# THE POTENTIAL FOR SOFT SHELL CRAB PRODUCTION UTILIZING HEATED EFFLUENTS FROM POWER PLANTS IN THE GALVESTON BAY SYSTEM

*by*
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## ABSTRACT

Blue crabs, *Callinectes sapidus*, stocked in cages at two different densities both with and without artificial habitats were compared for growth and survival in a power plant discharge canal and in a pond. Survival was higher for crabs in the pond but growth was significantly greater for those in the discharge canal. Artificial habitats increased survival of crabs cultured in the discharge canal but had no effect on those caged in the pond. In the laboratory no significant differences were found in weight, carapace width, or survival of crabs selected at random in regards to molting cycle and placed in individual molting chambers at 30 C and ambient temperatures (21-29 C). In 35 days the greatest increases in carapace width for individual crabs were 52, 33 and 14% for small, juvenile and sub-adult crabs, respectively. Crabs, all sizes pooled, molted earlier at 30 C than at ambient temperatures (22.2 vs 25.0 days to first molt). A raft holding wire cages with individual molting chambers is proposed for the commercial production of soft shell crabs in heated effluents.

## INTRODUCTION

The blue crab, *Callinectes sapidus,* supports a large fishery along the Gulf Coast. Crabs are collected by trawl but predominantly by crab pots baited with trash fish. The animals are then marketed directly to consumers, restaurants, or processing houses where those that have just molted (soft shells) command a much higher retail price ($10/doz) than the hard shell crabs ($2/doz). Since the molting of the crab is seasonal with little or no molting occurring during the winter months, the availability of soft shell crabs is restricted to the warmer seasons. If crabs could be induced to molt during the winter months by utilizing thermally enriched power plant effluents, then perhaps the soft shell crab industry could be established as a profitable enterprise throughout the year. Reimer and Strawn (1973) investigated this possibility by comparing the natural occurrence of soft shell crabs in the discharge canal with their occurrence in the intake canal of a power plant. Soft shell blue crabs were found to occur 60 times more frequently in the heated discharge.

We monitored growth, molting frequency, and survival of blue crabs both in cages and in flow-through chambers to evaluate the potential of soft-shell crab production in the heated effluent of a power plant. The objectives of the cage study were to determine the effect of habitat on survival and growth of blue crabs, and to develop an optimum stocking density for cage-cultured blue crabs. The objectives of the flow-through chamber study were to determine growth rates, molting frequency, and survival rates for individual crabs isolated in separate chambers. A further objective of both studies was to relate hydrological variables to biological results.

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## MATERIALS AND METHODS

### *Facilities*

The research was conducted at a laboratory operated by Texas A&M at Baytown, Texas, on the upper portion of the Galveston Bay System. The laboratory utilizes the heated effluent from Houston Lighting & Power's Cedar Bayou Generating Station (Fig. 1). Facilities consist of 25 0.1-hectare flow-through ponds, a 1,000 hectare cooling pond, and a greenhouse laboratory containing 60 thermally controlled flow-through aquaria placed over six 0.7 × 0.7 × 10m concrete troughs. Both the ponds and laboratory utilize the heated effluent from the power plant.

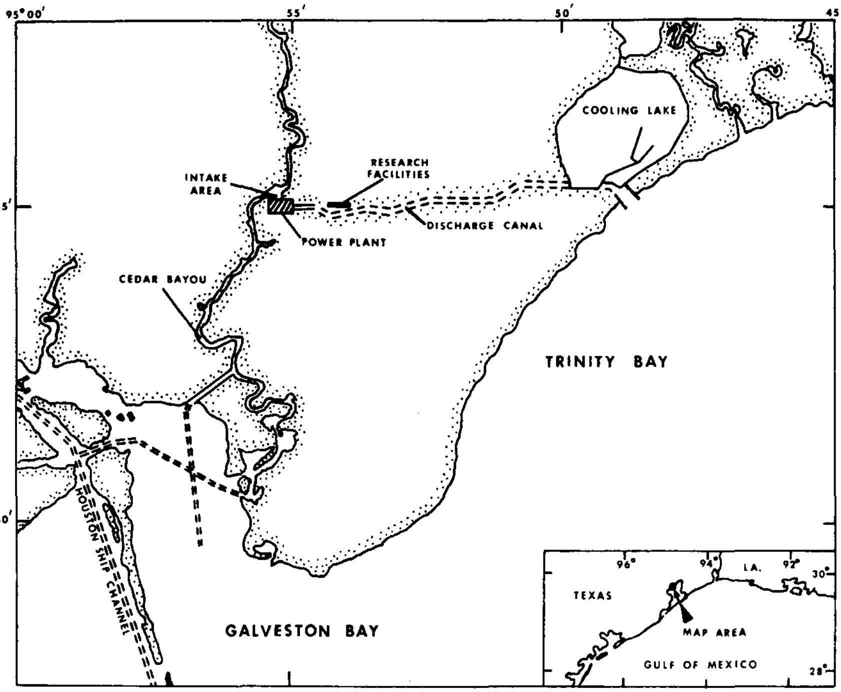


Fig. 1. Map showing the Cedar Bayou area.

*Field Study*

Floating cylindrical cages (0.18m$^3$) were used to culture blue crabs. Cages were placed in the discharge canal approximately 250 meters downstream from its origin. Blue crabs in cages were also placed in study pond 12 to serve as controls.

On 3 March, 20 crabs obtained from the plant intake screens were placed in each of four cages in the discharge canal. Two of the four cages did not contain artificial habitat (cages D1 and D2), while the other two cages each contained 40 sections of 5cm diameter, 15cm long, PVC pipe cemented together to serve as shelter (cages D3 and D4). In addition replicate cages containing PVC pipes and stocked with 40 crabs each were placed in the discharge (cages D5 and D6). For each treatment, duplicate controls were maintained in study pond 12 (cages P1 through P6 respectively). A total of 12 cages were stocked for 27 days.

*Laboratory Study*

In the first study blue crabs of 3 different size ranges (adults, sub-adults and juveniles) were obtained from the intake canal and cooling lake. No attempt was made to select crabs in the late pre-molt stage and no hormones or eye stalk ablations were employed. The crabs were stocked into 10 individual molting chambers formed by partitioning a V-shaped trough. The bottom of each partition was open to provide water flow along the bottom from the influent end to a stand-pipe drain in the effluent end of the molting troughs. The troughs were constructed of fiberglass-coated 0.64cm (¼") plywood with removable internal partitions of 0.48cm (3/16") asbestos. The "V" shape design was chosen to facilitate solid waste removal and thus lessen fouling.

The largest molting troughs were 150cm long with internal partitions 15cm apart; the V-shaped compartment was 25cm on each side. Intermediate size crabs were stocked in 100cm troughs with partitions on 10cm centers and "V" sides of 20cm. In the juvenile-sized units, partitions were 10cm apart and 15cm on the side. All molting troughs were fitted with tops to prevent escape of the crabs.

The molting troughs were placed above the concrete troughs in the laboratory. This placement allowed the effluent from flow-through aquaria above each concrete trough to pass through the molting chambers. Two molting troughs of each size were heated to 30 C and two replicate units were kept at ambient temperature. This treatment allowed evaluation of offseason molting in 20 adults, 20 sub-adults, and 20 juveniles at both 30 C and ambient. A total of 120 crabs were used for the first laboratory study (22 March-26 April; 35 days). The second study (26 April-15 May; 19 days) used 65 crabs (survivors from the first study) in the "V" shaped troughs and 20 crabs (maintained in aquaria since 22 March at ambient temperature) were placed in two 10-chambered wire cages. Each cage measured 24 × 90 × 40cm with the 10 individual crab chambers being 18 × 24 × 40cm. These wire molting units were placed in the concrete troughs below the flow-through aquaria. The third study (15 May-6 June; 22 days) using one V-shaped trough and the two wire molting cages, was a continuation of the second except only ambient temperatures were used. The second and third studies were designed to compare the survival of crabs in the V-shaped chambers and in the rectangular wire units.

*General Procedures*

Daily water temperature, dissolved oxygen, salinity, pH, turbidity, and gas saturation levels were monitored at both culture sites. In the laboratory, observations were made daily for indications of molting and mortality. Crabs in cages in the discharge canal and pond 12 were removed at weekly intervals to a bucket of ice water (which facilitated handling by decreasing activity of the animals), counted, and returned to the cage. Carapace width (greatest distance across the carapace including lateral spines) and weight of each crab were determined at stocking and at termination of the experiment. Statistical evaluations of results were made at the 5% level unless otherwise noted.

Fish and shrimp obtained from the plant intake screens were fed to the crabs daily. The food items were frozen in large plastic bags until needed and then refrigerated until utilized. Information concerning feeding rates is lacking, therefore an attempt was made to overfeed so as to eliminate food as a dependent variable in the experiment and to decrease the incidence of cannibalism in the cages. Feeding rates were ad lib with consideration being given to maintaining good water quality.

## RESULTS

*Hydrological Data*

Maximum, minimum and average hydrological values for the discharge canal and pond 12 were computed (Table 1). In the laboratory salinity ranged from 2.5 to 5.5 ppt and temperature of the ambient water was 20.9 C at the start of the first study but reached a peak of 22.4 C. In the second study (26 April-15 May) the ambient temperatures ranged from 24.7 to 29.2 C, salinity from 1.5 to 2 ppt and dissolved oxygen from 2.2 to 8.2 ppm. The third study (15 May-6 June) had ambient temperatures from 24.7 to 29.2 C, salinity from 1.5 to 2.7 ppt and dissolved oxygen from 3.2 to 7.0 ppm. The elevated temperatures of the thermally controlled units were not a constant 30 C due to the wide fluctuation of the air temperature (17 C in 24 hours) in the greenhouse and to the obstruction of water by silting. The "V" shaped molting chambers did not remain clean but loaded with silt. Fresh fish fed to the crabs quickly fouled the water and it was necessary to clean the chambers after feeding.

Table 1. The average, minimum, and maximum values for temperature, salinity, dissolved oxygen, pH, turbidity, total gas saturation and percent oxygen and nitrogen saturation in the discharge canal and pond 12.

| | *Discharge Canal* | | | *Pond 12* | | |
|---|---|---|---|---|---|---|
| | *Minimum* | *Mean* | *Maximum* | *Minimum* | *Mean* | *Maximum* |
| Temperature (C) | 18.0 | 24.3 | 29.5 | 14.0 | 19.5 | 23.7 |
| Salinity (ppt) | 3.3 | 6.0 | 7.7 | 4.0 | 6.1 | 7.5 |
| Dissolved Oxygen (ppm) | 6.9 | 8.8 | 11.0 | 5.5 | 8.1 | 10.9 |
| pH | 7.8 | — | 8.7 | 7.7 | — | 8.5 |
| Turbidity (JTU's) | 54.0 | 104.0 | 123.0 | 55.0 | 114.0 | 180.0 |
| Total Gas Saturation (%) | 102.0 | 109.8 | 115.1 | 95.4 | 102.0 | 111.1 |
| Oxygen Saturation (%) | 88.9 | 105.2 | 132.1 | 63.4 | 88.2 | 128.1 |
| Nitrogen Saturation (%) | 102.5 | 111.8 | 119.0 | 96.9 | 106.2 | 117.0 |

*Field Study*

A total of 160 crabs were stocked in cages in the discharge canal on 3 March and 51 (31.0%) were alive on 31 March. Seventy-six (47.5%) of the 160 crabs stocked in cages in pond 12 survived. Cage P1 crabs had the highest survival percentage of any cage stocked (70%), while cage D6 had the lowest (10%). Caged crabs stocked at 20 per cage and with the pipe habitat had the highest mean survival rates in the discharge canal (55%), while crabs stocked at 40 per cage had the lowest (20%). Pond 12 crabs cultured at 20 per cage with and without habitat averaged 55% survival, while crabs stocked at 40 per cage averaged 40% survival (Table 2).

Table 2. The number of blue crabs at stocking and surviving after 1, 2, 3 and 4 weeks and percentage ( ) surviving.

| | | *Date (1975)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Cage* | *Pipe Habitat* | *3/3* | *3/10* | | *3/17* | | *3/25* | | *3/31* | |
| | | *Discharge Canal* | | | | | | | | |
| D1 | Without | 20 | 7 | (35) | 7 | (35) | 7 | (35) | 6 | (30) |
| D2 | Without | 20 | 17 | (85) | 11 | (55) | 9 | (45) | 7 | (35) |
| D3 | With | 20 | 18 | (90) | 13 | (65) | 13 | (65) | 10 | (50) |
| D4 | With | 20 | 17 | (85) | 17 | (85) | 14 | (70) | 12 | (60) |
| D5 | With | 40 | 20 | (50) | 20 | (50) | 15 | (38) | 12 | (30) |
| D6 | With | 40 | 29 | (73) | 24 | (60) | 18 | (45) | 4 | (10) |
| | | *Pond 12* | | | | | | | | |
| P1 | Without | 20 | 18 | (90) | 18 | (90) | 17 | (85) | 14 | (70) |
| P2 | Without | 20 | 12 | (60) | 10 | (50) | 10 | (50) | 8 | (40) |
| P3 | With | 20 | 20 | (100) | 16 | (80) | 14 | (70) | 12 | (60) |
| P4 | With | 20 | 13 | (65) | 13 | (65) | 12 | (60) | 10 | (50) |
| P5 | With | 40 | 28 | (70) | 23 | (58) | 23 | (58) | 11 | (28) |
| P6 | With | 40 | 31 | (78) | 30 | (75) | 19 | (48) | 21 | (53) |

All crabs stocked at both locations were of similar size, but at harvesting, crabs from the discharge averaged greater total carapace widths and weights (Table 3). The final condition values of crabs cultured both in the discharge and pond 12 did not change significantly from stocking to harvest. Average carapace widths of cultured crabs in the discharge canal were found to be significantly larger ($P = 0.01$) than those in pond 12 for all treatments. Average weights of crabs stocked in the discharge at 20 per cage with habitat (cages D3 and D4) and without habitat (cages D1 and D2) were found to be significantly greater ($P = 0.01$) than crabs in any cage from pond 12. The average weights of crabs stocked in the discharge at 40 per cage with habitat (cages D5 and D6) were significantly smaller than those stocked at the lower density with or without habitat. There did not appear to be any significant difference in crab growth in cages with or without habitat.

Table 3. Number, average carapace width, weight and condition values for blue crabs caged in the discharge canal and in pond 12.

| | *Number* | | *Carapace Width (mm ± S.D.)* | | *Weight (g ± S.D.)* | | *Condition (K ± S.D.)* | |
|---|---|---|---|---|---|---|---|---|
| *Cage* | *Initial* | *Final* | *Initial* | *Final* | *Initial* | *Final* | *Initial* | *Final* |
| | | | | *Discharge Canal* | | | | |
| D1 | 20 | 6 | 37.70 ± 1.60 | 65.17 ± 6.68 | 4.50 ± 2.39 | 21.78 ± 5.44 | 7.86 ± 1.37 | 7.81 ± 0.75 |
| D2 | 20 | 7 | 34.80 ± 5.84 | 64.14 ± 16.91 | 3.52 ± 2.06 | 20.57 ± 16.20 | 7.82 ± 1.12 | 7.78 ± 0.91 |
| D3 | 20 | 10 | 38.25 ± 6.74 | 63.20 ± 16.23 | 4.73 ± 2.17 | 21.04 ± 14.17 | 8.12 ± 1.28 | 7.54 ± 1.08 |
| D4 | 20 | 12 | 37.50 ± 7.87 | 64.42 ± 17.44 | 5.29 ± 3.13 | 20.34 ± 12.07 | 9.30 ± 1.90 | 7.06 ± 1.27 |
| D5 | 40 | 12 | 36.90 ± 6.64 | 57.92 ± 11.27 | 4.04 ± 2.32 | 16.87 ± 10.94 | 7.56 ± 1.64 | 8.42 ± 3.79 |
| D6 | 40 | 4 | 35.95 ± 6.25 | 54.00 ± 18.01 | 3.67 ± 1.80 | 14.70 ± 13.21 | 7.55 ± 1.24 | 7.91 ± 1.03 |
| | | | | *Pond 12* | | | | |
| P1 | 20 | 14 | 40.20 ± 7.34 | 47.71 ± 8.77 | 5.62 ± 2.88 | 9.79 ± 4.82 | 8.01 ± 0.92 | 8.31 ± 0.56 |
| P2 | 20 | 8 | 35.40 ± 5.90 | 42.00 ± 10.30 | 3.78 ± 2.30 | 7.15 ± 6.83 | 7.86 ± 0.95 | 8.06 ± 0.74 |
| P3 | 20 | 12 | 35.40 ± 5.90 | 41.25 ± 8.49 | 3.98 ± 2.64 | 6.23 ± 3.45 | 7.52 ± 1.22 | 8.27 ± 1.12 |
| P4 | 20 | 10 | 39.85 ± 6.60 | 50.50 ± 8.59 | 5.59 ± 2.54 | 11.62 ± 5.22 | 8.32 ± 1.16 | 8.46 ± 0.92 |
| P5 | 40 | 21 | 34.85 ± 4.87 | 42.71 ± 7.86 | 3.66 ± 1.61 | 6.51 ± 3.67 | 8.31 ± 1.22 | 7.73 ± 0.87 |
| P6 | 40 | 11 | 38.40 ± 5.32 | 45.91 ± 6.83 | 4.57 ± 1.67 | 8.37 ± 3.87 | 7.94 ± 1.23 | 7.17 ± 1.18 |

Table 4. The average weights, widths, gains and percent gain for surviving blue crabs in Study 1 at 30 C (Molting troughs 71, 72, 75, 76, 79 and 80) and at ambient temperatures (Molting troughs 73, 74, 77, 78, 81 and 82) Crabs were initially stocked at 10 per chamber.

| *Molting troughs* | *N* | *Carapace Width (mm)* | | *Weight (g)* | | *Weight Gain* | | *Width Gain* | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Initial* | *Final* | *Initial* | *Final* | *g* | *%* | *mm* | *%* |
| 71 | 5 | 57.2 | 65.0 | 15.7 | 24.7 | 9.0 | 60.4 | 7.8 | 14.1 |
| 72 | 7 | 52.1 | 63.7 | 11.8 | 22.8 | 11.0 | 97.3 | 11.6 | 22.1 |
| 75 | 8 | 102.6 | 108.2 | 80.3 | 84.7 | 4.4 | 6.9 | 5.6 | 5.6 |
| 76 | 6 | 100.0 | 105.8 | 38.3 | 49.8 | 11.5 | 17.6 | 5.8 | 6.2 |
| 79 | 2 | 132.5 | 132.0 | 119.9 | 121.8 | 1.9 | 1.6 | −0.5 | −0.4 |
| 80 | 6 | 143.2 | 154.1 | 145.0 | 154.1 | 9.1 | 5.4 | 0.6 | 3.1 |
| Average | 5.7 | 97.9 | 103.1 | 68.5 | 81.3 | 7.8 | 31.6 | 5.2 | 8.4 |
| 73 | 5 | 43.0 | 54.7 | 6.9 | 14.8 | 7.9 | 132.7 | 11.7 | 28.4 |
| 74 | 10 | 55.8 | 66.2 | 14.6 | 25.4 | 10.8 | 82.8 | 10.4 | 17.5 |
| 77 | 10 | 96.3 | 103.5 | 64.6 | 74.9 | 10.3 | 17.7 | 7.2 | 7.4 |
| 78 | 4 | 95.5 | 96.5 | 53.4 | 58.4 | 5.0 | 11.2 | 1.0 | 4.8 |
| 81 | 7 | 134.6 | 134.9 | 130.9 | 138.5 | 7.6 | 5.7 | 0.3 | 0.2 |
| 82 | 9 | 137.4 | 141.2 | 140.1 | 168.7 | 28.6 | 17.3 | 3.8 | 2.8 |
| Average | 7.5 | 93.8 | 99.5 | 68.4 | 80.1 | 11.7 | 45.4 | 5.7 | 10.2 |

*Laboratory Study*

In Study 1, there was no significant difference in the weight or carapace width between ambient and 30 C crabs within any size group either at stocking or at harvest (Table 4). The average weight and carapace width at stocking was 11.7g, 51.4mm; 67.5g, 126.7mm; and 142.0g, 136.0mm for the three size groups, respectively, when crabs at both 30 C and ambient were considered as one group.

The crabs at ambient temperature had a slightly greater increase in weight, carapace width, and higher survival rates than did those at 30 C; however, the differences were not significant (Tables 4 and 5). Survival was inversely related to the number of molts and to temperature. A total of 41 molts occurred at 30 C with only 48% of the molters surviving, while those at ambient molted a total of 35 times with 62% survival. Some of the larger crabs had already reached the terminal molt prior to this study and some of the smaller crabs and medium size crabs died without molting. At 30 C, small,

Table 5. Molting rate, survival and gains for blue crabs in Study 1 at 30° C (Molting troughs 71, 72, 75, 76, 79 and 80) and at ambient temperatures (Molting troughs 73, 74, 77,78, 81 and 82).

| | *Molting Trough* | *Size Class* | *Number Surviving Molts* | *Number Dead Molting* | *Total Molt Attempts* | *Surviving Molters (%)* | *Average Gain/Day (g)* | *(mm)* |
|---|---|---|---|---|---|---|---|---|
| | 71 | Small | 6 | 4 | 10 | 60 | 0.26 | 0.22 |
| | 72 | Small | 8 | 3 | 11 | 72 | 0.31 | 0.33 |
| | 75 | Medium | 3 | 2 | 5 | 60 | 0.12 | 0.16 |
| | 76 | Medium | 2 | 4 | 6 | 33 | 0.33 | 0.16 |
| | 79 | Large | 1 | 4 | 5 | 20 | 0.05 | 0.01 |
| | 80 | Large | 0 | 4 | 4 | 0 | 0.26 | 0.02 |
| Total | | | 20 | 21 | 41 | 48 | 1.33 | 0.90 |
| Average | | | 3.3 | 3.5 | 6.8 | 8.0 | 0.22 | 0.15 |
| | 73 | Small | 7 | 3 | 10 | 70 | 0.23 | 0.33 |
| | 74 | Small | 8 | 0 | 8 | 100 | 0.31 | 0.30 |
| | 77 | Medium | 4 | 0 | 4 | 100 | 0.29 | 0.30 |
| | 78 | Medium | 1 | 6 | 7 | 14 | 0.14 | 0.03 |
| | 81 | Large | 0 | 3 | 3 | 0 | 0.22 | 0.01 |
| | 82 | Large | 2 | 1 | 3 | 66 | 0.81 | 0.11 |
| Total | | | 22 | 13 | 35 | 62 | 2.00 | 1.08 |
| Average | | | 3.7 | 2.2 | 5.8 | 10.3 | 0.33 | 0.16 |

medium and large crabs that molted averaged 19, 27, and 20 days to first molt. The same size crabs at ambient temperature averaged 27, 29, and 19 days respectively until the first molt. Crabs, all sizes pooled, molted earlier at 30 C than those at ambient temperature (22.2 vs 25.0 days). Student's t-test comparisons indicated there was no difference in the percent of weight gain, width gain, or survival either within or between ambient and 30 C experiments.

In the four units of small crabs the greatest weight gain per individual was 233% (5.5 to 18.3g) for a male crab in chamber 73. The width increase was 52% (40mm to 61mm) and was accomplished in two molts. The greatest weight increase for an intermediate size crab was 65% (41.8 to 68.8g) for a female crab (83 to 101mm; 22% width increase) in molting chamber 77. Another female crab in the same unit increased 33% (111 to 148mm) in length but only 56% (81 to 126g) in weight. (This disparity could have been the result of appendage loss by the second female crab). In crabs of the largest size group the greatest individual gain was 66% (166 to 276g) in weight and 14% (139 to 158mm) in carapace width for a male in unit 82. The average weight and width gains per day of all surviving crabs were 0.28g, 0.30mm; 0.22g, 0.14mm; and 0.34g, 0.04mm for the 3 size groups, small, medium, and large, respectively.

Numbers, average widths, widths and gains of crabs stocked in the second laboratory-study are given in Table 6. In the second study at 30 C only 40% of the crabs survived in the V-shaped molting chambers versus 59% at ambient temperatures. Survival was also better in the wire chambers (70%) than in the V-shaped chambers (59%). During the third laboratory-study survival was again greater in the wire chambers (92.8%) than in the V-shaped chambers (85.7%) (Table 7).

Table 6. Number, average carapace width, weight, and gain of blue crabs stocked in molting units in Study 2 at 30 C and ambient temperature in solid-wall and wire-walled molting units.

| *Molting Unit* | *Stocked (N)* | *Survivors (%)* | *Carapace Width (mm)* | | *Weight (g)* | | *Width Gain* | | *Weight Gain* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Initial* | *Final* | *Initial* | *Final* | *(mm)* | *%* | *(g)* | *%* |
| 71 | 5 | 60.0 | 65.0 | 66.0 | 24.7 | 24.9 | 3.0 | 5.5 | 2.5 | 15.8 |
| 72 | 7 | 42.9 | 63.7 | 56.3 | 22.8 | 16.1 | 0 | 0 | −0.3 | −1.9 |
| 76 | 6 | 16.7 | 105.8 | 121 | 79.8 | 106.1 | 14 | 13.1 | 21.2 | 25.0 |
| Average | 6 | 39.9 | 78.2 | 81.1 | 42.4 | 49.0 | 5.7 | 6.2 | 7.8 | 13.0 |
| 73 | 7 | 71.0 | 54.7 | 65.4 | 14.8 | 23.1 | 6.6 | 11.8 | 5.9 | 36.5 |
| 74 | 10 | 90.0 | 66.2 | 72.1 | 25.4 | 30.8 | 4.9 | 8.0 | 4.3 | 19.9 |
| 77 | 10 | 40.0 | 103.5 | 101.8 | 74.9 | 76.4 | −0.8 | −0.7 | 4.4 | 6.6 |
| 81 | 4 | 25.0 | 129.8 | 133.0 | 119.5 | 131.3 | 1.0 | 0.8 | 3.8 | 3.0 |
| 82 | 10 | 70.0 | 140.6 | 157.3 | 183.3 | 231.7 | 11.1 | 9.0 | 19.8 | 18.1 |
| 83* | 10 | 70.0 | 141.7 | 153.3 | 151.3 | 162.2 | 7.4 | 5.5 | 9.4 | 8.2 |
| 84* | 10 | 70.0 | 102.6 | 109.6 | 73.7 | 86.0 | 5.3 | 7.0 | 12.3 | 24.8 |
| Average | 8.7 | 62.3 | 105.6 | 113.2 | 91.8 | 105.9 | 5.1 | 5.9 | 8.6 | 16.7 |

* Wire-walled molting units.

Table 7. Number, average initial carapace width, weight, final carapace width and gain of blue crabs stocked at ambient temperature in solid-wall and wire-walled molting units in Study 3.

| *Molting Unit* | *Stocking (N)* | *Survivors (%)* | *Weight (g) Initial* | *Carapace Width (mm) Initial* | *Final* | *Gain mm* | *%* |
|---|---|---|---|---|---|---|---|
| | | | Solid Wall Units | | | | |
| 82 | 7 | 85.7 | 231.7 | 160.8 | 164.0 | 3.2 | 2.3 |
| | | | Wire Walled Units | | | | |
| 83 | 7 | 100.0 | 162.2 | 153.3 | 165.6 | 12.3 | 8.5 |
| 84 | 7 | 85.7 | 86.0 | 110.5 | 116.3 | 5.8 | 5.6 |
| Average | 7 | 92.8 | 124.1 | 131.9 | 141.0 | 9.1 | 7.1 |

## DISCUSSION

Temperature values in the discharge canal averaged 3.8 C above pond 12 values. Dissolved oxygen values at both stocking locations were above the minimum 4 ppm level sufficient for survival, growth, reproduction, and well being of estuarine animals as set forth by the committee on water quality criteria (U. S. Department of the Interior 1968). Total gas saturation levels in the discharge canal were above 100% throughout the study. No symptoms of gas bubble disease were detected. Dissolved oxygen, pH, turbidity, salinity and temperature values were well within ranges in which blue crabs are commonly found (Jackson 1974; Jones 1974).

It is believed that heated effluents affect the growth of organisms due to many factors; an important factor is the elevation of metabolic rate. Holland et al. (1971) reported the optimum temperature of growth of 5-40mm blue crabs to be 29-30 C. The mean temperature in the discharge canal (24.3 C) was closer to the optimum than the mean temperature in pond 12 (19.5 C). The larger harvest size of crabs cultured in the discharge canal could have been the result of the more favorable temperatures.

A tremendous number of small young-of-the-year fish, some of which had recently died, were present in the discharge canal. The dead fish became trapped on the wire mesh and flotation material of the cages. Although an attempt to supply an abundance of food was made, these fish could have been utilized as supplementary food. If this occurred, the hypothesis that cannibalism results from a lack of food would be questionable since pond 12 crabs, which did not receive supplemental food, had a higher survival rate than the discharge crabs. Cannibalism did not appear to be a result of a lack of food, but to crowding in the cages. As a result of cannibalism, the survival of blue crabs in the discharge canal and in pond 12 was lower than that which would be permissible for the successful mariculture of the species.

For each treatment, growth of surviving organisms in the discharge canal was significantly greater ($P = 0.01$) than growth in pond 12. Considering both survival and growth, the lower stocking density of blue crabs appears to be better than the higher density. The presence of the artificial habitat appeared to enhance survival at the lower stocking density in the discharge canal but had no effect in the pond cages.

Crabs in the flow-through chambers grew, but the growth rates were not as encouraging as reported for a closed system (Winget et al. 1973). In their closed recirculating system crabs averaged one molt in 27-28 days with an increase of 19.3% in carapace width and 104% increase in weight. In the flow-through "V" chambers crabs at 30 C increased only 31.6% (range, 1.6 to 97.3%) in weight and 8.4% (range, 0.4 to 22.1%) in carapace width. The controls averaged increases of 45.4% (range, 5.7 to 132.7%) and 10.2% (range, 9.2 to 28.4%) for weight and width, respectively.

The hydrological conditions of these two studies were certainly not the same (25 C and 25 ppt in the closed system versus 21 C to 30 C and 2.5 ppt to 5.5 ppt in the flow-through system) but results showed a greater disparity than expected for a euryhaline organism. Winget et al. (1973) felt it imperative to have particulate-free water and designed their system accordingly. Silt in our flow-through chambers was detrimental to water quality. Individual crabs became isolated from the water flow as the silt and waste food products obstructed water passages. When water quality deteriorated, crabs moved to the water-air interface to respire. However, during the molting process when good water quality became most critical, the crabs were unable to maintain a position at the water-air interface. It was during the molting stage as the carapace would be lifted and the crab was in the process of emerging from the old exuviate that most mortalities occurred.

The 30 C group molted more frequently than those at ambient temperature (41 vs 35 attempts) and the overall survival rate was much lower (46 vs 80%). Silt and poor water quality due to obstructed flows were considered to be the prime causes of low survival. If chambers are to be used to produce soft shell crabs they must be designed to insure adequate water flow. At elevated temperatures crabs molt more frequently, therefore, increased temperatures would be more desirable for commercial crab operations. As temperatures increase there is a greater demand for oxygen and good water; in practice it becomes more difficult to maintain good water quality with higher temperatures.

Reimer and Strawn (1973) reported that a soft shell crab industry in the heated effluent of a Texas power plant might be feasible since temperatures were favorable for molting and that blue crabs were abundant during winter in a discharge canal. Jackson (1974) found crabs to be abundant all year in the Cedar Bayou cooling lake. A commercial crabber operating throughout the year within this cooling lake has reported catches (unsubstantiated) as high as 150 doz/day.

Crabs could be collected throughout the year in the heated effluent and those in the pre-molt stage could be stocked in molting chambers to produce soft shell crabs. The selection of crabs in the late pre-molt stage would increase molting frequency and thus production. For the production of soft shell crabs in molting chambers to be successful the silt deposition and biological fouling will need to be reduced. Troughs placed adjacent to the discharge canal and receiving water by gravity flow could be used to hold the molting chambers. With sufficient flows the troughs would be swept clean and crabs could molt in wire baskets. These baskets would be readily accessible and convenient, but the use of stationary troughs beside the discharge canal would be limited seasonally by the high summer temperatures in Texas.

It would be possible to use specially designed cages in the discharge canal where the water movement would remove silt and waste food products. The cages would require frequent changing to control fouling. A raft could be designed to hold the molting cages in the water and to allow access to individual chambers. The raft, similar to the ones used for eel culture in Japan (Bardach et al. 1972), would provide a work and storage area and could be moved to areas of optimum temperatures allowing year around operation.

## CONCLUSIONS

Water quality was acceptable for culturing blue crabs throughout the study. Waste heat effluent was found to be beneficial to their growth in the discharge canal. Crabs cultured in cages in the heated effluent grew larger for all treatments than those kept in cages in a pond. Crabs stocked in the discharge at the lower density, with or without artificial habitat, grew larger than those stocked at the higher density. The low survival rates at these stocking densities (20 and 40 per 0.16$m^3$ cage) indicate that a successful crab mariculture operation must provide individual chambers for isolation of crabs.

In the laboratory studies the difference in growth of crabs cultured at 30 C and at ambient (20.9-29.2 C) was not statistically significant. Crabs at the higher temperatures did molt slightly more frequently than the controls but they also incurred greater mortalities than the controls. Silt and waste food products obstructed water flow and water quality deteriorated. Crabs in wire baskets with individual compartments had better survival than crabs in chambers with solid walls. If allowances were made to minimize silting and fouling a soft shell industry could be developed utilizing the heated effluents from power plants.

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# SUSCEPTIBILITY OF THREADFIN SHAD TO IMPINGEMENT[1]

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## ABSTRACT

Threadfin shad impingement at 13 Tennessee Valley Authority electric generating plants from August 1974 through July 1975 was analyzed to assess mortality resulting from low water temperature. Concurrent laboratory experiments were conducted to evaluate the ability of cold-stressed threadfin shad to avoid impingement. Temperatures of 12°C stressed fish in the laboratory, while those below 8°C caused high impingement mortality. At 5 of 12 fossil-fuel plants, 90 percent or more of the annual threadfin impingement occurred when water temperatures were below 10°C. At four plants, impingement was not related to low temperatures. Impingement at the Browns Ferry Nuclear Plant generally coincided with low water temperatures, but individual impingement peaks were not consistently associated with cold shocks.

## INTRODUCTION

The collection of fish on cooling water intake screens (impingement) at electric generating facilities is currently receiving attention throughout the country, owing primarily to licensing requirements for nuclear plants and enactment of the Federal Water Pollution Control Act, Section 316(b). In the southeast United States threadfin shad, *Dorosoma petenense* (Günther), comprise a large proportion of the fish which are impinged at inland generating facilities, occasionally accumulating in large enough numbers to cause physical damage to the intake screens.

Often the greatest threadfin shad impingement occurs during the colder winter and spring months. Threadfin shad are known to be sensitive to low water temperatures and are frequently observed in an apparent moribund condition throughout many reservoirs during this cold period. Laboratory studies have suggested that exposure of threadfin shad to temperatures below approximately 7-9°C causes high mortality, especially when associated with rapid decreases in temperatures (cold shocks) (Parsons and Kimsey 1954; Strawn 1965).

The Tennessee Valley Authority (TVA) has been conducting studies at its 12 fossil-fuel and one nuclear electric generating plants to assess the magnitude of fish impingement and its effect on the reservoir fish populations. Because of high impingement during the colder months of the year at several TVA power plants, it was hypothesized that much of the impingement represented a collection of threadfin shad that were dead or dying because of cold stress. To evaluate this hypothesis a cooperative study was undertaken between TVA and Oak Ridge National Laboratory in 1975. The purpose of this report is to present preliminary results of that study. Specific objectives are:

1. To describe the behavior and swimming ability of threadfin shad exposed to laboratory-induced cold temperatures.
2. To evaluate the susceptibility of cold-stressed threadfin shad to, and ability to recover from, impingement under experimental conditions.
3. To examine the quantitative seasonal aspects of threadfin shad impingement at each TVA electric generating station.
4. To assess the amount of impingement that may be attributed to cold stress.

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