, so they must purchase the license. The annual fee for the license is $105. Applications may be obtained from the Louisiana Department of Wildlife and Fisheries.

Louisiana Department of Wildlife and Fisheries
P.O. Box 15570
Baton Rouge, LA 70895
(504) 925-4435

In addition to a wholesale/retail dealer's license, it may be necessary to obtain a transport license. This is true when more than one vehicle is used at the same time to transport your product. A transport license is $30 annually. It is strongly suggested that you consult with the Louisiana Department of Wildlife and Fisheries to determine your need for this license.

Crawfish Size and Marketing

Soft crawfish are successfully marketed in sizes ranging from 20 to 45 count, or 20 to 45 per pound (see Table 2). Crawfish larger than 20-count size are not readily available in large quantities. Crawfish smaller than 45-count are frequently available but the producers must increase time and labor in culture, and they prefer not to exceed 45-count. Restaurants have not expressed interest in crawfish over 45-count.

Over the four years that the industry has been in existence, consumers have requested two size groups. Brokers want crawfish of fairly uniform size within a package. A 20- to 29-count crawfish is large enough to be served stuffed as well as fried. A 29-count crawfish is about 3.5 inches and a 20-count crawfish is close to 4 inches. Crawfish from 30- to 45-count vary from 3.5 to 3 inches, and are excellent for most types of preparation except stuffing. Thus, the two groups are reasonably uniform in size within each group and are requested by most buyers. Additional grading by size may become important as the market develops.

Table 2. Approximate length-weight relationship, count, and availability of red swamp crawfish held in soft crawfish production facilities.

Total Length (cm)	Total Length (in)	Weight (g)[a]	Number Per Pound	Product Availability
7.5 - 8.0	3.0 - 3.2	10-13	45-35	15%
8.1 - 8.5	3.2 - 3.4	13-16	35-28	80%
8.6 - 9.0	3.4 - 3.6	15-19	30-24	
9.1 - 9.5	3.6 - 3.8	17-21	27.22	
9.6 - 10.0	3.8 - 4.0	20-24	23-19	
10.0 - 10.5	4.0 - 4.2	24-31	19-15	5%
10.5 - 11.0	4.2 - 4.5	28-42	16-11	

[a]1 ounce equals 28 g.

Water Quality

Well water, surface water, or treated recycled water can be used in the trays, but the water must be of acceptable quality. If city water is used, the chlorine should be removed, either by aeration for 24 hours or by the installation of an activated charcoal filter. Some cities add chloramine rather than chlorine to the water supply. Activated charcoal filters will remove chlorine, which can be toxic to crawfish. However, the charcoal will only remove the chlorine molecule of chloramine, leaving the amine molecule, which contains ammonia (toxic). Thus, the charcoal filter is of little value. City water may be too expensive if the water is to be discharged, but using it only for makeup water in a recycling system is economically feasible.

Surface water is often used. During the winter, surface water can get quite cold and heating costs will increase. During the summer months water temperatures frequently exceed 90F. The culturist must accept this temperature, add a water cooler to the system (see next section), or devise another method to reduce or prevent heat buildup in the water.

Temperature

Ideally, water temperature should be maintained at about 80-82F, but temperatures as high as 85-90F are acceptable. Above 90F the molting rate is very rapid and mortality increases, though this is still economically favorable. Below 70F the molting rate will decrease and thus reduce production. Below 76-78F the fall crawfish (November-February) will not molt at an acceptable rate for commercial production (see "Influence of Season on Crawfish").

Suspended Matter

Pond water is occasionally used in the culture system,. but algae, dead organic matter, silt, and aquatic organisms can clog up spray nozzles at the culture tray. To avoid clogging, 1/4-inch holes should be used instead of spray nozzles. Unless the flow approaches 2 gpm, the water will not exit from a 1/4-inch hole with enough force to provide adequate aeration. The water should be aerated prior to entering the culture tray if flow rates are low.

Water Chemistry

Some water quality standards suitable for fish are also acceptable for crawfish. These include pH from 6.5 to 8.5; calcium hardness and total alkalinity (both as calcium carbonate) over 20 mg/l (ppm); and oxygen above 3 mg/l (ppm).

These values vary considerably in some cases; for example, calcium, alkalinity, and oxygen can be much greater, but high calcium causes the soft crawfish to harden faster. Less than 20 ppm of calcium is not detrimental and may be beneficial by lengthening the time for calcification of the new shell. The LSU system contains less than 5 ppm calcium.

Toxic Substances

The culturist should be cautious about substances such as hydrogen sulfide (H2S) (probably toxic above 1 ppm), saline water (above 0.8 percent), pesticides, sewage, industrial waste, and excess fertilizer (nitrogen compounds in particular). Water quality tests should be performed prior to facility development by a state agency or private company.

Research and observations at commercial facilities have identified three substances that most often cause deaths in soft crawfish facilities: total ammonia, nitrite, and iron. Deaths are most common in the molting trays. Observations in commercial facilities during the 1987-1988 season indicated that deaths in the culture trays averaged 1-3 percent per day overall, while mortality in the molting trays averaged 5-10 percent. Some systems with water quality problems exceeded 25 percent death in molting trays. In many cases, the loss could be traced to these toxic materials.

TOTAL AMMONIA. Total ammonia is defined as the concentration of NH3 (ammonia) plus NH4 (ammonium). Research with fish and crawfish has indicated that NH3 is highly toxic, whereas NH4 is relatively nontoxic. The ratio of NH3 to NH4 is directly related to the pH of the water (Figure 17). At pH levels below 7.3, all of the total ammonia is in the NH4 form. As pH levels rise above 7.3, NH4 begins to convert to the toxic form, NH3. Between a pH of 9 and 9.5, 30-50 percent of the total ammonia will be NH3. However, the conversion of NH4 to NH3, and the reverse, is complicated by the fact that ammonium hydroxide (NH4 OH) is formed between the conversion. That is, NH4 converts to NH4 OH and then converts to NH3 as the pH increases. As the pH decreases, the steps are reversed. Although NH3 is toxic, it is volatile, and therefore quickly evaporates into the air. Ammonium hydroxide is also toxic, but is soluble, thus remaining in the water. Deaths attributed to ammonia are probably caused by ammonia and ammonium hydroxide. A test for total ammonia includes a measurement of NH3 + NH4 + NH4 OH, but the test does not identify the quantity of NH4 OH.

Crawfish excrete ammonia and ammonium (NH3 + NH4) into the water. In addition, the breakdown of feed in the water contributes to the total ammonia load. Studies at LSU suggest that total ammonia should not exceed 0.5 ppm when the pH is below 9. In flow-through systems the concentration of total ammonia can be controlled by increasing the flow rate to flush ammonia from the system or by decreasing the crawfish density. In a recirculating system, biological filters contain bacteria that convert total ammonia to nitrite

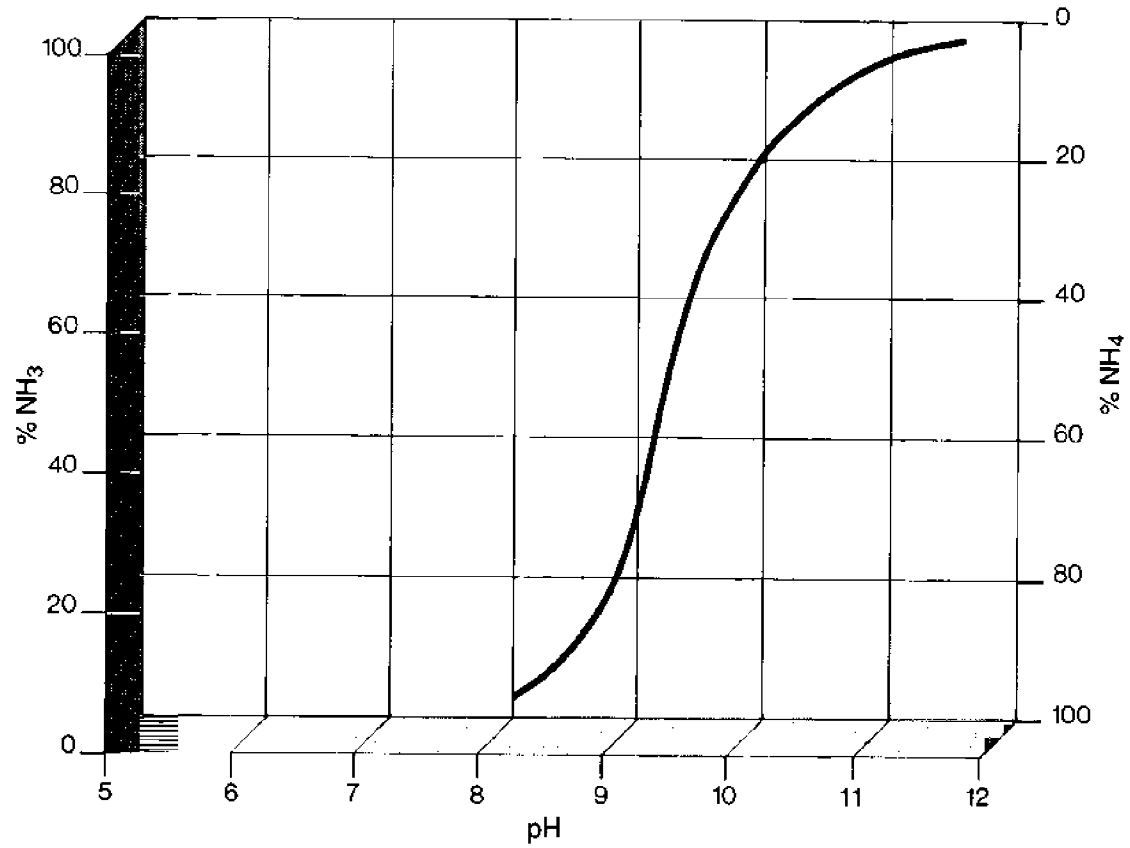


FIGURE 17

Effects of pH on the distribution of ammonia (NH_3) and ammonium (NH_4) in water at 70°F (20°C).

(toxic), and finally nitrate, which is nontoxic. If these filters are not designed properly or are not large enough to handle the incoming ammonia, problems can arise that will lead to deaths in the culture system.

In recirculating systems, bacteria break down total ammonia more efficiently when the pH is near 8. Holding the pH below 7.3 will maintain the total ammonia in the nontoxic NH4 form, but the bacteria will be less efficient in converting the NH4 to the nontoxic NO3. There will probably be an accumulation of NO2 (toxic) and mortality will inrease.

NITRITE. Nitrite ((NO2) is very toxic to crawfish. In flow-through systems nitrite does not appear to be a problem for culturists because it is formed by bacterial conversion of ammonia. These bacteria are not normally abundant in a flow-through system. The situation is different in recirculating systems. The bacterial populations in the biological filters function to convert total ammonia to the nitrate (NO3). However, the intermediate compound is nitrite. Soft crawfish producers operating recirculation systems must periodically monitor nitrite levels. If the filter system is improperly designed or not operating properly, severe problems can occur and NO2 will begin to accumulate in the water. Though crawfish can survive NO2 levels over 0.3 ppm, current recommendations are that this concentration should not be exceeded more than two to three days. Ideally, nitrite should be maintained below 0.2 ppm.

IRON. Iron (Fe) appears to be extremely toxic to crawfish. Initially, it was recommended that total iron not exceed 0.2 ppm in culture systems. However, as more information has become available concentrations as low as 0.1 ppm have been correlated with crawfish death, particularly in molting trays. Apparently, even at very low concentrations, iron is taken up by the crawfish and concentrates on the gills. Intermolt crawfish seem to tolerate iron, but die when they attempt to molt. It is thought that iron accumulation on the gills interferes with respiration (uptake of oxygen and release of carbon dioxide by the gills).

Iron is commonly found in Louisiana groundwater. As the groundwater is pumped into culture trays, iron oxidizes through exposure to oxygen, then precipitates out of solution and coats the gills. Two commonly used methods for iron removal are filtration and aeration with a settling pond in order to collect iron before the water is pumped into the culture system. Iron filters are expensive. In recirculation systems, iron removal is less of a problem because once the iron is removed by filtration or aeration, only makeup water has to be treated. The makeup water should contain less than 0.1 ppm iron.

At the LSU Agricultural Center, we have not experienced a problem with iron toxicity, as the iron concentration is below the detectable limit of 0.01 ppm. Though problems have occurred in commercial systems with levels of 0.1 ppm, currently we do not have enough information to recommend a safe iron concentration between 0.01 and 0.1 ppm.

Iron is also present in certain soils, particularly red and yellow clay soils. These soils release iron if the soil pH is below 6. If the soil pH is above 6 to 7, most of the iron remains in the soil. However, soft crawfish culturists should have their soils checked if they plan to use pond water and suspect that iron is present. For acid soils it may be necessary to add lime. Gumbo-type soils (typical of south Louisiana) also contain iron, but the iron is tightly bound to the soils and should not present problems.

Soft crawfish culturists should avoid iron if possible. Certainly the water source should be checked for iron before a soft crawfish system is set up. If the iron concentration exceeds 0.1 ppm, it is almost certain that iron toxicity will develop.

Monitoring Water Quality

Before a soft crawfish system is constructed, the water supply should be determined and the chemical quality established (see previous section). Assuming that the culture system is to have recirculating water, several chemicals must be routinely monitored. Most aquarium shops have kits for conducting the required chemical tests. Two companies that have excellent test kits for these determinations are Hach Chemical Co., Loveland, Colorado, and Chemetrics, Inc., Calverton, Virginia.

The essential chemical measurements include oxygen, pH, total ammonia, and nitrite. Ammonia and nitrite must be measured frequently (sometimes daily), and always after new crawfish are added to the systems. Ammonia and nitrite measurements tell the producer how much waste is in the system and how well the filter is working to remove these two toxic compounds.

Measuring the pH is essential to ensure that the filter bacteria are working properly. Bacteria work best at a pH of 8. If the pH drops to 70 or below, something is wrong, and the bacteria are unable to do their job properly. In a great many cases, the cause of a drop in pH is improper aeration of the water and a buildup of carbon dioxide, which can convert to carbonic acid and lower the pH. Increased aeration generally drives off the excess carbon dioxide which can easily form from a sludge layer at the bottom of the water reservoir. The monthly removal of bottom sediments may be required.

Measurements of oxygen are taken frequently during the early stages of operation to ensure that oxygen levels do not drop below 2 ppm (3 ppm preferred). The crawfish must have adequate oxygen, particularly during the actual molt when oxygen requirements increase. However, there is another reason for measuring oxygen. The bacteria in the filter also require a lot of oxygen. It is most important that the water coming out of the filter not have less than 2 ppm oxygen. If at least this level is maintained on the discharge side of the filter, then more must be entering on the intake side. Maintaining a frequent check for oxygen in the filter is essential.

Water Systems

In a culture facility, crawfish are confined to trays containing about 1 inch of continuously flowing water. The task of providing a total life support system involves providing sufficient water quality in the trays to insure survival and growth.

Two types of systems have been used for soft crawfish production: the open or flow-through system and the closed or recirculating system. Your choice depends upon your particular situation and economic considerations. If you must heat the water, the recirculating system is recommended. It is usually the most economical choice, as heating costs in the flow-through system are often prohibitive.

Flow-Through System

In a flow-through system, water flows through the tray and is discharged. A large quantity of high-quality water must be available. For example, in a 20-tray system with a flow of 2 gallons per tray per minute, 57,600 gallons of water will be required each day. Over six days, 1 acre foot of water will be required (1 acre of water 1 foot deep = 1 acre foot). If the water must be heated from 70F (typical well water) to 80F, the cost can exceed $1000 per month. Most commercial systems are shifting to treating and recycling water in order to reduce water demand and the cost of heating. The flow-through system should be considered only if you have available a large quantity of high-quality water that does not need to be heated, or if you have an inexpensive source of heat and do not need a permit to discharge water.

Recirculating Systems

In recirculating systems, water passes through the trays, a collection sump, biological filter, water heater, and reservoir before returning to the trays. The advantages of this system include low water usage, a lower heating cost, and water quality control. Capital costs are higher and the filter system requires frequent monitoring and management. Research at LSU, supported by Sea Grant and the Agricultural Center, has provided guidelines for both the design and management of recirculating systems (see recommended reading section for information on recirculating systems).

Two types of filters are used in most cases: the upflow sand filter and the fluidized bed. They are similar in design. The upflow sand filter provides the same function as the fluidized bed filter and it also traps solids. The solids must be removed from the filter two or three times per day by periodically fluidizing the sand bed. The flow rate required to fluidize an upflow filter containing a sand size of 8/16 is about 65 gallons per minute for each square foot of the sand bed, with 50 percent expansion of the bed. If the bed has a surface area of 3 square feet then 195 gallons per minute will be required to rapidly flush out the trapped solids. Adequate flushing can be achieved at 25 percent expansion, but it will take a few seconds longer.

Fluidized beds are more efficient than upflow systems, but cannot function without an upflow filter to trap solids. In a fluidized bed, 1 cubic foot of sand will treat the waste of 150 pounds of crawfish. About 20-30 days are required to fully activate a fluidized bed (develop a bacterial population).

Both filters must be operated according to the following guidelines for maximum efficiency: (1) pH should be maintained between 7.5 and 8.0, (2) upflow sand filters should be cleaned two or three times a day, (3) dissolved oxygen content of the water must be above 2 ppm in the filters, and (4) the amount of total water in the filters, reservoir, and trays should be between 5 and 10 gallons per pound of crawfish. For a system containing 1000 pounds of crawfish, there should ideally be 10,000 gallons of water for recirculation, but no fewer than 5000 gallons.

A small amount of water must be added each day to replace the water used to flush the solids from the upflow filter. Makeup water should not exceed 5 percent of the total volume (500 gallons for 10,000 gallons). With this small volume of water, the use of municipal water should be economical. If city water is used at a rate of 5 percent per day, there should be no need to remove the chlorine so long as it does not exceed about 1 ppm and is added directly into the sump or reservoir.

Recirculating systems should be well insulated to reduce heat loss. Trays should have insulated covers. The sump and reservoir can be insulated by placing them below ground level. High-density styrofoam can be framed and placed over the sump and reservoir or floated on the water to provide additional insulation. Retaining heat becomes an important economic factor in the production of soft crawfish during the winter months.

Structural Considerations

Soft crawfish must be cultured within an enclosed building, a greenhouse, or some other kind of structure that will (1) provide protection from predators such as mammals and birds, (2) offer personnel a reasonable work environment, (3) protect equipment and electrical circuits, and (4) provide reasonable environmental controls. There is no standard type of building that can be recommended at present. Your choice is dictated by economic considerations and availability.

Greenhouses

A greenhouse is a most economical building for producing soft crawfish. It can be covered with black plastic or sheet metal. If clear plastic is used, no less than a 92 percent shade cloth is required to prevent the sun from injuring the crawfish (Figure 18). It may be difficult to locate a black plastic cover that will last more than one year when exposed to the sun. The end walls should be of a material that blocks out the sun's rays if the building is facing east and west. Pigmented fiberglass, if translucent, will not be sufficient. A greenhouse placed in a shaded area with a 92 percent shade cloth has

FIGURE 18

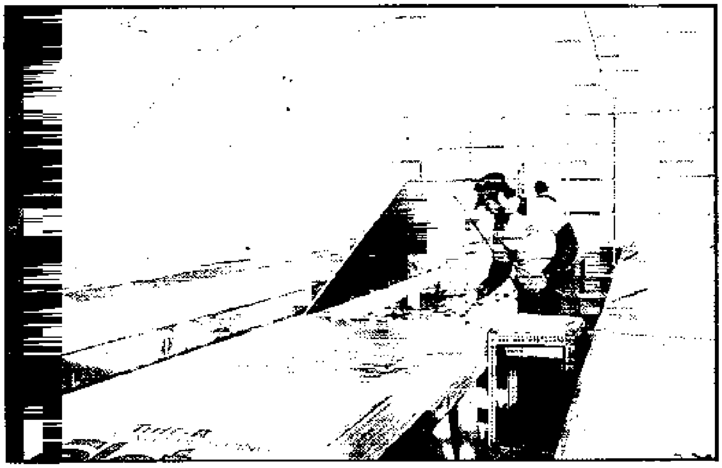
A greenhouse culture system with a black shade cover.

worked well, but lighting is often required to detect the darker colored premolt crawfish.

A greenhouse can have a single or double layer of plastic, though a double layer slightly delays heat loss and gain. On cold nights the temperature in the greenhouse will get very cold and the trays must be covered (Figure 19). Loss of heat from the trays not only increases heating costs, but reduces the molting rate as well.

FIGURE 19

Culture trays with hinged covers.



In the morning, greenhouses warm up quickly and even on cold cloudy days the atmosphere is pleasant to work in. Ventilation will often be required. Vent fans and shutters are expensive and require energy. Roll up sides (Figure 18) or open ends are a suitable option and are much cheaper. There will be days when there is no wind and the greenhouse will become quite uncomfortable even with the sides rolled up. Industrial box fans (36-48 inches) are less expensive than greenhouse fans and should provide sufficient air circulation on these days.

Deterioration of metal will be minimal in greenhouses. About the only maintenance required is replacement of the plastic cover every three years (if of good quality).

A ground-to-ground greenhouse, in which the side walls are not perpendicular to the ground, is the least expensive, but efficient use of the floor is reduced. The sides are slanted inward so that the outer rows of trays must be moved about 2 feet in from the bottoms of the sides. Trays cannot be double stacked on these outer rows.

Greenhouses with vertical side walls permit more efficient use of space. The outer row of trays can be placed directly against the wall, and double-stacked if the walls are 8 feet high. In vertical-wall greenhouses, about 65 percent of the floorspace can be used if a single layer of trays is set up. Double-stacking the trays is a more efficient use of floor space. The rows of trays are normally 3 feet wide and the aisles 2.5 feet. About 3 percent of the space will be lost in the actual culture space because of the support frames and thickness of the tray sides.

In a typical greenhouse, the shade cover is placed over the plastic on the building's top (Figure 18). On the sides, the same positions are retained unless the sides roll up. In the latter case, the shade cover is locked into place under the plastic and only the plastic can be rolled up. There are two reasons for this. Shade covers are necessary to block out the sun and also to control predators. Shade cover material is durable and a deterrent even to animals as strong as raccoons.

Heaters can be installed in greenhouses, but in most cases they are not required. Heating greenhouses to control water temperatures probably will not be economical, particularly at night. Most culturists simply heat the water and cover the trays.

Metal Buildings

Metal buildings are widely used. Compared with greenhouses, they are expensive, so the use of metal buildings is generally limited to existing structures. Temperature control in metal buildings is different from that in greenhouses. The buildings heat up much more slowly in the mornings, and on cloudy days remain quite cool in the winter. They tend to cool down more slowly at night. Some heat may be needed for the attendants in the winter. In warmer months, they tend to be cooler than greenhouses and ventilation is usually adequate if there is a large opening at each end of the building.

Flooring

Many types of floors are used. Hard floors (concrete or wood) are preferred where supply carts with wheels are used, though gravel, shell, and limestone are also widely used. Gravel rolls when it is walked on and is probably the least desirable. Some producers cover such flooring with mats to reduce this problem and to allow for the use of carts. Shell and limestone do not roll, but are hard on the feet. All three are impossible to clean, and if dead crawfish are dropped on the floor, fire ants can become a problem.

Tray Design, Placement, and Plumbing

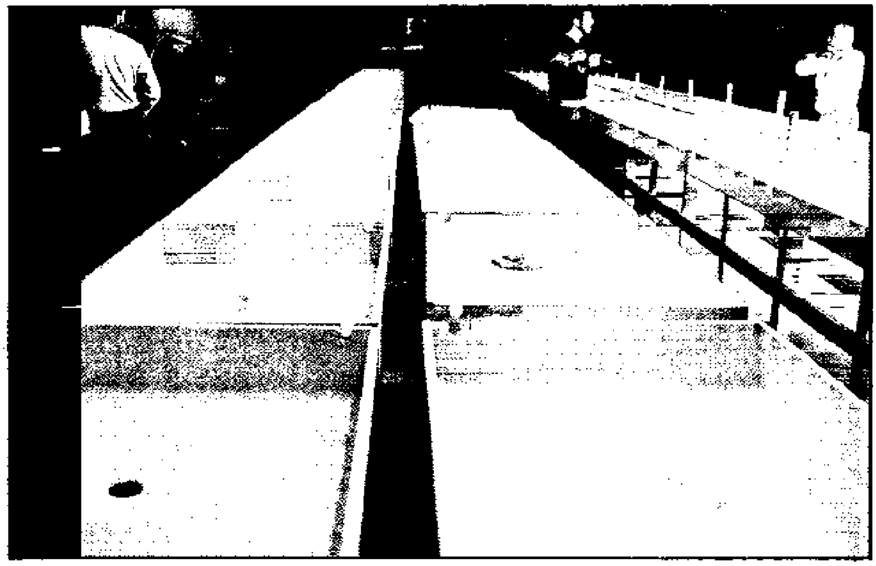
SIZE AND MATERIALS. The 3 x 8 foot trays (Figure 20) with 6-inch sides has become the standard, but a few systems use 3 x 4 foot trays (Figure 21). The width of the tray is limited by the reach of the attendant, as few people can comfortably reach over 3.5 feet.

FIGURE 20

Culture trays in a typical greenhouse system.

FIGURE 21

A production system containing 3 × 4 foot trays.



When crawfish stack up in the corners of 6-inch-high trays, they can crawl out, so it is desirable to place covers over the corners to prevent escape. Molded trays of polystyrene are FDA-approved and have smooth rounded corners, thus reducing crawfish loss.

Fiberglass-coated plywood with either 1 x 6 or 2 x 6-inch lumber for the sides is the most commonly used tray. Treated lumber is not acceptable because it is toxic. Most owners construct these trays for less than $35. However, annual maintenance is usually required. Not all fiberglass resin has FDA approval for use with foods for human consumption, but it is difficult to find out whether a particular resin is approved.

Wooden tray floors should be no less than 1/2-inch thick, or they will bow when water is added. Even with 1/2-inch ADX plywood or fiberboard, two cross-structure supports should be added beneath each tray.

Plastic liners for trays are currently being tested. If suitable, they will simplify and reduce the cost of construction. The high-density FDA-approved material is promising if the crawfish cannot puncture the material.

Culture, molting, and holding trays are designed identically. The latter tray is used to hold newly trapped crawfish so that daily replacement of crawfish into the culture trays will be possible.

TRAY PLACEMENT. With a single layer of trays, the top edge of the tray should be no less than 30 inches above the floor so that the attendant can easily reach the far side of the tray (36-40 inches) without back strain. For systems with double-stacked trays (also see discussion under Greenhouses), support structures for the upper trays should be above the head of the attendant (usually over 6 feet above the floor). A ramp or rolling platform (Figure 22) will be required to reach the upper trays. This platform can easily be constructed at any height; thus the space between the two trays should be sufficient to allow the attendant to lean over a tray without having to duck under the upper tray. If lights are required over the lower trays they should be high enough to be out of the way of the attendant. The use of covers on the lower trays requires enough space to lift the cover (usually hinged on the back side) without hitting the light.

When trays are double-stacked, attending the higher trays is a problem. Rolling platforms are most commonly used and require a hard or smooth floor. The aisle must be at least 30 inches wide for commercially constructed platforms to fit in the aisle. Platforms with railings are preferred. Wooden boardwalks that fold into place 3 or 4 feet above the main floor are being used. One facility has a wooden

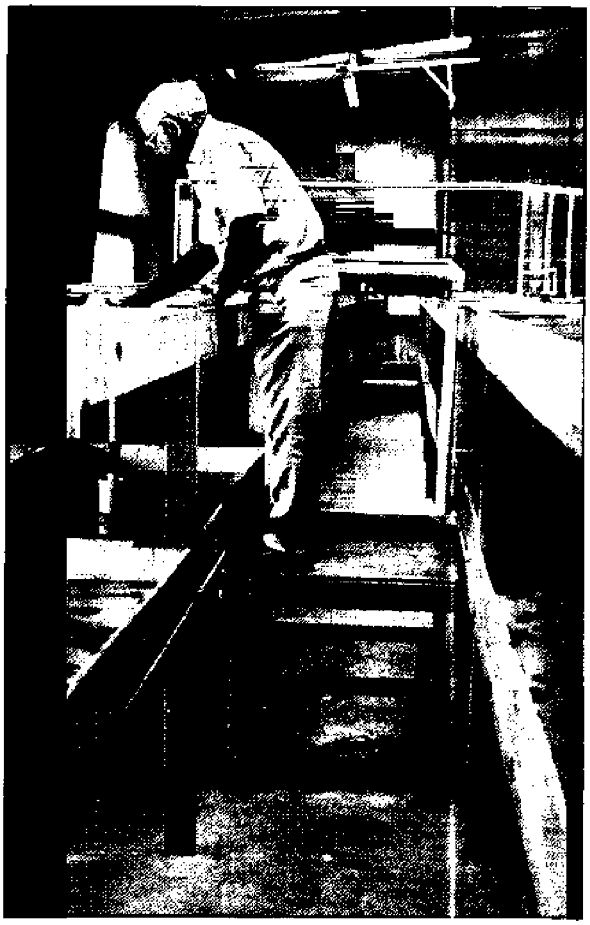


FIGURE 22

In double-stacked systems, a rolling platform makes access to upper trays easier.

floor that is mechanically raised into place to reach the top trays. There is a need to research efficient walkways. Soft crab culture systems use elevated walkways down every other aisle. The attendants can reach two top rows of trays from the elevated walkway and two bottom rows from the ground. There is a sacrifice of space with this arrangement, but the design is good.

WATER SUPPLY LINES. As the industry has developed over the last three years, water supply lines have been modified because of the need for ample water. In a 40-tray system, the main water line throughout the system should be no less than 1.5 inch. Many facilities use a 2-inch line. Flexible polypropylene pipe is the least expensive, but PVC is commonly used. The pipe size should be sufficient to prevent excessive pressure drop and to insure even water distribution.

Layout of the plumbing varies. Many facilities have a single valve to control a row of trays (often more than five trays) and may run a 2-inch pipe the full length of the row. In other facilities, a 1/2 to 1-inch pipe is stubbed off the main line, with a valve at each tray. The latter method is most desirable because it allows the attendant to isolate a single tray (for cleaning, repairing, etc.) and not interrupt water flow to the other trays. If the main line makes a complete loop through the tray system the water pressure is equally distributed.

Water delivery should be sufficient to provide about 2 gallons per tray per minute. Less water has been used successfully, but ammonia toxicity may develop.

DRAINS. Most trays have the drain (no less than 1 1/4 inches in diameter) in one corner, and the opposite end of the tray is elevated about 1/4 inch to insure rapid draining when necessary. Drains in the center of the tray work best if there is a small well in the tray floor around the drain hole. Molded trays have a groove in the bottom to help direct the water to the well.

Placement of a sleeve over the drain standpipe is preferable to the use of a screen on the standpipe to prevent crawfish from escaping. Screens tend to clog up and require frequent attention. The sleeves rest on scalloped edges, forcing the water under the sleeve and into the drain line. The sleeve is usually PVC pipe, 4 to 6 inches in diameter and about 5 inches high. It is placed around the standpipe and is large enough so that the attendant can reach in to pull out the standpipe when the tank needs draining. The standpipe is cut at a length that maintains 3/4 to 1 inch of water in the tray.

Main collection lines should not be less than 3 inches in diameter. In the case of double-stacked trays, most systems align the drain of the top tray directly over the standpipe of the lower tray and drop a flexible drain pipe from the upper tray into the sleeve (Figure 23). This technique reduces the main collection lines by about 50 percent and works quite well. There has been some concern about draining waste water from one tray into another tray. If the filter system works properly and sufficient flow goes to each tray, the water quality should be acceptable for draining the waste water of one tray into another tray.

Periodically trays must be drained. Trays that have a flat bottom should be slightly elevated (1/4 inch) to facilitate draining. Drains are usually placed in a front corner close to the service aisle. Placing a drain in a tray's back corner makes cleaning and draining more difficult.

FIGURE 23

In most double-stacked systems, the drains of the top and bottom trays are aligned and connected by a flexible pipe.

COLLECTION OF SOLIDS. For recirculating systems a screened box (commonly called a trap) is essential or the filter system will become clogged (see Malone and Burden, 1988). For systems with 40 to 60 trays, the trap is usually placed at the top of the sump and is made of a 1/8-inch rigid plastic mesh tightly secured to the bottom of the trap frame. Window-screen mesh clogs too quickly and should not be used. The rectangular frame is about 2 x 5 feet with 6-inch sides. The corners should be covered to prevent escape in case live crawfish are flushed into the trap. If the waste water is to be discharged, a trap is not needed to collect live and dead crawfish, shell, or wasted feed.

Cleaning the trap is an inconvenience, requiring daily attendance. This problem can be simplified by placing a crawfish sack over the mouth of the drain pipe, with the sack's lower portion lying in the trap. The mesh size of the sack is less than 1/8 inch and thus retains most solids coming through the drain. It is easier to remove the sack and add a new one each day than clean the trap.

Bacteria will grow and clog up the sack as well as the mesh in the trap. These bacteria can be easily dislodged from the trap with a pressurized spray nozzle (such as on a garden hose). Bacteria will then flow into the sump and filter and accumulate. The trap should be cleaned before the filters are back-flushed to remove solids.

AERATION. Although crawfish do well in trays having less than 2 ppm oxygen, it is safer to maintain a minimum of 3 ppm oxygen in the trays, and preferably 4-5 ppm. Water can be aerated with spray nozzles at the tray, but the nozzles may clog in recirculating systems. Frequent cleaning is required if the opening is less than 1/4 inch. If aeration is necessary it should be in the reservoir or collection sump. Air pumps are not required if water is allowed to cascade into the sump or reservoir (usually the screened trap breaks up the water flow enough for aeration).

Sometimes it is difficult to maintain a pH between 7.5 and 8, possibly because of excess carbon dioxide and low alkalinity. Aeration may be required to remove the excess CO_2. Carbon dioxide should be less than 5 ppm to prevent respiratory problems for the crawfish, and probably less than 2 ppm to control pH. Use of baking soda can help maintain the pH around 8, but mixed results have been obtained. Maintaining a pH of 8 is a complicated matter and not easily achieved.

Waste Disposal

Soft crawfish systems produce a lot of solid wastes: dead crawfish, exoskeletons produced by the molt, wasted feed, and bacteria from the filter system. All of these materials must be handled properly to maintain a clean culture system and to protect the environment. Several techniques are available and each commercial system uses techniques to fit its particular needs.

Solid Waste

Dead crawfish must be disposed of each day. Because dead crawfish produce pathogenic bacteria, some of which can be infective to humans, sanitation is a top priority for any soft crawfish culture system. In locations where garbage is picked up daily, the crawfish can be placed in plastic bags for pickup, but they should be removed from the culture facility. This convenience rarely occurs every day, so other alternatives are required.

Some producers have a lagoon in which to scatter the crawfish. Design criteria for lagoons have not been established for crawfish wastes. In the winter months, bacterial growth is reduced, and total ammonia and nitrites may accumulate in a lagoon. If the lagoon water is used as part of the recycling system, toxicity to the crawfish may occur.

One of the most efficient, if somewhat inconvenient, methods for the disposal of dead crawfish is to compost them. For a 40- to 60-tray system about 12 cubic yards of horse stable sawdust (mixed with manure) is used. Each day the dead crawfish are mixed into the compost pile. When the crawfish wastes are properly buried, flies will not be attracted to the compost pile.

Another technique used successfully is to spread the shells thinly over a pasture. They dehydrate rather quickly when exposed to the sun. Do not pile the dead crawfish or a serious fly problem will develop. Dead crawfish should be spread at least 100 feet from the facility.

A technique similar to composting but requiring a tractor is to set aside a plot of ground and disc the crawfish into the soil. They are quickly incorporated into the soil without a trace of odor, though during wet weather this is not a feasible alternative.

As soft crawfish systems increase in size, waste disposal will become a more serious problem. Plans should be made to handle this waste when designing the culture system.

Liquid Waste

Discharges from the filter system contain bacteria, wasted feed, and crawfish fecal material. These solids, if not properly disposed of, can putrify and attract flies. If the producer can tie into a sewage system, the disposal is easy, but there could be a sewage use fee.

A small lagoon can also be used, but it may be necessary to aerate the lagoon to prevent odors from developing. No management criteria have been developed for lagoons.

Overland flow is another option for handling the waste. The discharge is placed on gently sloping land and allowed to percolate through the vegetation. Each day the discharge should be placed in a different spot. After three to four days the discharge can be placed at previously used locations.

One facility (34 trays) used a 1/10-acre pond to handle the discharge. This pond successfully handled the discharge for four months, but the discharge was initiated after water temperature reached 70F. A larger pond may be required for the winter months to prevent ammonia and nitrite accumulation.

Economic Analysis Estimates

System Design and Production Process

In this analysis, the hypothetical facility used (see Caffey, 1988) to house the soft crawfish system is a greenhouse measuring 18 x 56 feet. Tray size is standard: 3 x 8 feet, with sides 6 inches high. The analysis employs 44 trays with four trays for molting purposes only. This facility is stocked with a total of 960 pounds of crawfish (24 pounds x 40 trays), and it is assumed that this density is maintained by daily replacement.

Other assumptions are that the facility operates seven months out of the year (December-June), with December a start-up period (no production). After the first month, crawfish are marketed each week. It is further assumed that demand will be sufficient to sell all of the produce at a market price of $8.00 per pound.

Because there is no production in December, 100 percent capacity is assumed for the six months of January through June. During these months, the maximum production is based on maintaining 100 percent capacity at all times multiplied by an efficient daily molting rate of 2.5 percent. It is important to point out, however, that commercial operations rarely exceed 2 percent. Also included is a 1 percent daily mortality rate for crawfish in the culture trays. Dead and molted crawfish are replaced daily to maintain a theoretical 100 percent capacity.

The facility is assumed to be constructed on the owner/operator's land and, therefore, investments for land are not included. The owner/operator provides 90 percent of the required labor at $5.00 per hour for four hours per day. The cost of part-time help is calculated for 10 hours a week at $4.00 per hour from January through June. It is assumed that a well will be drilled for use in the system.

Supply crawfish used in stocking and replacement are estimated at $1.00 per pound. These crawfish are stocked at a density of

1 pound per square foot, which is maintained at all times.

To facilitate construction, a commercial loan is obtained in September, secured by using the owner/operator's land as collateral, and the loan is amortized for four years at a 12 percent commercial interest rate. Terms of the loan include no payments until January, when the first income is accrued for the business. A revolving line of credit is established that allows for short-term borrowing for operating items such as inventory and wages. The rate is 1.5 percent per month. Short-term loans generally last no longer than three months.

Investment Costs

Table 3 provides a detailed breakdown of costs and associated depreciation for all inputs used in the hypothetical 40-tray flow-through and recirculating systems. All estimates have been calculated to include labor and materials. Depreciation is calculated for each input by using a straight-line method and assuming no salvage value.

Table 3. Estimated investment requirements and depreciation charges for soft crawfish production systems, Louisiana, 1988.

	FLOW-THROUGH SYSTEM		RECIRCULATING SYSTEM	
Item	Investment	Depreciation	Investment	Depreciation
Greenhouse	$ 4,990.00	$ 490.00	$ 4,990.00	$ 490.00
Limestone Slab	345.00	17.50	345.00	17.50
Water Well	2,665.00	266.50	1,700.00	170.00
Plumbing	318.00	31.80	---	---
Commercial Water Recycling Component System	---	---	3,485.00	348.50
Sump and Reservoir	---	---	350.00	17.50
Wiring	100.00	5.00	100.00	5.00
Gas Line	150.00	7.50	150.00	7.50
Trays (44)	1,660.00	415.00	1,660.00	415.00
Stands	572.00	190.66	572.00	190.66
Refrigerator/Freezer	600.00	85.71	600.00	85.71
Double Sink	55.00	3.60	55.00	3.60
Desks, Tables, Chairs	50.00	10.00	50.00	10.00
Water Heating (250,000 BTU Boiler)	1,130.00	56.60	---	---
Water Heating (Hot Water Heater)	---	---	300.00	30.00
Miscellaneous	619.00	---	709.00	---
TOTAL COSTS	$ 13,254.00	$ 1,580.00	$ 15,066.00	$ 1,791.00

The total investment cost for the flow-through system is estimated at $13,254, while the investment cost of the recirculating system is estimated at $15,066. Differences in investment costs are primarily because of differences in sources of water and the investment in recycling equipment. In addition, a boiler is used in the flow-through system, whereas commercial water recycling equipment is required for the recirculating system.

Estimated Operating Costs and Income

Income for each of the systems was estimated assuming a six-month production period, an $8.00 price for soft crawfish, and a 1 percent daily mortality rate. Table 4 presents the projected annual income statement for the 40-tray flow-through and recirculating systems. Net return estimates in Table 4 represent a return to land and management. The operating cost estimates shown in Table 4 indicate that labor, monthly replacement of crawfish, and energy requirements are the major expenses for the flow-through system. The major expenses for the recirculating system include labor and replacement of crawfish. There is a substantial cost saving associated with water

Table 4. Estimated annual income for alternative soft crawfish production systems, Louisiana, 1988.

Item	Flow-Through System	Recirculating System
INCOME		
Sales	$ 34,560	$ 34,560
Total cash income	34,560	34,560
OPERATING EXPENSES		
Labor		
owner/operator	4,200	4,200
part-time	1,008	1,008
Crawfish		
initial stocking	1,000	1,000
monthly replacement	6,048	6,048
Transportation	510	510
Electricity	1,065	500
Water heating[a]	5,075	300
Feed	330	330
Miscellaneous	700	700
Total operating expenses	19,936	14,596
FIXED EXPENSES		
Interest	1,686	1,765
Depreciation	1,600	1,792
Total fixed expenses	3,286	3,557
TOTAL EXPENSES	23,222	18,153
NET RETURNS	11,338	16,407

[a]Natural gas is used to heat water.

heating for the recirculating system.

Net returns for the flow-through system are estimated at $11,338 while net returns for the recirculating system are estimated at $16,407. Fixed costs for the recirculating system are slightly higher than for the flow-through system. However, these higher fixed costs for the recirculating system are offset by savings in operating costs. Energy requirements for heating water for the recirculating system are estimated at $300 while these same costs for the flow-through system are estimated at $5,075.

Table 5 shows the break-even analysis based on operating capacity (efficiency of production) and length of season. Using an $8.00 per pound wholesale price, a plant must operate at 63.5 percent of capacity to break even, or 3.8 months at 100 percent efficiency.

Table 5. Break-even price analysis of various plant capacities and production seasons as related to total annual costs for a 40-tray recirculating system.

Plant Capacity Break-Even Analysis

At full capacity and a 2.5 percent molting rate, the plant will be capable of producing 24 pounds per day, 720 pounds per month, or 4,320 pounds per average season (six months, January-June). Using this standard seasonal production value, the required prices per pound can be calculated for various plant capacities that will cover the total annual costs.

TOTAL ANNUAL COSTS PER POUND OF PRODUCTION AT GIVEN CAPACITY = REQUIRED BREAK-EVEN PRICE PER POUND

AVERAGE SIX-MONTH CAPACITY	PRICE PER POUND
100% Plant Capacity (4,320 lbs.)	$ 5.02
90% Plant Capacity (3,888 lbs.)	$ 5.58
80% Plant Capacity (3,456 lbs.)	$ 6.28
70% Plant Capacity (3,024 lbs.)	$ 7.10
63.5% Plant Capacity (2,743 lbs.)	$ 7.90

$8.00/lb. Market Price

Production Season Break-Even Analysis

In recent years, production seasons have varied in length. Assuming full plant capacity, different seasons have been incorporated into a break-even analysis to determine the required prices per pound to cover annual costs.

LENGTH OF SEASON	PRICE PER POUND
7 Months (5,040 lbs.)	$ 4.30
6 Months (4,320 lbs.)	$ 5.02
5 Months (3,600 lbs.)	$ 6.02
4 Months (2,880 lbs.)	$ 7.50
3.81 Months (2,743 lbs.)	$ 7.90

$8.00/lb. Market Price

CULTURE TRAY
RECORD SHEET

Tray Number__________

Number of Crawfish Removed

Date	Premolts	Dead	Mature	Total	Comments	Attendants

MOLTING TRAY
RECORD SHEET

Tray Number__________

	Molts Removed				
Date	Live	Dead	Total	Temp.	Comments

WATER CHEMICAL ANALYSIS RECORD SHEET

Tray Type:

Culture ______________

Molting ______________

Acclimation ______________

Date	Tray Number	Temp.	pH	Fe	Total Ammonia	NO_3	NO_2	CO_2	O_2	Hardness	Alkalinity

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