Electrotechnology Application in Soft-shell Crawfish Separation

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SUMMARY: The basic concept and main components of an automatic soft-shell crawfish separation system are introduced. The performance of the electric shocking gate used to inhibit the downstream migration of crawfish is discussed, and the electronic counters employed to monitor crawfish activity and the number of crawfish leaving the system are evaluated.

KEYWORDS: Aquacultural Engineering, Crawfish, Electrotechnology, Separation, Counter

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I. Introduction

Crustaceans, such as crawfish, are encased by a hard exoskeleton which must be periodically replaced for growth to occur (Aiken and Waddy, 1987). The process of shell replacement which occurs in a crawfish is called molting (Lowery, 1988). The new shell of a just molted crawfish is very soft and remains so for only a few hours. The intermolt period varies from a couple of days for very small crawfish to over several weeks for those approaching maturity. The molting frequency is determined by age, temperature and other conditions (Lowery, 1988).

Soft-shell crawfish, much like the soft-shell crab, have long been considered a sea-food delicacy. However, availability was limited by the lack of production. Recently developed technological and management strategies now permit small scale commercial production of soft-shell crawfish (Culley and Duobinis-Gray, 1990). These production facilities are "hand-picked" systems in which pond raised immature crawfish are brought indoors and placed in shallow trays until they molt. Within a few hours after molting, the soft-shell crawfish are removed by hand and are immediately frozen. Because this process is highly labor intensive, the production costs of "hand-picked" systems are usually high, resulting in high prices of the end product.

The automated hydraulic separation process (Malone and Culley, 1988) discussed in this paper was designed to reduce labor costs. Hydraulic force is used in the process to separate the weakened soft-shell crawfish from the intermolt population. This process employs electrical shocking gates to enhance the separation efficiency.

The use of electricity directly for animal management has a long history. Two popular applications are electrofishing and electric fences (Reynolds, 1983; Wakefield, 1983) which are based on the fact that animals can be electrically shocked through stimulation of their nervous systems caused by the electric current. The same principle also applies to the shocking gate for soft-shell crawfish separation; a mild electric shock frightens crawfish and keeps them away from the gate.

The automatic soft-shell crawfish separation system also uses electronic counting and monitoring systems for management, permitting automation in large scale operations. Electronic counters have been used for postlarvae and juvenile giant freshwater prawns (West et al., 1983; West and Thompson, 1983) and for fishery management (Ewing et al., 1983). This application provides a new example of electronic counters applied to aquaculture.
The objective of this paper is to introduce the basic concept of hydraulic soft-shell crawfish separation and to present the preliminary results of the separation system, shocking gate and counter performance evaluations.

II. Materials and Methods

The Principle of Operation

The automatic separation system is based on three mechanisms: (1) hydraulic force, (2) biological change in a molting crawfish, and (3) electric shocking. A continuous water current is provided in the system. A crawfish in the water current is subjected to a drag force. The magnitude of the drag force is determined by the current velocity and the size of the crawfish. Having a pair of claws and 4 pairs of legs, the crawfish can resist a flow by holding its claws stationary (Holdich and Reeve, 1988) and by gripping on the surface with the propodus of the first two walking legs. This prevents the crawfish from being carried away by the water current. However, when a crawfish molts, the newly developed soft shell is so weak that it cannot grip the surface against a current. The crawfish can use its legs only like oars flat on the substratum (Lochhead, 1961) until its shell becomes hard again. Therefore, a soft-shell crawfish will flow with the current and be eventually flushed out from the system providing that the current is strong enough. Similarly, a dead crawfish and old crawfish shells that are shed are also flushed out.

Some intermolt crawfish also follow the water current, migrating downstream. The downstream migration is inhibited by a shocking gate which delivers a mild shock. Therefore, this separation system keeps intermolt crawfish in and allows soft-shell crawfish to leave.

Basic Configuration of the Separation Tray

The basic unit of the automatic separation system is a separation tray. A typical separation tray consists of raceways, flowing water and a shocking gate. Design of separation trays is still an empirical art requiring proper selection of several critical parameters. The design problem is complicated by the fact that the crawfish are alive, mobile and sensitive to their environment.

A schematic diagram of the separation tray used in this study is presented in Figure 1. This 2.44 m x 1.22 m x 0.1 m tray was made from
Figure 1. Schematic diagram of the experimental separation tray used for soft-shell crawfish separation
fiberglass. It consisted of 4 raceways of 0.28 m wide, a shocking gate and water outlet. Crawfish were loaded in the separation tray at a specified density (4.8 kg of crawfish/m²). Water was delivered to the tray at the water inlet, then flowed through the raceways, leaving the tray through the outlet where the shocking gate was located. The flow rate was chosen to effectuate relatively rapid separation of the soft-shell crawfish (0.88 l/s). The water depth in the raceways varied with water flow rate but was typically less than 4 cm.

The location of the shocking gate on the separation tray is also illustrated in Figure 1. Functionally, the shocking gate served as two electrodes; one electrode (-) was located under the surface of the water and the other (+) was mounted to suspend above the water surface. This suspended electrode was made from a stainless steel sheet having a thickness of 0.002 gauge. The sheet was 28 cm x 6 cm, mounted on a stainless steel bar and suspended above the water surface. The lower part of this sheet was alternatively cut to form strips with gaps (<1 cm). These strips were flexible enough for dead and soft crawfish to pass through without stopping them on the gate. This sheet was connected to the positive pole of the power supply. About 20 cm from the sheet, a negative pole placed in water was connected to the ground of the power supply.

The gap between the suspended strips and the water surface was determined according to the crawfish size. The gaps used in this study ranged from 14 to 17 mm, and the crawfish had a carapace height of 17 to 19 mm. The power supply used in this study was 19 volt DC. Because of the gap between the suspended strips and the water surface, the normal status of the circuit was open. However, when a crawfish came in contact with the strips, the circuit was completed. A mild shock forced the crawfish to withdraw from the gate area. In contrast, soft-shell or dead crawfish had no ability to respond and followed the water current passing through the gate.

Counting and Monitoring Systems

A computerized data acquisition and control system was developed to monitor the separation process. This data acquisition and control system consisted of a Zenith supersport laptop computer (model 2), two data acquisition devices (ADC-1 and ADC-2, Remote Measurement Systems, Seattle, Washington), and a multiple port controller (MPC-524). The ADC-1 and ADC-2 were used for analog input and digital input, respectively. The multiple port controller was used to alternatively switch
Zenith Computer

MPC-524

Analog Input → ADC-1 → MPC-524 → ADC-2 → Digital Input

Figure 2. Configuration of the counting and monitoring system
the computer connections to either of the two devices (Figure 2). The data acquisition and control system also monitored temperature, conductivity, and water levels of the separation system. A program written with Turbo Pascal 4.0 was used for data acquisition. The computer continuously sampled all the input channels and displayed the results on the screen.

Two types of counters were used in the experiments: a gate contact counter and a crawfish escape counter. The gate contact counter was used to monitor the activity of crawfish by reporting the number of contacts made between the crawfish and the shocking gate. The gate escape counter recorded the number of crawfish escaped from a separation tray. This was done by using infrared LED transmitter and phototransistor detector (Radio Shack, 276-142) installed on the discharge side of the gate (Figure 1).

III. Results and Discussion

Separation Efficiency

The shocking gate inhibited but did not stop crawfish downstream migration. 10-hour experiments with initially 100 crawfish in a trough similar to a raceway of the tray illustrated (Figure 1) indicated that only 17 of the crawfish escaped when the shocking gate was provided with electrical power. But as many as 78 crawfish escaped when no voltage was applied to the shocking gate. This demonstrates that the shocking gate effectively inhibited crawfish escape from the tray.

With the inhibition from the shocking gate, the described separation system effectively separated the soft-shell crawfish from the hard ones. The separation efficiency was mainly determined by the escaped number of intermolt crawfish. The number of escaped intermolt crawfish depended on several main operational parameters such as flow rate, crawfish loading density, and acclimation period. Figure 3 gives an example of the effects of acclimation time on intermolt crawfish escape rate. The data were recorded in a 20-hour period starting with newly loaded crawfish. Figure 3 illustrates that the total number of crawfish leaving the separation tray decreased as the crawfish stayed longer, implying that the crawfish could learn to adapt themselves to the separation tray. In the crawfish pond where the crawfish were used to, the water current was much slower than in the separation tray. Therefore, the newly loaded crawfish needed to learn to adapt to the new environment to live with a stronger water current. It was noted that this learning process took three to five days.
Figure 3. Number of soft-shell crawfish and number of total crawfish leaving the separation tray versus the time starting with newly loaded crawfish.
The number of soft-shell crawfish leaving the tray, on the other hand, was relatively constant as indicated in Figure 3. Therefore, the percentage of the soft-shell crawfish in the total number of crawfish leaving the system was determined by the number of escaped intermolt crawfish. For example, immediately after the loading, the percentage of soft-shell crawfish was less than 20% of the total number of those that left the separation tray. However, approximately three days (80 hours) after loading, soft-shell crawfish constituted 50% (16 to 32) of those that came out the system through the shocking gate.

In a typical soft-shell crawfish operation, 1.4 to 3.8% of the crawfish population molt each day (Culley and Duobinis-Gray, 1990). This means that if both the soft-shell and intermolt hard crawfish had the same probability to escape from the tray, the percentage of soft-shell crawfish in the total escaped crawfish would also be 1.4 to 3.8%. In fact, the obtained soft-shell percentage in the total number of crawfish which came out of the separation tray was much higher (approximately 10 to 50%, Figure 3), suggesting that the separation of soft-shell crawfish by the described system was effective.

**Effect of Water Flow Rate**

Water flow rate impacted the performance of the separation tray (Figure 4). The escaped intermolt crawfish increased with flow rate. This is because when the flow rate is increased, the drag force acting on the same crawfish is increased. Consequently, more crawfish drifted with the flow and their chance to escape from the system increased. When the flow rate was greater than 0.88 l/s, the number of escaped crawfish increased rapidly. It was also noticed that at this flow rate, the soft-shell and dead crawfish could be easily separated from the hard population. Therefore, 0.88 l/s was recommended for the tray and the crawfish used.

**Crawfish Activity**

The activity of the crawfish in the separation tray was monitored by the gate contact counter. It was observed that there were at least four main factors affecting crawfish activity. These factors were acclimation time in the tray, flow rate, temperature, and light. Changes in crawfish activity were monitored by using a gate contact counter. For Example, Figure 5
Figure 4. Crawfish escape rate as a function of flow rate delivered to the separation tray.
Figure 5. Gate contact counting showing crawfish activity differences with and without light.
indicates that light suppressed crawfish activity. During the period when
light was on, the cumulative crawfish contact count increased much slower
than during the period when the light was off.

A problem encountered with the gate contact counter was that
sometimes the flushing water dripped from the suspended gate strips could
conduct the circuit and cause false counts. However, the error caused by the
dripping water was not significant. Another problem was that a dead
crawfish stuck on the gate caused a continuous count. This problem was
corrected by proper programing of the computer.

*Escape Counting*

The number of crawfish leaving the tray was counted using the infrared
sensor. The computer count and manual count followed a linear relationship
(Figure 6). The performance of the counter was consistent. However, the
counter count number was bigger than the manual count. This was mainly
carried by some big crawfish used in the experiment. When these crawfish
came to the gate, their claws extended through the gate gap first. These
crawfish were so long that they could physically block the infrared ray before
the crawfish contacted the gate. However, once they contacted the shocking
gate, some of these crawfish withdrew back into the tray. False counts
resulted. However, this problem can be corrected by choosing a better
position to install the sensor.

The main disadvantage of the sensor was that it also counted empty
shells. It was difficult to get exact crawfish number counts. But a very close
estimation of the number of crawfish leaving the separation tray could be
provided after calibrations.

**IV. Conclusions**

The combination of principles of hydraulics and electric shocking with
the biological features of a molting crawfish makes automatic separation of
soft-shell crawfish from the hard population possible. The results presented
demonstrated that electric shocking gates effectively inhibited crawfish
downstream migration and thus increased the efficiency of separation. The
results also showed that electronic counters designed to monitor the effect of
environmental conditions upon activity of the crawfish and to detect the
number of crawfish leaving the separation tray performed reasonably well.
Figure 6. Escaped crawfish number: manually counted versus that counted with the computer.
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Reference


