EFFECTS OF SOIL AND WATER HARDNESS ON SURVIVAL AND GROWTH OF THE RED SWAMP CRAWFISH, Procambarus clarki, IN PLASTIC POOLS

By LARRY DE LA BRETONNE, JR., JAMES W. AVAULT, JR., and R. ONEAL SMITHERMAN

School of Forestry and Wildlife Management
Louisiana State University
Baton Rouge, Louisiana

ABSTRACT

The effects of soil and water hardness on growth and survival of red swamp crawfish, *Procambarus clarki,* were studied in plastic pools.

Pools had no soil or Calhoun soil, with water hardnesses adjusted with calcium chloride to 9, 50, 100 or 150 parts per million, or pools had Sharkey soil with water hardnesses of 50, 100, 150 or 200 ppm.

Water hardness was the most significant factor affecting growth and survival of crawfish. As water hardness increased, so did the mean weight gain and per cent survival.

At 9 ppm water hardness, the presence of soil resulted in similar weight gain per crawfish as in no-soil pools but crawfish survival in pools containing soil was 53 to 77 per cent and only 9 per cent in pools with no soil.

Good growth of crawfish occurred in the absence of soil, if water hardness was high.

The highest mean weight gain per crawfish and per cent survival were in pools containing Sharkey soil.

Average production per acre figures ranged between 28 to 411 pounds per acre with the greatest production from a single pool being 778 pounds per acre. The average growth period was 36 days.

INTRODUCTION

According to Penn (1959) there are four genera and 29 species of crawfish in Louisiana. Crawfish of commercial importance in Louisiana are the red swamp crawfish, *Procambarus clarki,* and the white river crawfish, *P. blandingi acutus.* The average commercial catch consists of 90 per cent red swamp crawfish and 10 per cent white river crawfish.

There are approximately one and three-quarter million acres of fresh water marsh and about two and one-half million acres of salt water marsh in Louisiana (Viosca, 1928) much of which is suitable for crawfish (Penn, 19).

In natural production areas, the commercial crawfish fishery is on a seasonal basis, being limited to spring and early summer months. The Atchafalaya Basin, a prime area for this natural production, produced a commercial catch of 2.8 million pounds of crawfish in 1959 (Lambou, 1965). This total does not include a large catch of crawfish harvested by non-commercial fishermen. The Louisiana Department of Agriculture values the present crawfish industry at over $5 million.

Historically, the natural crawfish production has fluctuated from 200,000 to 1,000,000 pounds (Broom, 1963; LaCaze, 1966). Two thousand acres of impoundments for crawfish culture were constructed in 1959-1960 (Viosca, 1961) and the acreage has increased to approximately 10,000 acres in 1968 (LaCaze, 1968). The impoundments are of three distinct types:

1. Ponds constructed only for crawfish production.
2. Rice fields in which crawfish are rotated with the rice crop.

3. Wooded or swampy crawfish ponds in which vegetation remains standing in the impounded area.

With impoundments, crawfish farmers can exert some control on factors such as water level, stocking rate, supplemental feeding, time of draw down and method of harvest. These factors are otherwise controlled by nature or are impossible to accomplish in the vast areas of natural production. Using management techniques, the crawfish farmer is able to produce a crop earlier than the bulk of the natural production and therefore receive a premium price.

The crawfish spends its entire life surrounded by soil and water and in this environment all life processes must occur. Therefore, due to the increased interest in impoundments and the importance of the environment, a prime consideration in crawfish culture should be water quality.

Smitherman, *et al.* (1967), while conducting experiments to determine the effects of supplemental feeding and fertilization on production of red swamp crawfish in plastic pools, found that the effects of the treatments were masked by the total hardness of the water.

Because of the apparent importance of water hardness to growth and survival of crawfish, this study was begun. In this study the effects of soil and water hardness were studied as related to survival and production of the red swamp crawfish in plastic pools.

MATERIALS AND METHODS

Experimental Units

Plastic pools, 10 feet in diameter and three feet deep were used as experimental units. The pools contained no soil, four inches of Calhoun soil from Baker, Louisiana, or four inches of Sharkey soil from Ben Hur Farm at L. S. U. Calhoun soils, low in fertility and calcium content, and Sharkey soils, high in fertility and minerals, are characterized by Lytle (1968). Artesian well water located on the L. S. U. Ben Hur Farm was used to fill all experimental pools.

Experimental Procedure

The experiment was designed as follows:

Pools	Total Hardness (ppm)				
No soil	9	50	100	150	–
Calhoun	9	50	100	150	–
Sharkey	–	50	100	150	200

Calcium chloride was used to adjust hardness levels in pools weekly. Each level contained three replications. One-fourth of a pound of calcium chloride, that was added to a pool, increased the hardness about 25 ppm. Hardness was determined by titration with ethylene-di-amine-tetra-acetic acid (Anonymous, 1960). After adjusting the hardness, crawfish were stocked.

Two experiments were conducted, trial 1 in 1967 and trial 2 in 1968. Crawfish used in both trials were collected on Ben Hur Farm. Crawfish used in trial 1 measured between 8 and 20 mm; the most frequent range was 8 to 12 mm. Nineteen crawfish per pool were stocked on 6-15-67. The average weight per crawfish was 1.67 grams and the stocking rate was 10,555 crawfish per acre. Crawfish used in trial 2 measured between 32 and 50 mm; the most frequent range was 32 to 40 mm. Thirty-six crawfish per pool were stocked on 5-4-68. The average weight per crawfish was 4.02 grams and the stocking rate was 20,000 crawfish per acre.

Once crawfish were stocked, daily feeding was begun with a commercial fish pellet. Because of the possibility of oxygen depletion on overcast and rainy days, feeding was suspended on such days. When crawfish were fed, top and bottom water temperatures were taken.

One-fourth inch hardware-cloth ladders were placed in each pool as an extra precaution against possible oxygen depletion. A 2 x 5 foot piece of hardware cloth was crimped along all sides, bent along its length and placed in pools at an angle from pool bottom to three inches below the rim. In the event of possible oxygen depletion, crawfish could, if necessary, leave the deeper unoxygenated waters by climbing up the screen ladder to more oxygenated waters.

Trial 1 was terminated after 27 days and trial 2 after 45 days.

Analyses of Data

Top and bottom samples were collected of Calhoun and Sharkey soils for chemical analyses. Samples were taken from pools used in both trial 1 and trial 2. Top soil samples were a composite of the upper one-fourth inch from the three replications within each soil type for each hardness level. The bottom samples were composites of bottom soils below the one-fourth inch soil level at the various hardness levels. Phosphorous, potassium, calcium, magnesium and pH of the soil samples were determined by the Louisiana Agricultural Experiment Station at the Soil Testing Laboratory.

Claw and tail meats from trial 1 crawfish were separated from the exoskeletons. Each meat and exoskeleton sample from the various water hardness levels was analyzed by the L. S. U. Feeds and Fertilizer Laboratory for per cent protein, fat, moisture, ash, calcium, magnesium, nitrogen, phosphorous, and potash.

RESULTS AND DISCUSSION

GROWTH AND SURVIVAL OF CRAWFISH

Experimental Units and Procedure

An important factor to consider, when dealing with natural ponds, is the loss of crawfish from burrowing, migrations, and predation. This factor was controlled in this study by use of artificial plastic pools. The plastic pools are inexpensive experimental units. However, the liners can be punctured by the sharp chela of maturing crawfish. Puncture most frequently occurred at the stretched area along the soil-water level.

Water hardness of pools fluctuated slightly after the initial hardness was regulated. Pools with a 100 ppm water hardness decreased 10 to 15 ppm and water hardness of the 150-200 ppm pools decreased about 20 to 25 ppm each week. Hardness was corrected by addition of calcium chloride. Calcium chloride is probably the most soluble source of calcium and therefore served as a good agent to adjust water hardness. Cheaper but less soluble commercial lime could be substituted for the expensive calcium chloride used in this study.

Sharkey soil caused hardnesses in overlying water of 40 to 80 ppm; therefore a 9 ppm level was not possible and the 50 ppm water hardness level was considered as the control level.

During the trial 2 experiment, the mean pool temperature of the top water was 35.0° C. and the mean pool bottom water temperature was 33.0° C.; air temperatures averaged 38.0° C. All temperatures were taken between three and four o'clock in the afternoon.

Effect of Soil

The highest mean weight gain per crawfish and per cent survival were in pools containing Sharkey soil (Table 1). The mean weight gain per crawfish for soil types is a combination of all trial and water hardness levels found in the soil type.

The top weight gain per individual crawfish in pools with Sharkey soil, Calhoun soil and no soil were 15.61, 13.41 and 20.65 grams, respectively.

Mean per cent survival of crawfish was better in Sharkey soil pools (84 per cent) as compared to Calhoun (76 per cent) and no-soil pools (59 per cent) (Table 2).

Crawfish exoskeletons from no-soil pools were generally soft. The degree and per cent exoskeleton softness was greatest in no-soil pools at the lower water hardness levels with progressively fewer soft shells at the higher water hardness levels. Crawfish from pools containing soil had hard exoskeletons. Evidently the soil added a factor which aided exoskeleton rigidity.

Effect of Hardness

Water hardness was the most significant factor affecting mean weight gain and per cent survival of crawfish. As water hardness increased, so did the mean weight gain and per cent survival (with one exception); the average per cent survival decreased in 200 ppm pools. Further tests need to be conducted to check the effect of hardnesses of 200 ppm and above on growth and survival.

For any given hardness the variability in growth and survival was apparently less for crawfish in pools containing the Sharkey soil, with one exception (Table 1). Growth of crawfish in Sharkey soil at a hardness of 150 ppm (trial 2) showed a variability in average growth of –2.03 to 12.95 grams. The weight loss in one pool (–2.03 grams) was lower than in the other five pools. The next lowest gain was 10.47 grams. Apparently some unknown factor caused the weight loss in one of the experimental pools and the data from this pool were not considered in the experiment.

TABLE 1. Growth and per cent survival in pools containing no soil, Calhoun and Sharkey soil at the various water hardness levels

Pool	Hardness (ppm)	Avg. gain per crawfish	Growth variability	Avg. % survival	% survival variability
No soil	9	5.39	–1.91-20.65	9	0-22
No soil	50	9.99	5.52-13.06	65	22-89
No soil	100	11.34	8.43-15.21	78	42-95
No soil	150	11.37	9.31-13.59	83	72-89
Calhoun	9	5.93	2.71- 9.58	53	25-84
Calhoun	50	7.82	5.24-11.53	78	42-89
Calhoun	100	9.12	4.78-12.78	87	56-100
Calhoun	150	9.51	6.02-13.41	87	79-95
Sharkey	50	10.48	8.82-15.37	85	68-100
Sharkey	100	9.87	8.30-11.61	88	79-100
Sharkey	150	11.88	10.47-12.95	91	81-100
Sharkey	200	12.35	10.26-15.61	71	61-95

Each treatment is an average of six replications, three from trial 1 and three from trial 2.

TABLE 2. Mean weight gain per crawfish and per cent survival per pool as compared to soil type and water hardness level. The mean is a combination of means from trials 1 and 2

Soil	Weight gain per crawfish *		Per cent survival	
	Mean	Range	Mean	Range
No soil	9.52	4.66-13.25	59	9-83
Calhoun	8.10	3.28-11.42	76	53-87
Sharkey	11.15	9.24-12.43	84	71-91
Hardness				
9 ppm	5.66	3.20- 8.65	31	9.70
50 ppm	9.43	5.67-11.99	76	53-91
100 ppm	10.11	7.01-13.25	85	72-91
150 ppm	10.92	7.39-13.17	87	77-96
200 ppm	12.35	12.27-12.43	71	64-77

* Weights are in grams.

Data from experiment at the 9 ppm level indicated that the presence of soil resulted in greater crawfish survival (53 to 77 per cent) than in the absence of soil (9 per cent). A good example of the effects of low water in the pool. The crawfish were transferred to a pool containing no the experiment. One pool containing Sharkey soil, with a hardness adjusted to 150 ppm and containing 21 hard-shelled crawfish, lost all the water in the pool. The crawfish were transferred to a pool containing no soil with a water hardness of 9 ppm. After one month, seven softshelled crawfish remained in the pool.

Even though soil was necessary for hard-shelled crawfish, good growth of crawfish occurred in the absence of soil and in the presence of high water hardness levels. Average gain per crawfish and per cent survival in no-soil pools was greater at hardnesses of 50 ppm and above than in comparable Calhoun soil pools.

Production per acre

Forney (1958) reported a range of production from 80 to 352 pounds per acre of cultured *Orconectes immunis.*

There are few production figures of red swamp crawfish, probably because of the vast natural areas where crawfish are trapped by both commercial and sport fisherman. With the advent of impoundments, more production figures have been compiled. Thomas (1965) recorded production of red swamp crawfish as high as 1,000 pounds per acre. This estimate was based on crawfish placed in wire cages located in rice fields. Broom (1961) produced up to 1,200 pounds per acre in plastic pools and ponds.

Smitherman, *et al.* (1967) in pools with Sharkey soil, found production ranging from 90 to 372 pounds per acre. Average production in pools with no soil was 38 to 52 pounds per acre, probably because of the low water hardness.

Average crawfish production per acre observed in this study is given in Table 3. Sharkey soil produced the highest mean crawfish production per acre. At the various hardness levels, the mean crawfish production per acre was 365 for Sharkey pools, 202 for Calhoun pools and 276 pounds per acre for no-soil pools.

The average means for crawfish production per acre at the various hardness levels were as follows:

Hardness (ppm)	Production per acre (lbs.)
9	39
50	264
100	359
150	357
200	350

The data show crawfish production is progressively greater up through 100 ppm but does not increase after the 100 ppm water hardness level.

The greatest crawfish production was from one pool in which 778 pounds per acre were produced. This pool contained no soil and had a water hardness of 100 ppm.

The data indicate that the average weight gain per crawfish was greater at the higher, trial 2 (20,000 per acre), stocking level. Future experiments should determine the various stocking rates and carrying capacity of experimental plastic pools.

Analyses

Soil

Soils were analyzed for phosphorous, potassium, calcium, magnesium and pH and the results for both trials were compared (Table 4). All minerals were highest in the Sharkey soil. Top soils had the most calcium, probably because of the calcium chloride added to all but the control pools.

TABLE 3. Crawfish production per acre for trials 1 and 2 in plastic pools containing no soil, Calhoun soil and Sharkey soil at various water hardness levels

Pool	Hardness (ppm)	Average total weight*		Mean total weight	Production per acre** Mean	Range
		Trial 1	Trial 2			
No soil	9	0.04	0.06	0.05	28	0- 78
No soil	50	0.44	0.51	0.47	261	128-495
No soil	100	0.34	1.12	0.73	405	122-778
No soil	150	0.43	1.06	0.74	411	230-694
Calhoun	9	0.14	0.04	0.09	50	47-317
Calhoun	50	0.27	0.34	0.30	166	139-544
Calhoun	100	0.32	0.70	0.51	283	150-655
Calhoun	150	0.32	0.79	0.55	305	139-683
Sharkey	50	0.42	0.96	0.66	366	190-567
Sharkey	100	0.41	0.99	0.70	388	190-611
Sharkey	150	0.54	0.74	0.64	355	83-600
Sharkey	200	0.45	0.81	0.63	350	200-511

* Weights are in grams.
** Average growth period—36 days.

Crawfish

Chemical analyses of crawfish exoskeletons and peeled tail and claw meats from the trial 1 crawfish revealed that fifty per cent less calcium occurred in exoskeletons from crawfish of the 9 ppm Calhoun pools than in other pools. Low survival prevented analyses of crawfish from the 9 ppm no-soil pools.

At draining, pools containing no soil had approximately 50 per cent soft-shelled crawfish at the higher hardness levels, and 90 to 100 per cent soft-shelled crawfish at the lowest water hardness level. This might be correlated with magnesium in exoskeletons. The magnesium level was three times greater in the exoskeletons from pools with soil.

Crawfish meats were all similar in chemical analyses. Sophisticated studies of the effects of magnesium and calcium on growth and survival of crawfish should be investigated.

SUMMARY

Plastic pools were used as experimental units to determine growth and survival of red swamp crawfish, *Procambarus clarki*.

Pools containing no soil or Calhoun soil had water hardnesses of 9, 50, 100 or 150 parts per million; pools containing Sharkey soil had water hardnesses of 50, 100, 150 or 200 ppm. Calcium chloride was used to adjust water hardness levels.

The highest mean weight gain per crawfish and per cent survival were in pools containing Sharkey soil.

Crawfish exoskeletons from no soil pools were generally soft; those from pools containing soil were hard.

Water hardness was the most significant factor affecting mean weight gain and per cent survival of crawfish. As water hardness increased, so did the mean weight gain and per cent survival.

For any given water hardness, the variability in growth and survival was apparently less for crawfish in pools containing Sharkey soil.

Below 50 ppm water hardness, (9 ppm) data indicate that the presence of soil resulted in greater crawfish survival (53 to 77 per cent) as compared to nine per cent survival without addition of soil.

TABLE 4. Parts per million potassium, phosphorous, calcium, magnesium and the pH of top and bottom Calhoun and Sharkey soils at the various water hardness levels (trials 1 and 2)

Soil type	Hardness level (ppm)	P Top	P Bot.	K Top	K Bot.	Ca. Top	Ca. Bot.	Mg. Top	Mg. Bot.	pH Top	pH Bot.
Trial 1											
Calhoun	9	33	20	75	75	360	320	180	163	7.1	6.5
Calhoun	50	25	23	90	75	1,770	600	124	161	7.6	6.7
Calhoun	100	30	25	90	75	2,160	790	108	124	7.5	7.0
Calhoun	150	25	33	95	85	2,720	1,280	96	117	7.4	6.9
Sharkey	50	118	151	180	160	2,440	2,400	779	1,000+	7.0	6.4
Sharkey	100	156	179	190	150	4,000+	2,320	545	881	7.3	6.6
Sharkey	150	136	161	255	175	4,000+	3,000	484	1,000+	7.3	6.7
Sharkey	200	151	166	220	160	4,000+	2,320	350	608	7.2	6.5
Trial 2											
Calhoun	9	24	122	105	80	670	450	190	106	7.3	6.7
Calhoun	50	44	24	100	80	2,000	920	311	175	7.7	7.0
Calhoun	100	27	27	135	75	4,000+	1,200	179	125	7.8	7.2
Calhoun	150	24	24	100	80	3,530	1,560	130	171	7.7	7.5
Sharkey	50	132	137	200	160	3,580	3,130	1,000+	1,000+	7.7	7.3
Sharkey	100	170	178	215	215	4,000+	3,530	1,000+	983	7.6	7.3
Sharkey	150	127	129	180	200	3,430	4,000+	999	1,000+	7.4	7.5
Sharkey	200	129	146	220	155	4,000+	3,580	1,000	1,000+	7.7	7.4

Average gain per crawfish in no-soil pools was greater at 50 ppm and above water hardnesses than in comparable hardness levels in pools with Calhoun soil; per cent survival was also comparable at and above the 50 ppm water hardness levels.

The data show crawfish production was progressively greater up through 100 ppm water hardness but did not increase above that level. Greatest crawfish production was from one pool in which 778 pounds per acre were produced.

Analysis of the soils showed mineral levels highest in Sharkey soil; top soils had the most calcium.

Fifty per cent less calcium occurred in exoskeletons from crawfish of the 9 ppm Calhoun soil pools than in other pools.

The magnesium level was three times greater in exoskeletons from pools with soil. Crawfish meats were all similar in chemical analyses.

LITERATURE CITED

Anonymous, 1960. Standard methods for the examination of water and waste water, including bottom sediments and sludges. 11th Edition. American Public Health Association, Incorporated, New York. 626 pp.

Broom, J. C. 1961. Production of the Louisiana red crawfish, *Procambarus clarki* (Girard), in ponds. Masters Thesis. Auburn University. 38 pp. Unpublished.

Forney, J. L. 1958. Raising bait fish and crayfish in New York ponds. Cornell Extension Bulletin 986. 30 pp.

LaCaze, Cecil G. 1966. More about crawfish. Louisiana Wildlife and Fisheries Commission Wildlife Education Bulletin No. 96. 16 pp.

LaCaze, Cecil G. 1968. Personal communication regarding crawfish pond acreage in Louisiana.

Lambou, Victor W. 1965. The commercial and sport fishery of the Atchafalaya Basin floodway. Proceedings Southeastern Association of Game and Fish Commissioners 17:256-282.

Lytle, S. A. (1968). Soil Survey of East Baton Rouge Parish, Louisiana. United States Department of Agriculture, Soil Conservation Service. Government Publication (in press).

Penn, G. H., Jr. 1943. A study of the life history of the Louisiana red crawfish, *Cambarus clarki* (Girard). Ecology 24(1):1-18.

Penn, G. H., Jr. 1959. An illustrated key to the crawfishes of Louisiana with a summary of their distribution within the state. Tulane Studies in Zoology 7(1):3-20.

Smitherman, R. O., J. W. Avault, L. W. de la Bretonne, and H. A. Loyacano. (1967). Effects of supplemental feed and fertilizer on production of red swamp crawfish, *Procambarus clarki*, in pools and ponds. Proceedings Southeastern Association of Game and Fish Commissioners 21:452-458.

Thomas, Carl H. 1965. A preliminary report on the agricultural production of the red swamp crawfish, *Procambarus clarki* (Girard) in Louisiana rice fields. Proceedings Southeastern Association of Game and Fish Commissioners 17:180-186.

Viosca, Percy, Jr. 1928. Louisiana wetlands and the value of their wildlife and fishery resources. Ecology 9:216-230.

Viosca, Percy, Jr. 1961. Crawfish culture, mudbug farming. Louisiana Conservationist 13(3):5-7.