The Impact on the Native Appalachian Brook Crayfish (*Cambarus bartonii*) by the Exotic Rusty Crayfish (*Orconectes rusticus*)

By: Noble Robinette and Mark Quickel
Tennessee High School
Special Projects Class

Personal Contacts and Acknowledgments

Robin Cooper, University of Kentucky - rlcoop@pop.uky.edu

Kevin Hamed, Steele Creek Nature Center Manager (989-5616)

Don Holt, Steele Creek Nature Center

Pete Wyatt, Tennessee Wildlife Association (1-800-332-0900)

Mike Johnson, Director of Leisure Services Department
325 McDowell St.
Bristol, Tennessee 37620

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Abstract

The research for this project took place at two locations in Steele Creek Park. The first area was located in Steele Creek above the dam, and the second are was located in Steele Creek below the dam. The point of this project was to discover whether the Appalachian Brook crayfish had been forced out of Steele Creek Park by the Rusty crayfish. Throughout this project a total of 369 crayfish were caught and documented with a total of 304 Rusty crayfish and 74 Appalachian crayfish. Research also took place indoors in a lab in order to obtain a closer look at the interactions between the two species. The information that was discovered through this project shows that the Rusty crayfish has become more dominant and the number of Appalachian Brook crayfish is decreasing.

Introduction and Literature Review

The displacement of native crayfish by Rusty Crayfish (*Orconectes rusticus*) has been evident in many studies (Clancy 1997; Lodge 1985). One such example of displacement is occurring in the northern Wisconsin lakes, *Orconectes rusticus* is replacing the native *Orconectes virilus* and *Orconectes propinquus* (Hill 1999). These non-indigenous crayfish have eradicated the natives due to many factors such as: predation, competition for food, dwellings, as well as mates. These factors have greatly reduced the amount of native crayfish in numerous locations. The Rusty Crayfish has therefore become well known as one nasty crayfish (Roush 1997).

In past studies by Paul Clancy, the *Orconectes rusticus* has been identified as the most troublesome of the invading crayfish species. Rusty Crayfish were spread by fishermen who had been using them as bait and had been throwing the remaindor into the waters (Clancy 1997). This introduction caused the decline of native crayfish population and a great increase in the population of Rusty Crayfish. This problem did not go unnoticed, but even with the outlawing of Rusty Crayfish as live bait the economic troubles had already begun (Lodge 1985). This new invader which was located in only nine locations in the Tennessee Cumberland River Basin as of 1985 can now be found in as many as 39 separate places in that area(Clancy 1997).

One main reason for the displacement of the native crayfish is directly from their competition of food with the Rusty Crayfish. The *O. rusticus* consumes more food than their native counterparts (Clancy 1997). They readily eat plants, small invertebrates, and even small mammals. In one location, the Rusty Crayfish consumed all plants except for water celery, and completely eliminated one species of snail (Lodge 1985). Not only

does the Rusty Crayfish eat other animals, but they also consume smaller native crayfish. This observation was discovered in both the field and the laboratory (Hill 1999).

Greatness in size and aggressiveness of the Rusty Crayfish is another key factor in the loss of the natives. The greater size is an advantage in fighting and in warding off would-be predators. In some observances if a small mouth bass fails to attack the Rusty from the rear, the bass will in turn have to escape from the powerful pinchers that have grabbed its lips. The aggressiveness has also been a factor in the skirmishes for dwellings. The mere sight of a Rusty Crayfish sends native crayfish running. Even when the crayfish flee to their shelters, the Rusty Crayfish will force them out and keep the dwelling as its own. This works for juveniles as well (Lodge 1985).

Reproduction is another reason for the displacement of the natives. The Rusty Crayfish more commonly misidentifies other crayfish as members of their own species. The Rusty Crayfish will mate with the other species, *O. propinquus* and *O. virilis*, thus preventing the females reproducing with their own species (Lodge 1985). This inter-species relationship also produces hybrids. The hybrids are more aggressive and better adapted than the Rusty Crayfish. Most hybrids are thought to be sterile, however the hybrid formed by the Rusty and *Orconectes propinquus* have proved to be fertile. This also increases the amount of competition in the environment. Together, the Rusty and hybrid crayfish accounted for 30% of the total population of crayfish in one lake in Wisconsin (Roush 1997). The Rusty Crayfish young also grow at a faster rate than the natives (Hill 1999). The density of *O. rusticus* in some areas is much as 13 adults to one square yard (Lodge 1985). These studies suggest that the Rusty Crayfish is becoming the most numerous invader in many areas; diminishing the amount of the native crayfish.

Methods and Materials

Research began in the field at Steele Creek Park in Sullivan County Tennessee. Work took place in Steele Creek above the dam, as well below the dam (see Figure 1). Methods consisted of taking the temperature of the water with a standard thermometer, and then proceeding into the creek in simple hip waders. Research would then head upstream with one of us stirring up the rocks and debris ahead while the other stayed behind with a kick net and caught whatever swam in. When a crayfish was caught, it was measured (see Figure 2), its gender and species recorded (see Figure 3), whether or not it had any abnormalities, where it was caught, and the water depth. It was then placed back in the water downstream. The length was measured using a standard meter stick and we measured the crayfish from the tip of its rostrum to the end of its tail. The difference in the species was discovered by the difference in the rostrum, claspers, and color of the two species. Research would proceed upstream until the segment of the Steele Creek that was being studied had been completed.

The research inside the lab began after four crayfish were brought back for studying. Two Rusty and two Appalachian Brook crayfish were brought back from the creek in buckets. One of the Rusty and one of the Appalachian were placed in a large fifty gallon tank together with a filter, aquarium gravel, and rocks set up as caves for them to live in. In studying these crayfish, their weight was documented daily on an Acculab electric scale, and the daily temperature of their water was documented as well. To weigh the crayfish, they would be caught using two aquarium nets and then placed in baskets to keep them in place while they were weighed. Their weight would then be

found by subtracting the weight of the basket. The other two crayfish were put in two separate fifteen gallon tanks, under the same conditions, as our control groups. The same documentations were taking on them daily also. When it came to feeding the crayfish, they were originally fed small pieces of raw catfish fillets. The catfish was weighed and each piece weighed approximately 1.13 grams. Two pieces of the catfish were then placed in the large tanks and one piece each in the little tanks. Their interactions with the food and each other were documented. After the catfish, they were fed live worms to give them a chance to react to other living creatures. Night crawlers were used. When they were being fed live worms, one full worm was dropped in the large tank, and two halves of a worm were dropped in the smaller tanks, one half in each tank. Their interactions with the live worms were then observed.

Results

At the first location in Steele Creek Park above the dam, seventy crayfish total were found over a period of five days. Of these crayfish, sixty-nine were *Orconectes rusticus* and one of the crayfish was *Cambarus bartonii* (see Chart 2). All seventy crayfish were found under rocks in the creek. The average water depth for the Rusty crayfish that were found was 19.327 centimeters (see Chart 7). The one Appalachian Brook crayfish that was found was found in a water depth of 22 centimeters. The average length of the 69 rusty crayfish found above the dam was 43.4 millimeters ranging from 23 millimeters to 80 millimeters (see Chart 8). The one Appalachian Brook measured at the length of 70 millimeters. The ratio of the number of male Rusty crayfish to the number of female rusty crayfish was thirty-six to thirty two (see Chart 1). One rusty female was found to have eggs. The Appalachian Brook crayfish was a male. The most common abnormality that was documented among the Rusty crayfish was a re-growing left claw. Five rusty crayfish had this abnormality. The other abnormalities that were documented were missing claws, broken claws, broken rostrum and death. The Appalachian Brook crayfish did not have any abnormalities.

The second location in Steele Creek Park was below the dam. The total number of crayfish that were caught numbered 299. These crayfish were caught over a period of seven days. The combined number of Rusty crayfish totaled 225 (see Chart 4). The Appalachian Brook crayfish totaled 73. There was also one undistinguishable crayfish. The average water depth of all the crayfish found below the dam totaled 24.58 centimeters. The average water depth of the Rusty crayfish that were found was 26.02 centimeters. 16.30 was the average water depth for the 73 Appalachian crayfish (see

Chart 7). The length of the Appalachian Brook crayfish averaged 37.6 millimeters, with the smallest measuring 19 millimeters and the largest measuring 80 millimeters. The average Rusty crayfish measured 53.5 millimeters (see Chart 8). The largest Rusty crayfish that was caught was a female with approximately 30 eggs and a missing left claw, and the smallest Rusty crayfish measured 12 millimeters. She measured at a length of 96 millimeters. The largest Appalachian Brook crayfish that was found was a male that measured 80 millimeters. This crayfish had no abnormalities.

The combined number of male crayfish that were found was 191. The total number of females that were found was 104. The gender of four crayfish that were found was unidentifiable. Of the 191 males that were found, 165 of them were Rusty. Twenty-six of the 191 were Appalachian Brook. Fifty-seven of the 104 females that were found were Rusty. The remaining 47 females that were found were Appalachian (see Chart 6). Nineteen Rusty females total were found to have eggs. Only two Appalachian Brook females were found to have eggs (see Chart 9). Twenty-five Rusty crayfish that were found below the dam were documented as just having molted. Only nine Appalachian Brook crayfish were found that had just molted (see Chart 10). The most common abnormality that was found was a missing right or left claw. The second most common abnormality was re-growing left and right claws.
Fifty-seven Rusty crayfish and 14 Appalachian Brook crayfish were found to have some sort of abnormality.

The results of the research that took place in the school lab consisted of twenty-three days of documentation. Throughout the research that took place in the lab both Rusty crayfish gained weight whereas both Appalachian Brook crayfish lost weight. The

starting weight of the Rusty crayfish that was in the large tank was 13.6 grams. The final weight of the Rusty on the last day was 15.7 grams. It gained 2.04 grams. The beginning weight of the Appalachian Brook that lived in the large tank with the Rusty was 13.75 grams. Its final weight was 13.5 grams. It lost .25 grams. The Rusty crayfish in the smaller tank by itself originally weighed 8.2 grams. Its final weight totaled 9.89 grams. It gained a total of 1.6 grams. The Appalachian Brook crayfish that made the other control group, originally weighed 14.1 grams. The final weight of this Appalachian Brook was 13.9 grams. A total of .2 grams was lost. Another key point in the research that took place in the lab was that both the large Rusty and the small Rusty molted during their time in the tanks. Neither Appalachian Brook molted during this time. After the Rusty crayfish molted in the large tank, the Appalachian acted scared submissive for the next few days by backing away from the Rusty crayfish at all encounters.

Throughout the twenty-three days the Rusty crayfish in the large tank appeared to be more dominating than the Appalachian Brook crayfish on several occasions. On 7 documented days this consisted of the Rusty crayfish forcing the Appalachian Brook crayfish out of his cave using physical contact. It was also documented on three occasions that the Appalachian Brook crayfish was digging a hole to protect itself. During these times that the Appalachian Brook was digging, the Rusty roamed about the tank.

Discussion

Sixty-nine to one was the ratio of Rusty crayfish to Appalachian Brook crayfish in the first location above the dam. This near absence of Appalachian Brook could be explained by years of being out competed for food and shelter by the Rusty. The loss of vital food and shelter would be detrimental the Appalachians. Another point is that the number of Rusty females to the number of Rusty males was 36 to 32, and there was one female with eggs. The only Appalachian Brook crayfish that was found was a male. Without the presence of females, the Appalachian Brook crayfish would not be able to reproduce and therefore eventually die out in that location. Strength in the area of competing for food and shelter have definitely aided the Rusty crayfish in becoming the more dominate species above the dam.

Steele Creek below the dam had a ratio of 225 Rusty crayfish to 73 Appalachian Brook crayfish. All of the Appalachian Brook crayfish were found along the section where Steele Creek and Beaver Creek join. This explains for the lack of Appalachians near the dam. If all of the Appalachian Brook crayfish are coming from Beaver Creek, they might not be able to swim upstream towards the dam, therefore secluding their living quarters to just that one area. The average water depth of the Rusty crayfish that were found below the dam was 26.02 centimeters. The average water depth for the Appalachian Brook crayfish below the dam was 16.30. This was a rather large difference of 9.72 centimeters. Possibly, the Appalachian Brook crayfish prefers to live in the shallower water, or it could be that the preferred dwelling is in the deeper water and the Rusty is forcing the Appalachian out. If this was the case, the deeper water could offer better protection or a better supply of food. That would be a large factor in the number

of Appalachian crayfish that would be able to survive under these conditions.

Size might be yet another reason why the Rusty crayfish are displacing the native Appalachian Brook crayfish. The average length of the rusty crayfish below the dam was 53.5 millimeters. The average length of the Appalachian Brook crayfish below the dam measured only 37.6 millimeters. The fact that the Appalachian are so much smaller might explain why they are having a harder time surviving in the creek. Having a smaller size would make it easier to defeat them in battles, it would also make them have a harder time against a predator. If this were the case, then the Rusty crayfish would clearly have the advantage. Along with size and numbers, another benefit that the Rusty crayfish below the dam have is the ratio of males to females and females with eggs. One hundred and sixty-five Rusty males were found below the dam and 57 Rusty females. The number of Rusty females with eggs was 19. The ratio of Appalachian males to females was 26 to 47, and only two females had eggs. The lack of Appalachian males would reduce the amount of offspring that could be produced, and hence give the Rusty crayfish a better chance for survival. The Appalachian Brook breeding season may be later in the year, this would still be another benefit to the Rusty because their young would be out first and be able to out compete the younger Appalachian. The number of abnormalities might also be a reason why the Rusty crayfish are more dominant in the wild. The fact that the Rusty crayfish had more abnormalities shows that they may be more aggressive and tend to fight more than the Appalachian Brook. This could be another reason why they are the more dominant species.

The results of the research that took place in the lab show that the Rusty is clearly the more dominant species. The fact that the Rusty beat the Appalachian Brook to the

food shows that they are a very aggressive species and do not back down from confrontation. This type of behavior would clearly be an asset in the wild where it is survival of the fittest. Also when the Rusty forced the Appalachian out of his home in the tank, this proved that the Rusty has the choice of the preferred dwellings. Growth was another aspect in which the Rusty crayfish in the lab had an advantage. Both Rusty crayfish molted and gained a considerable amount of weight whereas neither Appalachian Brook crayfish molted, and both lost weight. This suggests that the Rusty either grow faster, or that the Appalachian are not able to get the right nutrition in their diet. If all of the points that were visible in the lab took place in the wild, then it would be easy to see why the Rusty is in fact the dominating species. Out competing for food and shelter, growing at a faster rate, as well as the issue of reproduction are all strengths that the Rusty crayfish have over the Appalachian Brook crayfish, and if this trend continues, the Rusty crayfish could wipe out the entire Appalachian Brook population in Steele Creek.

Conclusion

This project clearly showed that the Rusty crayfish has become more dominate over the Appalachian Brook crayfish. From the near absence of Appalachian in the area above the dam to the extreme difference in number below the dam, there is definitely a larger presence of Rusty crayfish. This extreme difference could be the result of competition for food and shelter, lack of reproduction by the Appalachian, or predation from other animals or even larger size of the Rusty crayfish. From the results in the lab, it is concluded that the Rusty is more dominant in all cases of growth, shelter, and food. Any or all of these factors could play a vital role in the loss of the Appalachian Brook crayfish in Steele Creek Park, but the Rusty crayfish has definitely shown itself as being the crayfish that is better suited to live in this area.

Literature Cited

Clancy, Paul. 1997 "Feeling the Pinch: the Troubled Plight of America's Crayfish." Nature Conservancy. p10-15.

Hill, Anna M. and David M. Lodge. 1999 "Replacement of Resident Crayfishes by an Exotic Crayfish: The Roles of Competition and Predation." Ecological Applications. p678-690

Lodge, David M., Annamarie L. Beckel and John J. Magnuson. 1985 "Lake Bottom Tyrant: Aggressive and Prolific, the Rusty Crayfish Has Clawed Its Way To the Top of the Food Chain in Northern Wisconsin Lakes." Natural History. v94 p32-36

Roush, Wade. 1997 "Hybrids Consummate Species Invasion (Invading and Native Crayfish Species Form Hybrids)." Science. v277 p316

http://srd.yahoo.com/goo/crayfish+home+page+brigham+young/0/*http://bioag.byu.edu/mlbean/crayfish/crayhome.htm. Crayfish Home Page. Brigham Young University, Monte L. Bean Life Science Museum, Crandall Lab Home Page

FIGURE 1: MAP OF STEELE CREEK PARK

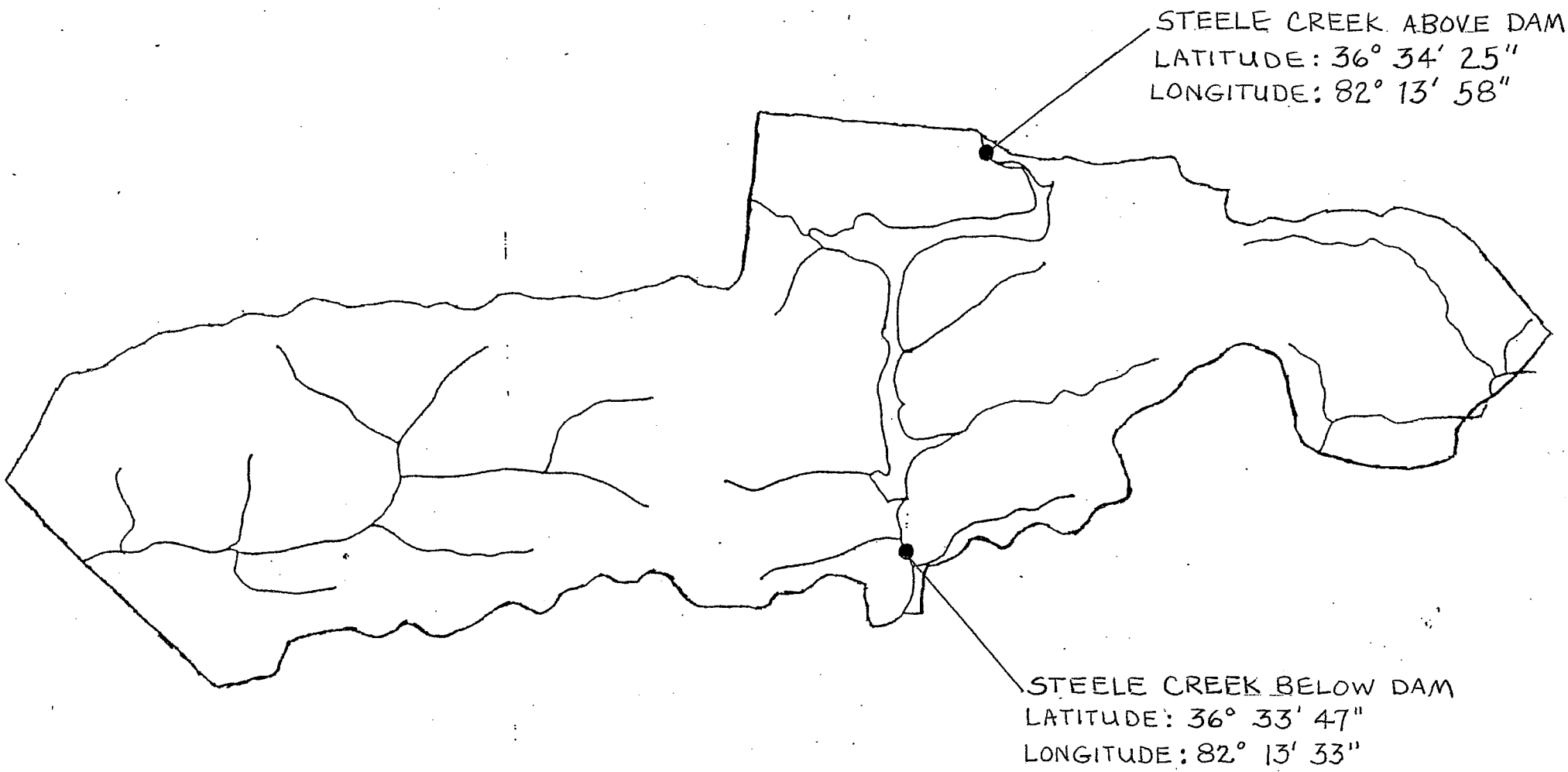
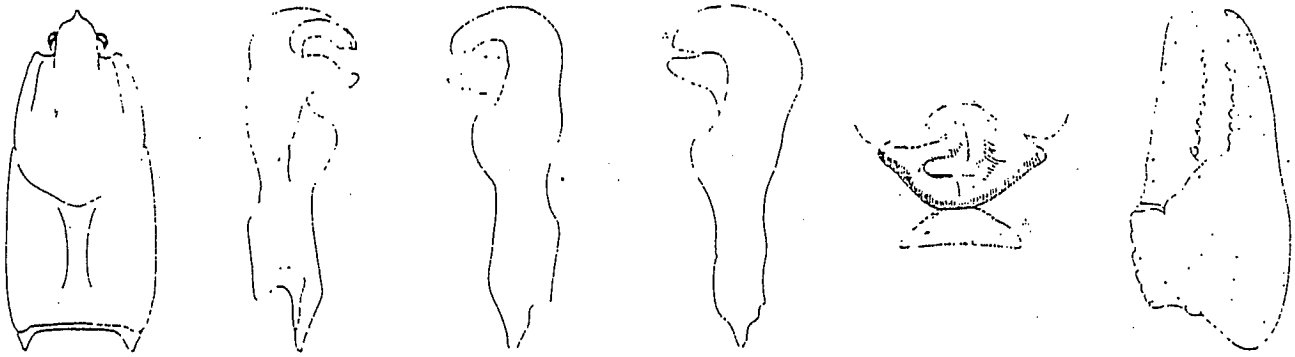
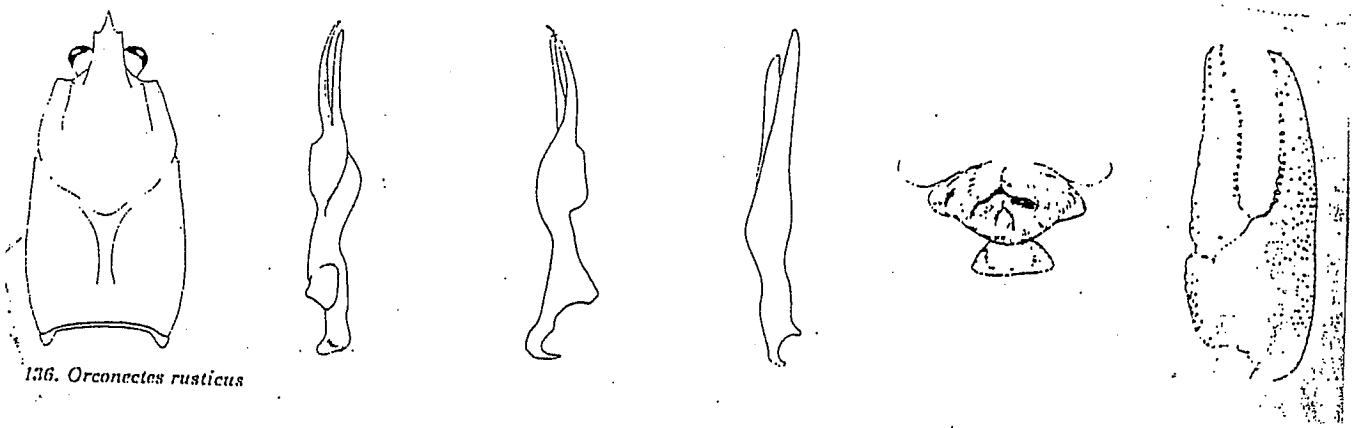


FIGURE 3

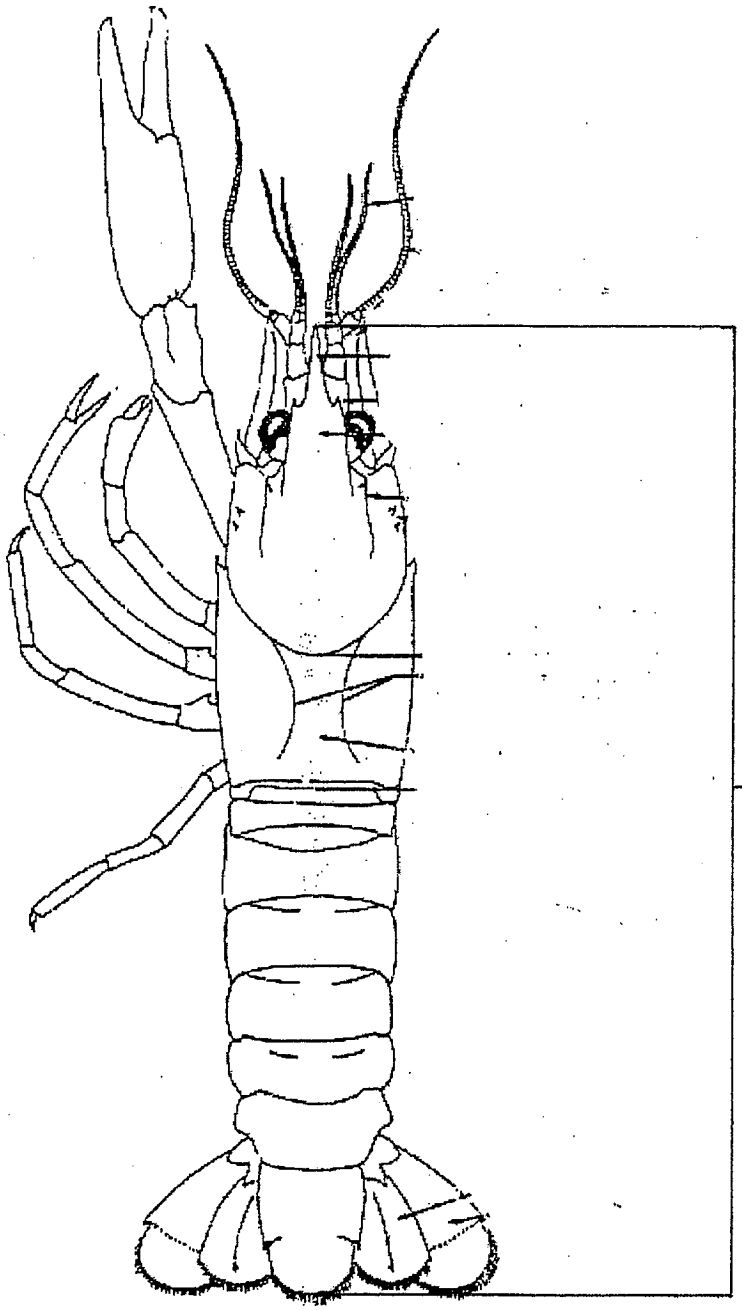


23. *Cambarus (Cambarus) bartonii bartonii*



136. *Orconectes rusticus*

FIGURE 2



DATA SHEETS

Site 1	Water Depth	Species	Sex	Length	Observations
3/9	15.24cm	R	M	55mm	N/A
3/9	17.145cm	R	M	63mm	Missing Claw
3/9	12.065cm	R	F	35mm	N/A
3/9	17.78cm	R	M	55mm	N/A
3/9	21.59cm	R	F	35mm	N/A
3/10	24.13cm	R	F	40mm	NRC
3/10	25.4cm	R	F	45mm	NRC
3/10	20.32cm	R	M	47.5mm	N/A
3/10	20.32cm	R	M	55mm	N/A
3/10	22.225cm	R	F	45mm	NLC 40 Eggs
3/10	16.51cm	R	M	55mm	N/A
3/10	16.51cm	R	M	35mm	N/A
3/10	16.51cm	R	M	50mm	N/A
3/10	19.05cm	R	F	50mm	N/A
3/10	35.56cm	R	F	27.5mm	N/A
3/10	30.48cm	R	F	25mm	N/A
3/10	30.48cm	R	M	60mm	N/A
3/10	12.7cm	R	M	55mm	N/A
3/10	12.7cm	R	M	35mm	NLC
3/10	25.4cm	R	F	55mm	N/A
3/10	27.94cm	R	M	65mm	N/A
3/10	27.94cm	R	M	55mm	NRC
3/10	33.02cm	R	F	30mm	NLC
3/10	22.86cm	R	M	60mm	N/A
3/10	17.145cm	R	M	50mm	Regrowing Left Claw
3/10	19.05cm	R	F	55mm	N/A
3/10	16.51cm	R	M	55mm	N/A
3/10	24.765cm	R	M	30mm	N/A
3/14	12.5cm	R	M	47.5mm	N/A
3/14	16cm	R	F	50mm	N/A
3/14	16cm	R	F	32.5mm	N/A
3/14	10cm	R	M	50mm	N/A
3/14	15cm	R	F	32.5mm	N/A
3/14	17cm	R	F	35mm	Regrowing Left Claw
3/14	15cm	R	F	52.5mm	N/A
3/14	17.75cm	R	F	30mm	N/A
3/14	20cm	R	M	55mm	N/A
3/14	14cm	R	F	37.5mm	N/A
3/14	14cm	R	M	75mm	N/A
3/14	35cm	R	M	50mm	N/A
3/16	15cm	R	M	55mm	N/A
3/16	15cm	R	F	25mm	N/A
3/16	28cm	R	M	80mm	N/A
3/16	19cm	R	F	35mm	N/A
3/16	16cm	R	M	50mm	N/A
3/16	14.25cm	R	F	35mm	Broken Right Claw
3/16	14cm	R	F	30mm	Broken Right Claw
3/16	19cm	R	F	50mm	Regrowing Left Claw
3/16	23cm	R	F	55mm	N/A
3/16	15.5cm	R	Unknown	75mm	Dead

3/16	15.5cm	R	F	30mm	N/A
3/16	27cm	R	F	50mm	N/A
3/16	18cm	R	F	35mm	N/A
3/16	18cm	R	F	23mm	N/A
3/16	16cm	R	F	52mm	N/A
3/16	22cm	R	M	55mm	N/A
3/19	12cm	R	F	32.5mm	N/A
3/19	12cm	R	M	65mm	Broken Rostrum
3/19	17.5cm	R	M	30mm	Regrowing Left Claw
3/19	19cm	R	M	47.5mm	NRC
3/19	19cm	R	M	50mm	N/A
3/19	22cm	AB	M	70mm	N/A
3/19	24cm	R	M	60mm	Broken Body/Dying
3/19	21cm	R	F	35mm	N/A
3/19	21cm	R	F	32.5mm	N/A
3/19	20cm	R	M	30mm	N/A
3/19	20cm	R	M	30mm	Dead
3/19	20cm	R	M	60mm	Regrowing Left Claw
3/19	16cm	R	M	65mm	N/A
3/19	17cm	R	M	50mm	N/A
Key:					
NLC:	No Left Claw				
NRC:	No Right Claw				
Site 1:	Steele Creek	Above Dam			
R:	Rusty				
AB:	Appalachian	Brook			

DATA SHEETS

Site 2	Water Depth	Species	Sex	Length	Observations
4/2/2001	31cm	R	M	60mm	RLC
4/2/2001	22cm	AB	M	65mm	BR
4/2/2001	39cm	R	F	40mm	RLC & eggs (50)
4/2/2001	28.5cm	R	F	65mm	dead
4/2/2001	35cm	R	M	67mm	N/A
4/2/2001	30cm	R	M	45mm	N/A
4/2/2001	18cm	R	M	40mm	NRC
4/2/2001	35cm	R	M	55mm	N/A
4/6/2001	19cm	R	M	40mm	BR & RLC
4/6/2001	32cm	R	M	30mm	N/A
4/6/2001	50cm	R	M	70mm	N/A
4/6/2001	50cm	AB	F	50mm	NRC and eggs (50)
4/6/2001	43cm	R	M	35mm	N/A
4/6/2001	53cm	R	M	45mm	N/A
4/6/2001	37cm	R	F	40mm	N/A
4/6/2001	38cm	R	M	40mm	N/A
4/6/2001	43cm	R	M	47mm	N/A
4/6/2001	43cm	R	M	50mm	N/A
4/6/2001	43cm	R	F	40mm	N/A
4/6/2001	45cm	R	M	85mm	N/A
4/6/2001	31cm	R	M	40mm	N/A
4/6/2001	18cm	R	F	40mm	N/A
4/6/2001	18cm	R	F	38mm	RLC
4/6/2001	18cm	R	F	12mm	N/A
4/6/2001	22cm	R	M	18mm	N/A
4/6/2001	18cm	AB	F	55mm	N/A
4/6/2001	18cm	R	F	35mm	N/A
4/6/2001	35cm	R	M	50mm	NRC
4/6/2001	35cm	R	F	30mm	N/A
4/6/2001	30.5cm	AB	M	55mm	NLC
4/6/2001	29cm	R	M	55mm	HNB
4/6/2001	23cm	R	F	48mm	N/A
4/6/2001	10cm	AB	F	25mm	RLC
4/6/2001	10cm	AB	M	30mm	NRC
4/6/2001	10cm	R	?	31mm	Dead
4/6/2001	10cm	AB	F	19mm	NLC
4/6/2001	10cm	AB	F	35mm	N/A
4/6/2001	17cm	AB	F	25mm	NRC
4/6/2001	17cm	AB	F	35mm	N/A
4/6/2001	17cm	R	M	44mm	N/A
4/6/2001	17cm	AB	M	55mm	NLC
4/6/2001	17cm	AB	F	25mm	N/A
4/6/2001	13cm	AB	F	50mm	N/A
4/6/2001	15cm	R	F	40mm	N/A
4/6/2001	23cm	AB	F	30mm	N/A
4/6/2001	20.5cm	AB	F	50mm	N/A
4/6/2001	33cm	AB	F	55mm	N/A
4/6/2001	33cm	R	F	35mm	N/A
4/6/2001	30.5cm	R	F	45mm	JM
4/6/2001	30.5cm	R	M	40mm	BR

4/6/2001	36cm	R	M	90mm	N/A
4/6/2001	36cm	R	M	75mm	BR
4/6/2001	23cm	R	M	70mm	N/A
4/6/2001	23cm	R	F	60mm	100 - 125 eggs
4/6/2001	23cm	R	F	45mm	N/A
4/6/2001	33cm	R	F	50mm	75 - 100 eggs
4/6/2001	33cm	R	F	53mm	40 brown eggs
4/6/2001	44cm	R	M	65mm	N/A
4/6/2001	12.5cm	R	M	23mm	N/A
4/6/2001	31cm	R	M	50mm	N/A
4/6/2001	45cm	R	F	96mm	NLC & 30 eggs
4/6/2001	45cm	R	F	32mm	N/A
4/6/2001	36cm	R	M	47mm	N/A
4/6/2001	45cm	R	M	50mm	RLC
4/6/2001	34cm	R	F	23mm	N/A
4/6/2001	17cm	R	F	47mm	RLC & 75 eggs
4/6/2001	14cm	R	F	18mm	NRC
4/6/2001	23cm	R	F	43mm	N/A
4/6/2001	24cm	R	M	40mm	N/A
4/6/2001	39cm	R	F	57mm	N/A
4/9/2001	18cm	AB	F	35mm	NLC
4/9/2001	12cm	AB	F	40mm	N/A
4/9/2001	12cm	AB	F	35mm	JM
4/9/2001	12cm	AB	M	55mm	N/A
4/9/2001	9cm	AB	F	40mm	JM
4/9/2001	5cm	?	?	?	Dead
4/9/2001	11cm	AB	F	35mm	N/A
4/9/2001	12cm	AB	F	60mm	50 eggs
4/9/2001	25cm	AB	M	70mm	N/A
4/9/2001	17cm	R	M	35mm	RBC
4/9/2001	23cm	R	M	30mm	N/A
4/9/2001	21cm	R	M	90mm	N/A
4/9/2001	21cm	R	M	50mm	N/A
4/9/2001	21cm	R	M	50mm	N/A
4/9/2001	21cm	R	M	55mm	N/A
4/9/2001	21cm	R	F	35mm	N/A
4/9/2001	22cm	R	M	50mm	N/A
4/9/2001	22cm	R	F	60mm	eggs
4/9/2001	12cm	AB	?	40mm	Dead & NS
4/9/2001	20cm	AB	F	35mm	JM
4/9/2001	10cm	AB	M	30mm	N/A
4/9/2001	12cm	AB	M	65mm	MBC
4/9/2001	9cm	R	M	60mm	N/A
4/9/2001	13cm	AB	F	30mm	N/A
4/9/2001	12cm	AB	F	35mm	JM
4/9/2001	16cm	AB	F	30mm	N/A
4/9/2001	8.5cm	AB	M	43mm	N/A
4/9/2001	8.5cm	AB	M	50mm	N/A
4/9/2001	8.5cm	R	F	45mm	N/A
4/9/2001	8.5cm	AB	M	45mm	N/A
4/9/2001	17cm	AB	F	25mm	N/A
4/9/2001	26cm	R	M	75mm	N/A
4/9/2001	26cm	AB	M	40mm	NRC
4/9/2001	20cm	R	F	45mm	NLC & eggs

4/9/2001	26cm	AB	F	30mm	N/A
4/9/2001	26cm	AB	F	40mm	N/A
4/9/2001	16cm	AB	M	40mm	N/A
4/9/2001	48cm	R	M	45mm	JM
4/9/2001	48cm	AB	F	35mm	N/A
4/9/2001	18cm	R	M	45mm	N/A
4/9/2001	8.5cm	R	F	45mm	N/A
4/9/2001	16cm	R	F	35mm	N/A
4/9/2001	16cm	R	M	45mm	NRC
4/9/2001	12cm	AB	F	35mm	JM
4/9/2001	14cm	R	F	50mm	N/A
4/9/2001	24cm	AB	F	50mm	N/A
4/9/2001	24cm	R	M	45mm	N/A
4/9/2001	20cm	R	M	57mm	N/A
4/9/2001	20cm	R	M	40mm	N/A
4/9/2001	24cm	R	M	85mm	N/A
4/9/2001	30cm	AB	F	35mm	N/A
4/9/2001	29cm	R	M	80mm	NRC
4/9/2001	19cm	AB	F	30mm	N/A
4/9/2001	19cm	R	F	60mm	JM ML
4/9/2001	24cm	R	M	50mm	JM
4/9/2001	20cm	AB	M	40mm	JM
4/9/2001	20cm	AB	F	35mm	N/A
4/9/2001	23cm	AB	F	33mm	N/A
4/9/2001	17cm	AB	M	40mm	JM
4/9/2001	17cm	AB	M	35mm	N/A
4/9/2001	13cm	AB	F	45mm	N/A
4/9/2001	13cm	AB	M	30mm	N/A
4/9/2001	16cm	AB	M	70mm	BLC
4/9/2001	16cm	AB	F	30mm	NLC
4/9/2001	16cm	AB	F	30mm	N/A
4/9/2001	16cm	AB	M	30mm	N/A
4/9/2001	16cm	R	M	55mm	JM
4/9/2001	10cm	AB	F	40mm	N/A
4/9/2001	10cm	AB	M	50mm	JM
4/9/2001	17cm	AB	F	35mm	N/A
4/9/2001	15cm	R	F	40mm	N/A
4/9/2001	15cm	AB	M	55mm	RBC
4/9/2001	13cm	R	F	50mm	JM
4/9/2001	13cm	AB	F	35mm	N/A
4/9/2001	30cm	AB	M	55mm	N/A
4/9/2001	26cm	R	M	50mm	N/A
4/9/2001	18cm	R	F	55mm	Dead with eggs
4/9/2001	23cm	R	F	50mm	50-75 eggs
4/9/2001	23cm	R	F	40mm	N/A
4/9/2001	30.5cm	R	M	90mm	Dead & BLC
4/11/2001	26cm	R	F	25mm	RLC
4/11/2001	26cm	R	F	35mm	N/A
4/11/2001	24cm	R	M	65mm	N/A
4/11/2001	15cm	R	M	50mm	N/A
4/11/2001	15cm	R	?	40mm	SO
4/11/2001	20cm	R	M	70mm	N/A
4/11/2001	20cm	R	M	80mm	N/A
4/11/2001	29cm	R	F	40mm	75 eggs

4/11/2001	17cm	R	M	45mm	N/A
4/11/2001	14cm	R	M	50mm	RRC
4/11/2001	15cm	R	M	85mm	N/A
4/11/2001	24cm	R	M	75mm	NLC BRC
4/11/2001	20cm	R	F	40mm	N/A
4/11/2001	23cm	AB	M	70mm	N/A
4/11/2001	24cm	R	M	40mm	TO
4/11/2001	19cm	R	M	70mm	N/A
4/11/2001	23cm	R	M	85mm	NRC
4/11/2001	15cm	R	M	40mm	Dead NS
4/11/2001	13cm	R	M	70mm	N/A
4/11/2001	32cm	R	F	45mm	Dying
4/11/2001	22cm	R	M	45mm	MBC
4/11/2001	16cm	R	M	30mm	N/A
4/11/2001	12cm	R	M	50mm	NRC
4/11/2001	25cm	R	F	50mm	eggs
4/11/2001	24cm	R	M	45mm	JM
4/11/2001	32cm	R	M	40mm	N/A
4/11/2001	32cm	R	F	45mm	N/A
4/11/2001	32cm	R	F	30mm	N/A
4/11/2001	26cm	R	F	40mm	N/A
4/11/2001	26cm	R	F	30mm	N/A
4/11/2001	23cm	R	M	40mm	N/A
4/11/2001	34cm	R	M	85mm	RLC
4/11/2001	34cm	R	M	60mm	NLC & BRC
4/11/2001	34cm	R	F	35mm	JM
4/11/2001	34cm	R	M	35mm	N/A
4/11/2001	31cm	R	M	70mm	N/A
4/11/2001	25cm	R	M	80mm	NRC
4/11/2001	25cm	R	M	60mm	NLC
4/11/2001	26cm	AB	F	50mm	NLC
4/11/2001	22cm	R	F	35mm	N/A
4/11/2001	32cm	R	F	60mm	RRC
4/16/2001	29cm	R	M	95mm	N/A
4/16/2001	1.5cm	AB	M	55mm	JM
4/16/2001	32cm	R	M	65mm	N/A
4/16/2001	42cm	AB	M	80mm	N/A
4/16/2001	42cm	R	M	40mm	N/A
4/16/2001	30cm	R	M	35mm	NLC
4/16/2001	30cm	R	M	40mm	N/A
4/16/2001	22cm	AB	M	65mm	N/A
4/16/2001	14cm	R	F	60mm	50 eggs
4/16/2001	28cm	R	M	50mm	N/A
4/16/2001	9cm	R	F	50mm	eggs
4/16/2001	22cm	R	M	35mm	N/A
4/16/2001	35cm	R	F	70mm	RLC & 75 eggs
4/16/2001	35cm	R	M	45mm	RRC JM
4/20/2001	32cm	R	M	70mm	N/A
4/20/2001	20cm	R	M	45mm	NLC
4/20/2001	26cm	R	M	35mm	BRC
4/20/2001	16cm	R	F	35mm	N/A
4/20/2001	27cm	R	M	50mm	N/A
4/20/2001	17cm	R	F	40mm	JM
4/20/2001	17cm	R	F	40mm	N/A

4/20/2001	17cm	R	M	60mm	RLC
4/21/2001	30cm	R	M	80mm	BRC
4/21/2001	13cm	R	F	50mm	N/A
4/21/2001	13cm	R	M	30mm	JM
4/21/2001	38cm	R	M	50mm	NLC
4/21/2001	38cm	R	M	70mm	BRC
4/21/2001	2.5cm	R	M	45mm	N/A
4/21/2001	32cm	R	F	80mm	NRC
4/21/2001	WF	R	M	65mm	BLC
4/21/2001	35cm	R	M	65mm	NLC
4/21/2001	35cm	R	M	55mm	RLC
4/21/2001	35cm	R	M	60mm	N/A
4/21/2001	37cm	R	M	45mm	N/A
4/21/2001	37cm	R	M	70mm	NLC
4/21/2001	40cm	R	M	92mm	N/A
4/21/2001	31cm	R	M	70mm	N/A
4/21/2001	31cm	R	M	55mm	JM
4/21/2001	20cm	R	M	50mm	N/A
4/21/2001	20cm	R	F	35mm	RBC
4/21/2001	20cm	R	M	70mm	N/A
4/21/2001	20cm	R	M	75mm	JM
4/21/2001	20cm	R	M	60mm	N/A
4/21/2001	20cm	R	M	45mm	N/A
4/21/2001	20cm	R	M	60mm	N/A
4/21/2001	53cm	R	M	80mm	N/A
4/21/2001	18cm	R	M	85mm	N/A
4/21/2001	53cm	R	F	55mm	JM
4/21/2001	9cm	R	M	70mm	N/A
4/21/2001	9cm	R	M	45mm	N/A
4/21/2001	9cm	R	M	55mm	N/A
4/21/2001	9cm	R	M	56mm	N/A
4/21/2001	9cm	R	M	45mm	NRC
4/21/2001	9cm	R	M	45mm	N/A
4/21/2001	9cm	R	F	40mm	RLC 25-30 eggs
4/21/2001	16cm	R	F	55mm	RRC 15-20 eggs
4/21/2001	15cm	R	M	60mm	NLA BRA
4/21/2001	20cm	R	M	55mm	BLC
4/21/2001	9cm	R	F	80mm	75 eggs
4/21/2001	9cm	R	M	50mm	N/A
4/21/2001	9cm	R	M	70mm	20-40 eggs
4/21/2001	9cm	R	M	45mm	N/A
4/21/2001	9cm	R	M	45mm	NRC
4/21/2001	9cm	R	M	70mm	JM
4/21/2001	9cm	R	M	50mm	JM
4/21/2001	9cm	R	M	60mm	N/A
4/21/2001	9cm	R	M	60mm	N/A
4/21/2001	9cm	R	M	45mm	JM
4/21/2001	61cm	R	M	60mm	N/A
4/21/2001	61cm	R	M	75mm	JM RLC
4/21/2001	61cm	R	M	70mm	NRC
4/21/2001	22cm	R	M	70mm	N/A
4/21/2001	22cm	R	M	70mm	N/A
4/21/2001	52cm	R	M	65mm	NRC
4/21/2001	17cm	R	M	80mm	RRC

4/21/2001	OR	R	M	50mm	N/A
4/21/2001	13cm	R	M	50mm	JM
4/21/2001	30cm	R	M	70mm	N/A
4/21/2001	34cm	R	M	70mm	BLC
4/21/2001	34cm	R	M	80mm	JM
4/21/2001	34cm	R	M	45mm	N/A
4/21/2001	34cm	R	M	70mm	N/A
4/21/2001	34cm	R	M	70mm	N/A
4/21/2001	34cm	R	M	80mm	N/A
4/21/2001	34cm	R	M	85mm	JM
4/21/2001	34cm	R	M	75mm	N/A
4/21/2001	34cm	R	M	50mm	NRC
4/21/2001	34cm	R	M	50mm	N/A
4/21/2001	45cm	R	M	85mm	N/A
4/21/2001	45cm	R	M	50mm	Dead
4/21/2001	12cm	R	M	50mm	NLC
4/21/2001	32cm	R	M	70mm	N/A
4/21/2001	12cm	R	M	65mm	N/A
4/21/2001	25cm	R	M	55mm	N/A
4/21/2001	12cm	R	M	55mm	Dead
4/21/2001	30cm	R	M	55mm	N/A
4/21/2001	30cm	R	F	50mm	eggs
4/21/2001	20cm	R	M	95mm	N/A
4/21/2001	20cm	R	M	60mm	N/A
4/21/2001	20cm	R	M	85mm	NLC
4/21/2001	20cm	R	M	85mm	N/A
4/21/2001	19cm	R	M	60mm	N/A
4/21/2001	61cm	R	M	85mm	RRC
4/21/2001	61cm	R	M	75mm	N/A
4/21/2001	61cm	R	M	70mm	JM
4/21/2001	61cm	R	F	45mm	JM
4/21/2001	61cm	R	M	45mm	JM
4/21/2001	61cm	R	M	60mm	JM
Key					
NLC:	No Left Claw		BRC:	Broken Right Claw	
NRC:	No Right Claw		BLC:	Broken Left Claw	
R:	Rusty		MBC:	Missing Both Claws	
AB:	Appalachian Brook		OR:	On Rock	
JM:	Just Molted		WF:	Water Fall	
RRC:	Regrowing Right Claw		NLA:	No Left Antennae	
BR:	Broken Rostrum		BRA:	Broken Right Antennae	
RLC:	Regrowing Left Claw		RBC:	Regrowing Both Claws	
NS:	No Shell		TO:	Tail Only	
HNB:	Has No Body		ML:	Missing Leg	
SO:	Shell Only		Site 2:	Steele Creek Below Dam	

CHART 1

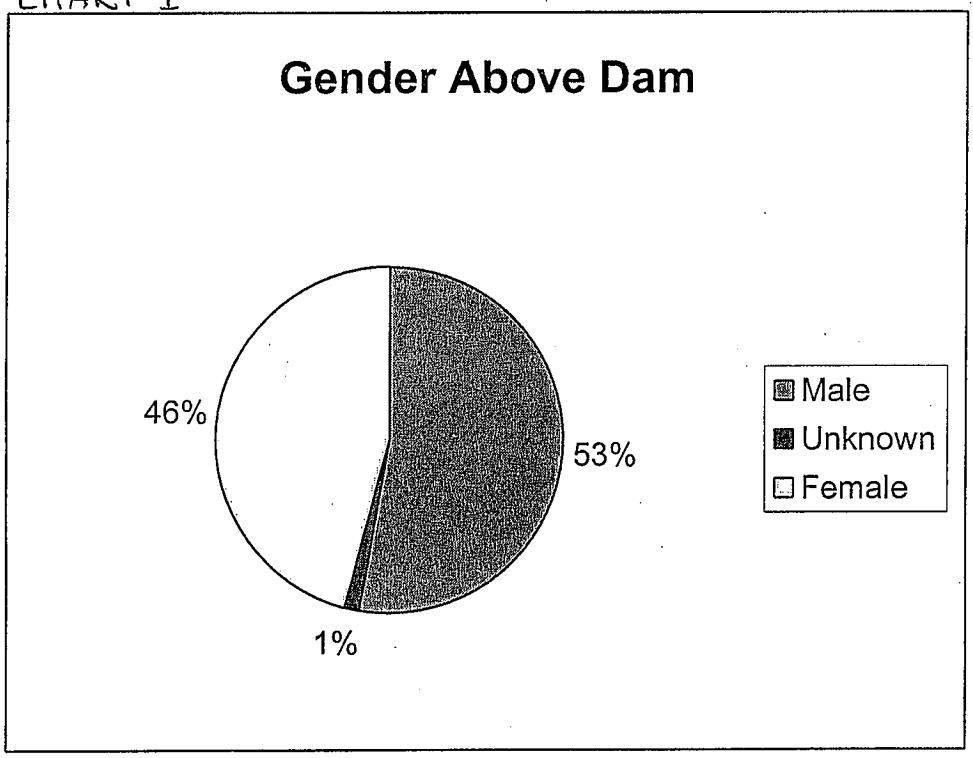


CHART 2

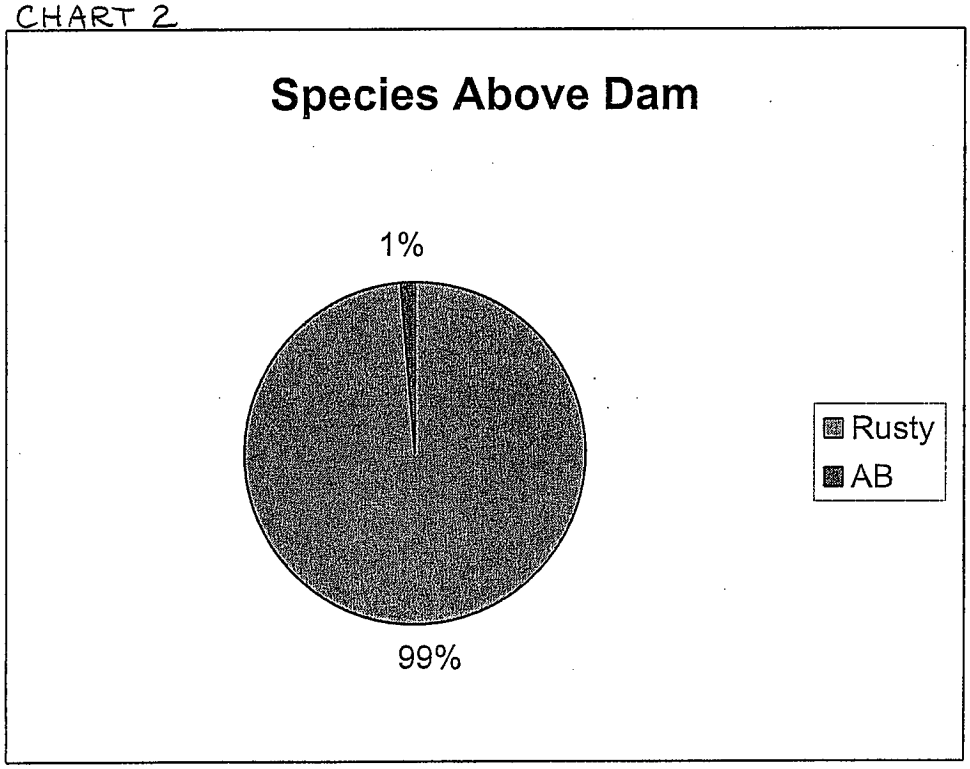


CHART 3

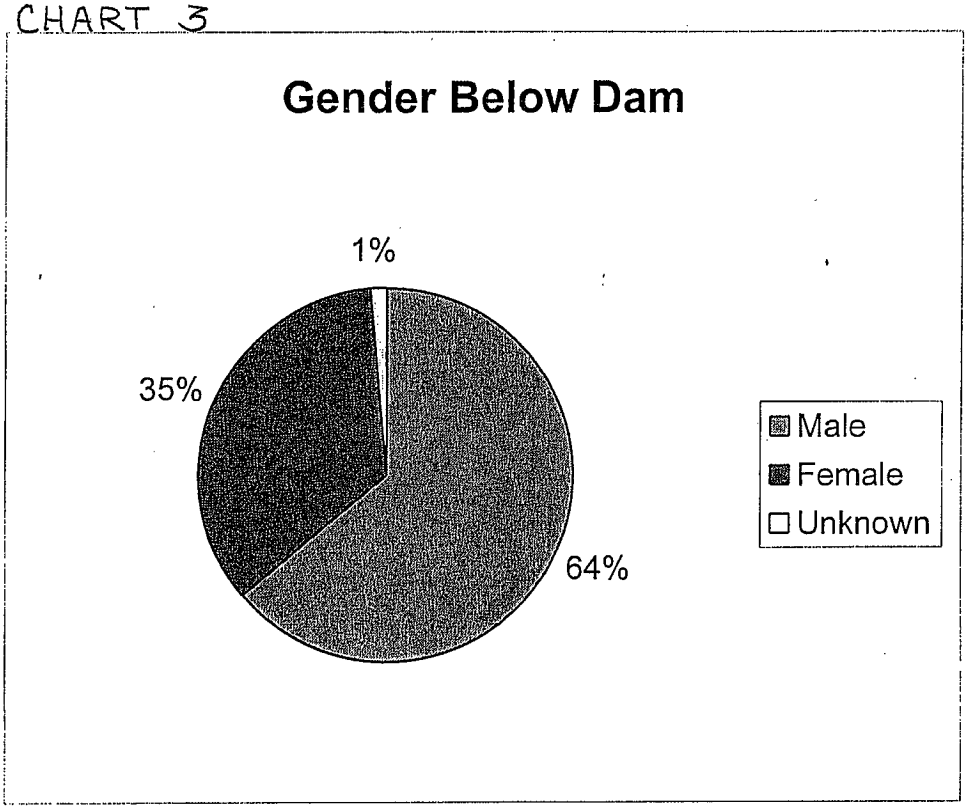


CHART 4

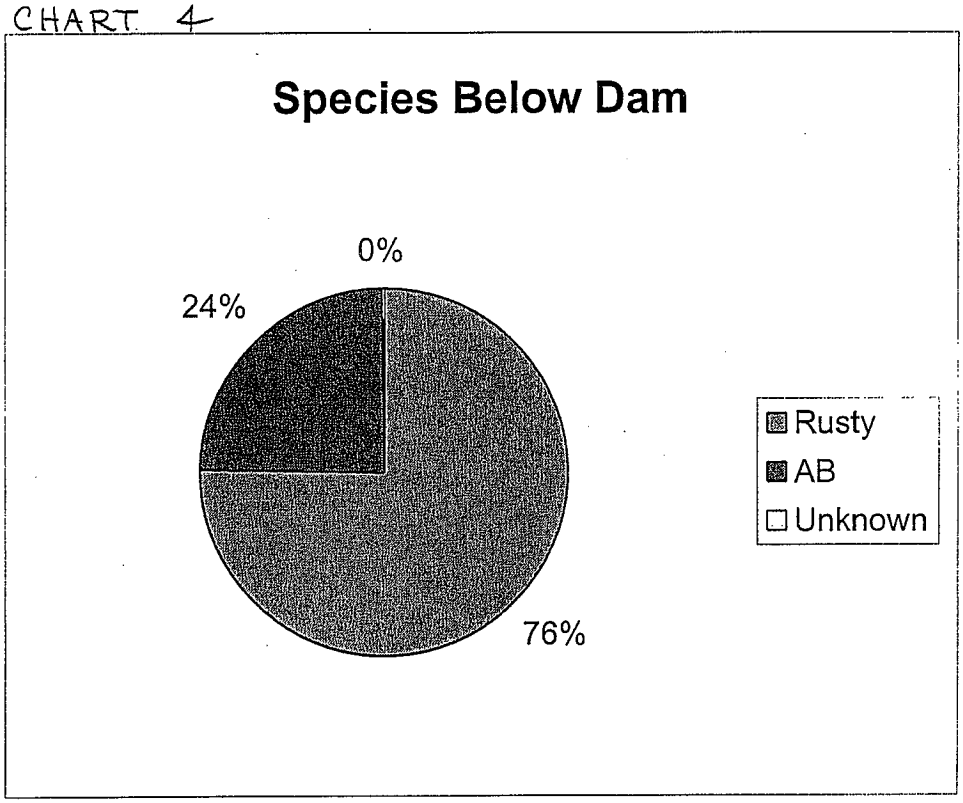


CHART 5

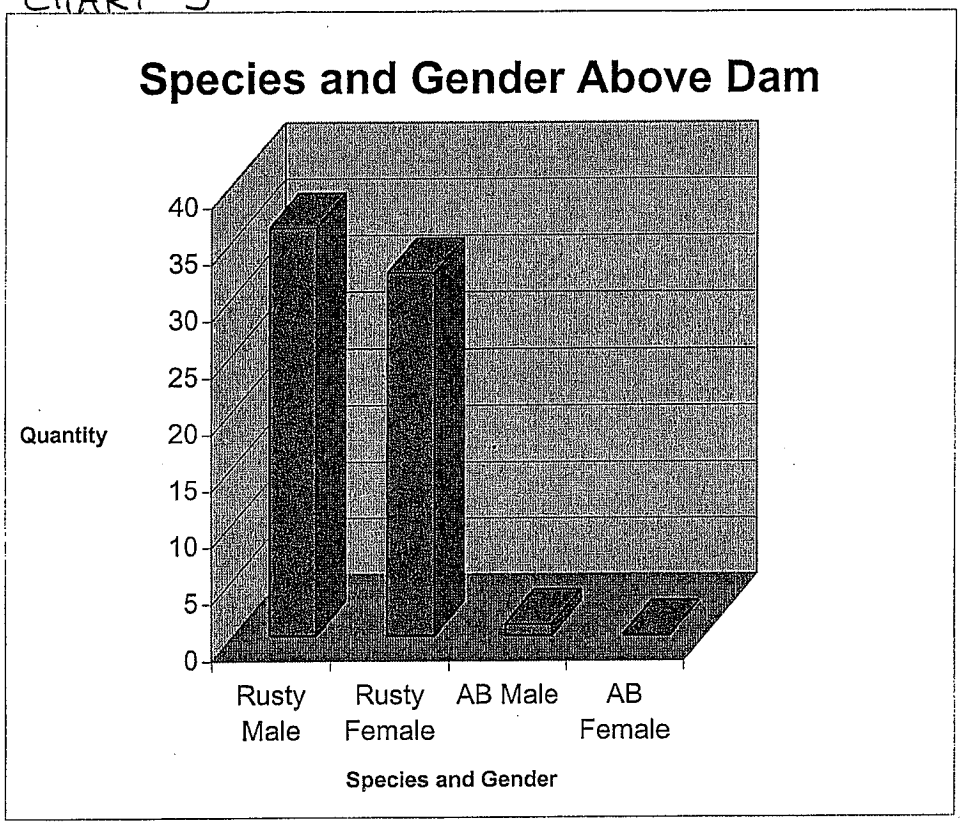


CHART 6

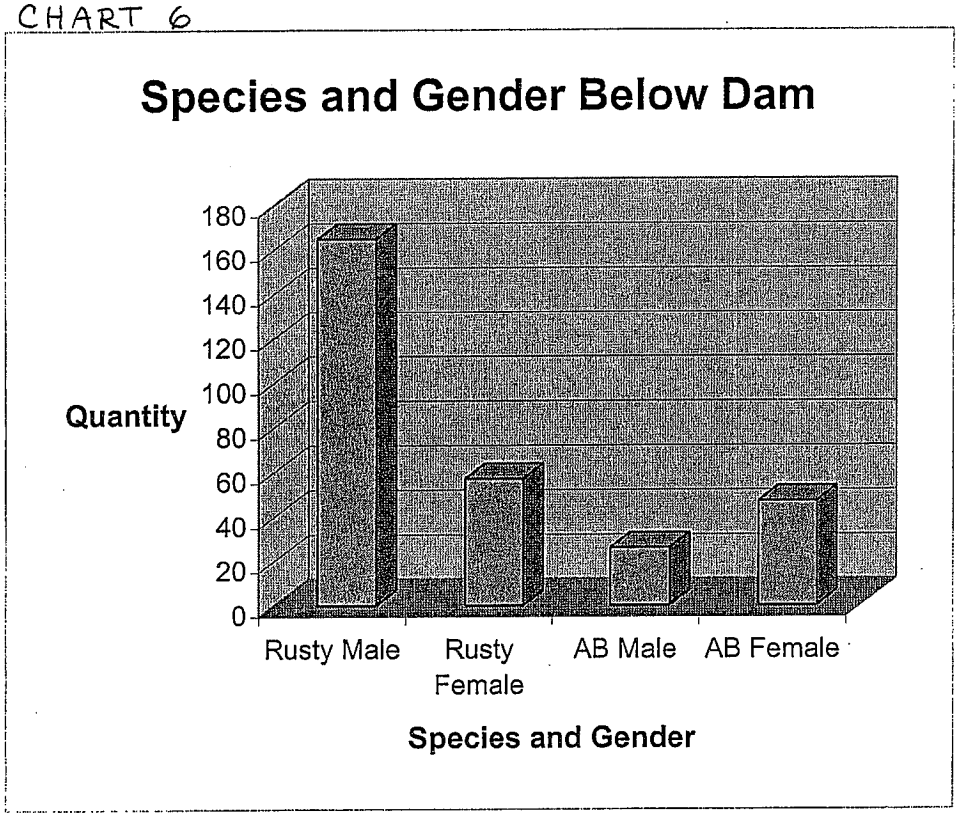


CHART 7

Average Water Depth (cm)

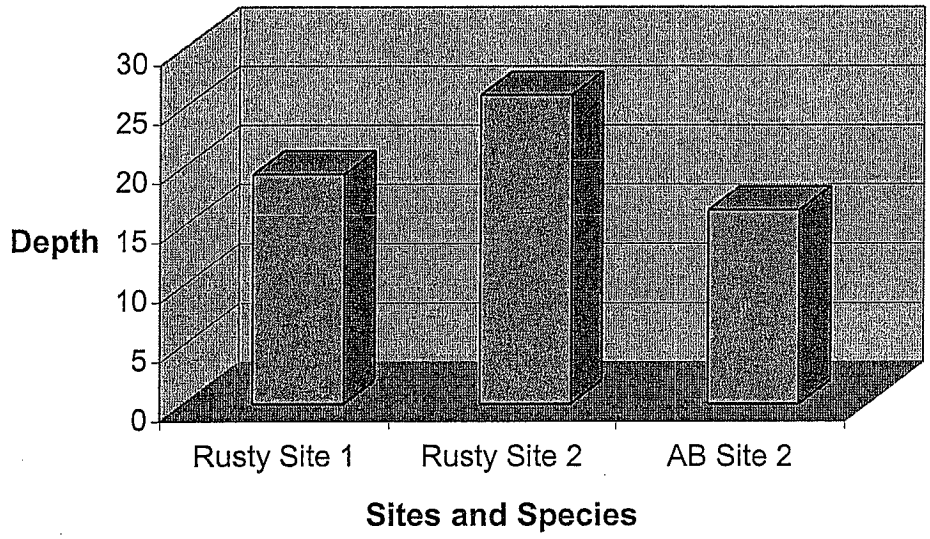


CHART 8

Average Length (mm) of Crayfish

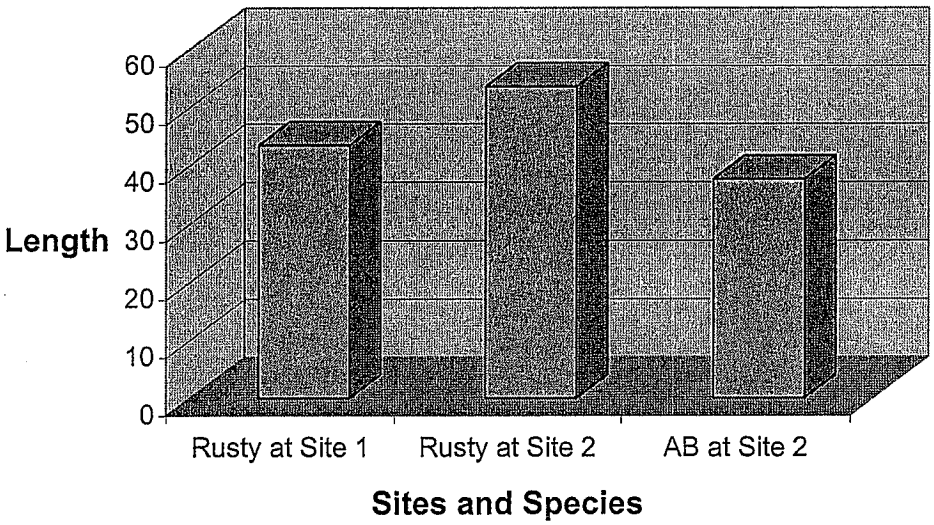


CHART 9

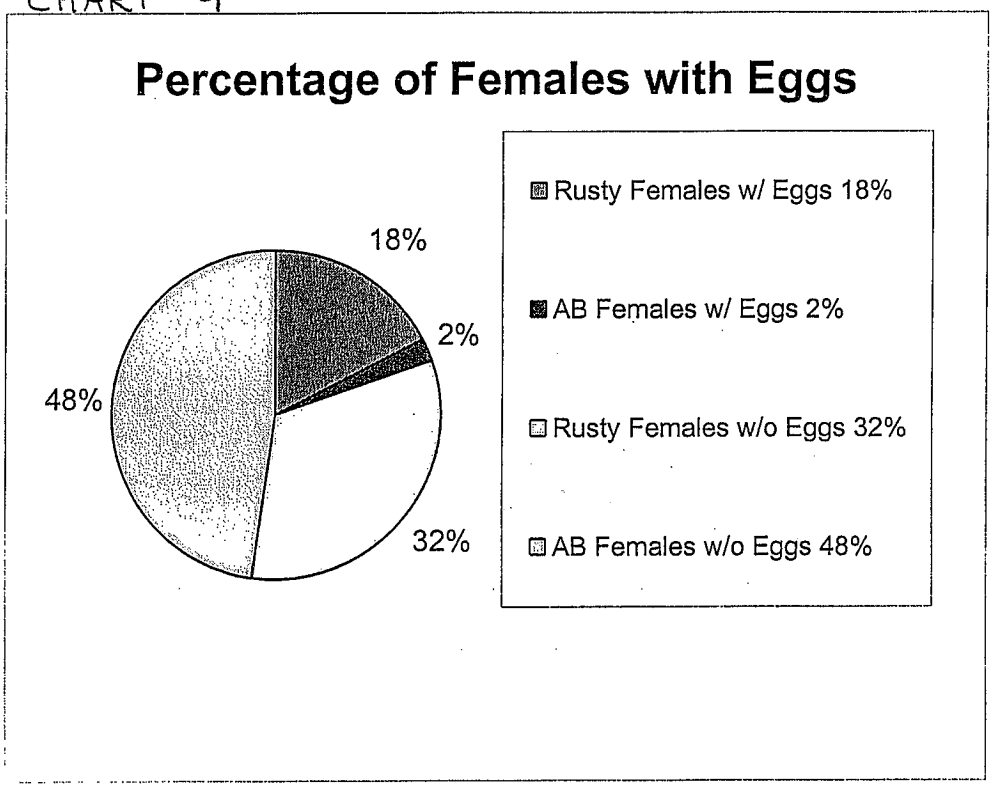


CHART 10