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THE STATUS AND DISTRIBUTION OF INVASIVE CRAYFISHES AND THEIR EFFECTS ON NATIVE CRAYFISH COMMUNITIES IN WEST VIRGINIA

A Thesis submitted to
the Graduate College of
Marshall University
Huntington, WV

In partial fulfillment of
the requirements for the degree of
Master of Science
Biological Sciences

by

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Approved by

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Marshall University
May 2012

ABSTRACT

Introductions of non-native crayfish species have resulted in the global decline of native crayfish populations, including those in North America. The last large survey of crayfishes from West Virginia was in 1988 and 1989. In this thorough document Raymond Jezerinac, Whitney Stocker, and Donald Tarter identified three separate areas in West Virginia where non-native crayfish species have been introduced.

One area is located in the Potomac River drainage in northeastern West Virginia commonly referred to as the eastern panhandle of the state. This is also the only drainage in West Virginia where the native spiny cheek crayfish (*Orconectes limosus*) occurs. A survey of this area in 1988 and 1989 resulted in the capture of 14 *O. limosus* individuals and an abundance of the non-native virile crayfish (*O. virilis*). In 2005 and 2006, crayfish were collected from streams within the West Virginia portion of *O. limosus* range, including locations where previously documented captures had occurred. The absence of *O. limosus* and abundance of *O. virilis* in the surveys conducted indicate extirpation of populations from this portion of its range. These data along with similar accounts of invasive crayfishes in West Virginia including the rusty crayfish (*O. rusticus*) and decline of native crayfish populations prompted surveys in each drainage where invasive crayfishes have been documented in West Virginia: The Potomac River drainage in northeast West Virginia, the New River Gorge National River and tributaries, and the Kanawha/Ohio River and tributaries. Results from the three study areas suggest non-native crayfishes are actively expanding their range and displacing native crayfish populations in West Virginia.

Keywords: crayfish, orconectes, limosus, virilis, rusticus, New River, Kanawha River, Ohio River, invasive, non-native

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Finally, thank you to my mother, father, and sister for always saying you can achieve anything if you put your mind to it, this is for you.

To all the individuals in the fields of Malacology and Astacology that have inspired me,

~ Thank You ~

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 Introduction

Crayfish, commonly known as crawfish, crawdads, or mudbugs, are a diverse and important component of freshwater aquatic and semi-aquatic ecosystems around the world (Taylor et al. 2004). Crayfish are one of the most understudied freshwater invertebrates making up more than 500 species worldwide and are native to every continent except Antarctica and Africa (although six species are native to Madagascar) (Adegboye 1983; Hobbs 1988). Crayfish are members of a large phylum of invertebrates known as arthropods. They are further classified into the subphylum Crustacea referring to arthropods that breathe with gills and have two pairs of antennae. They are in the class Malacostraca and of the Order Decapoda which includes shrimps, crabs, and lobsters. The term "decapod" translated to Latin is "ten footed", refereeing to the five pairs of jointed appendages that all decapods possess (Pelieger 1996). Crayfish many times referred to as keystone species because of their abundance and important role of the breakdown of organic matter found in lentic, lotic, and semi-aquatic habitats. They are primarily opportunistic omnivores eating detritus, benthic invertebrates, macrophytes, algae and whatever else is available from lakes (Chambers et al. 1990; Lodge et al. 1994; Momot 1995), and streams (Huryn and Wallace 1987; Charlebois and Lamberti 1996; Whitledge and Rabeni 1997).

Crayfish are major prey items for hellbenders, queen snakes, raccoons, and fish (Roell and Orth 1993; Lodge and Hill 1994; Dorn and Mittelbach 1999). Additional threats to crayfish are loss of habitat, disease, over harvest, and invasive species pressures. Current estimates designate around one-half of all freshwater crayfish as threatened with population decline or extinction (Taylor 2002). The introduction of non-native crayfish has historically proved to result in the decline of native crayfish populations. This was first acknowledged indirectly by the crayfish plague in Europe. The crayfish plague, also known as the fungi *Aphanomyces astaci*, is carried by North American crayfish species that are resistant to the fungus. This crayfish plague is the most commonly cited case of incursion of an exotic disease in aquatic animals (Edgerton 2004). The crayfish plague was first recorded in Italy in the 1860's; however it quickly spread throughout Europe devastating native crayfish populations. With a momentous loss of native species, replacement species were imported from the United States to help replace the lost stocks which were used for food and aquaculture. Crayfishes including *Orconectes limosus* (spiny cheek crayfish) a native species known to occur in West Virginia, now one of the most common crayfish in Europe (Holdich 2007), displaced Europe's native species as well as continued the spread of the infectious fungus. Out competition for food, shelter, habitat, and sheer displacement are also associated with the introduction of non-native crayfishes.

Loss of native species due to the introduction of non-indigenous crayfishes is well documented in Europe and North America. Non-native crayfishes have eliminated native crayfish species from lakes and streams, eliminated aquatic vegetation where it is important fish and macroinvertebrate habitat, reduced abundance of insect larvae and other invertebrates used by fishes, and reduced abundance of native amphibians. Non-indigenous species have also devastated commercial fisheries for native European crayfishes, which have much greater market value than the introduced species. European harvests of crayfish for human consumption in 2000 were only five percent of their historic levels (Lodge, Taylor, Holdich, and Skurdal 2000). Because of these startling numbers the implementation of severe restrictions on the transport of live non-indigenous crayfishes has been set in place in Ireland and Norway (Gherari and Holdich 1999). North America allows the importation of crayfish from other countries, and the regulations limiting the movement of crayfish within the country are rarely enforced. At least ten species of crayfish have had human assistance in expanding their North American range (Hobbs et al. 1989).

One of the challenges of preserving crayfish biodiversity in North America is because many of the species have naturally small native ranges (Taylor et al. 1996; Lodge et al. 1998; Crandall 1998). Eleven species are known from only a single location, and another 20 species from five or fewer locations (Taylor et al. 1996). Numerous other species are shared by two states or provinces but are restricted to single river drainages that cross state or provincial lines. Crayfishes have much smaller range sizes than those of other well-known and also imperiled freshwater groups such as the fifteen percent of unionid mussels that are endemic to a single state or province (Williams et al. 1993). The best documented North American example of the ecological effects of a non-indigenous crayfish species involves the range expansion of *Orconectes rusticus* (rusty crayfish). It originates from streams in western Ohio and parts of Indiana and Kentucky (Taylor 2000). *Orconectes rusticus* has expanded its range into streams, rivers and lakes throughout much of Illinois, Michigan, Wisconsin, and Minnesota (Page 1985; Taylor et al. 1996; Hamr 1998). *Orconectes rusticus* has continued its range expansion into parts of West Virginia, Maryland, Pennsylvania, New Jersey and now appears to be the dominant species in the middle Ohio River. In extremely abundant cases adult *O. rusticus* densities have reached 15 individuals per square meter (10.7 ft^2) (Lodge and Hill 1994).

As of 2006, twenty-one species and one subspecies comprised the crayfish fauna of West Virginia. *Cambarus elkensis* (Elk River crayfish) and *Cambarus nerterius* (Greenbrier cave crayfish) are endemic to West Virginia and found nowhere else on the planet. Two species in danger of becoming extirpated or that are potentially already gone from West Virginia include *O. limosus* (spiny cheek crayfish) and *Cambarus veteranus* (Big Sandy crayfish). *Orconectes limosus* has been pressured due to the introduction of non-native crayfish (i.e. *O. virilis*) to its range, while loss of habitat has brought a decline in populations of *C. veteranus* from the state. Four primary burrowers are native to West Virginia. *Cambarus dubius* (upland burrowing crayfish) is unique in that it has three color morphs that occur within the state (blue body form; red/orange body form; and black body orange claw form). *Cambarus monongalensis* (blue crayfish) is another colorful burrower that always results in a deep royal blue color. *Cambarus thomai* (little brown mudbug) and *Fallicambarus fodiens* (digger crayfish) are primary burrowing species and are found in lower elevations and in wetlands. *Cambarus longulus* is a stream dwelling species that has a restricted range in West Virginia which is only present in the James River drainage. *Cambarus bartonii bartonii* along with a subspecies *Cambarus bartonii cavatus* and former subspecies *Cambarus carinirostris* once a subspecies that has since been elevated to species (Thoma and Jezerinac 1999) are common throughout the state. Additional species that occur in West Virginia are *Cambarus sciotensis* (abundant in the New River), *Cambarus chasmodactylus* (restricted to the Greenbrier River drainage), *Cambarus robustus,* Orconectes *sanbornii, Orconectes obscurus,* and *Orconectes spinosus.* Taylor (2000) described a new species of crayfish (*Orconectes cristavarius*) which includes all prior records of *O. spinosus* in West Virginia. This species was originally given the name as *O. spinosus* by Hobbs (1981) and recognized by Jezerinac (1995).

The Crayfishes of West Virginia was published in 1995 by Ray Jezerinac, Whitney Stocker, and Donald Tarter. In this thorough document, historical collections along with a distributional crayfish survey of the state in 1988-89 documented three geographically separate areas where invasive crayfish species occurred. First, a population of *O. virilis* was identified from tributaries of the Potomac River in Berkeley and Jefferson counties West Virginia. Secondly, populations of *O. virilis* were documented in the New River and Bluestone Reservoir near the town of Hinton, West Virginia. Finally, a single specimen of *O. rusticus* was recorded from the Kanawha River in Black Betsy West Virginia, and additional collections from Wayne and Cabell Counties from Beech Fork Lake, Fourpole Creek, and Twelevepole Creek near Huntington, West Virginia. New research throughout the state has brought about additional data on the invasive crayfish status in West Virginia. A series of research (2001 – 2005) from each of the three areas (Figure 1) will better examine the extent of non-native invasive crayfish populations in West Virginia.

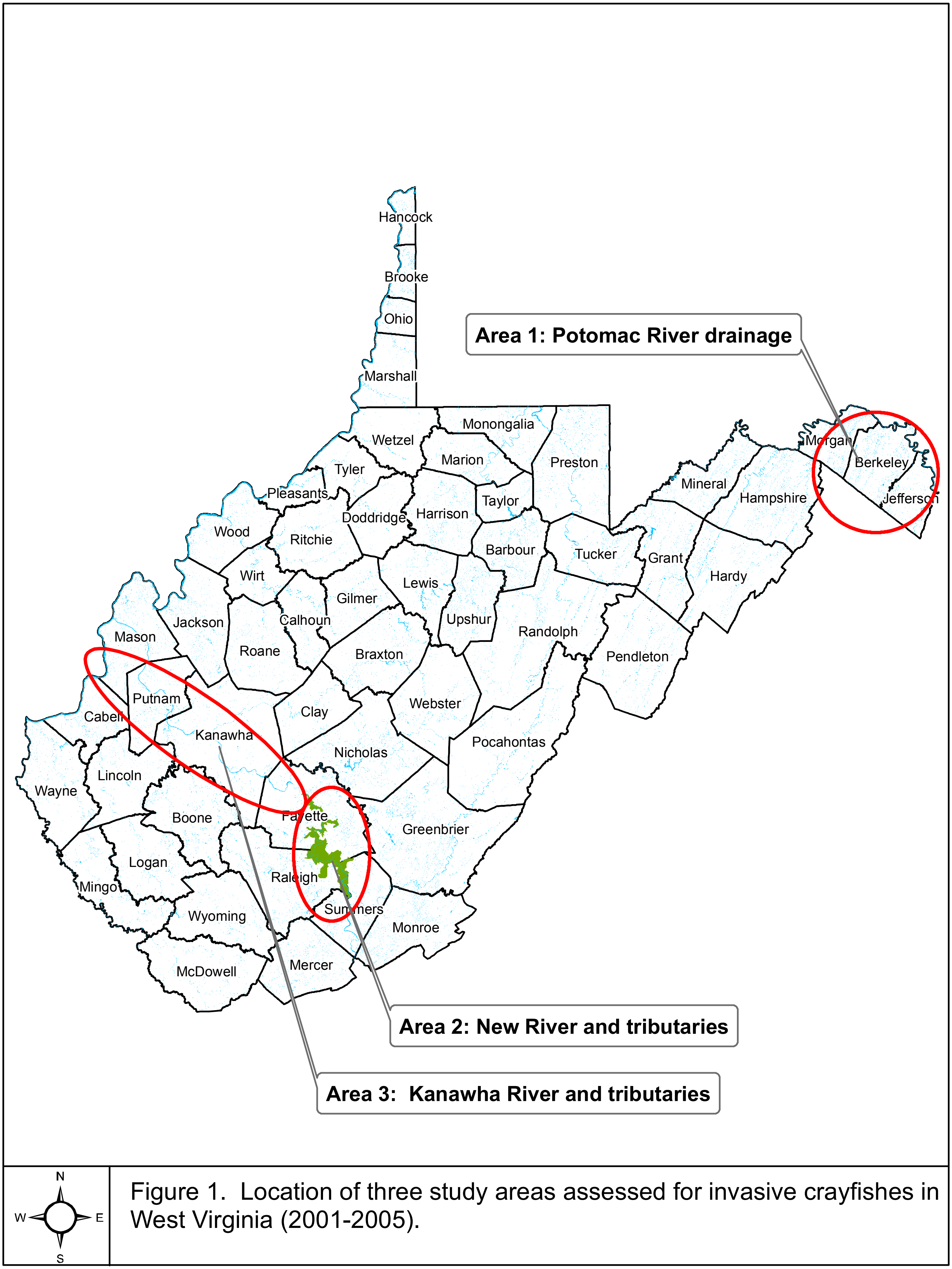

Figure 1. Location of three study areas assessed for invasive crayfishes in West Virginia (2001-2005).

2.0 The extirpation of Spiny Cheek Crayfish (*Orconectes limosus*) populations in West Virginia

Orconectes virilis was first recorded in West Virginia in 1970 from the New River in Summers County. This species is accepted to be an introduction due to its historical range from Saskatchewan to Ontario, Canada, and from Montana and Utah to Arkansas, New York, and Maine (Hobbs 1989). This species has been widely cultured for food and for fish bait. Aquaculture and biological supply facilities sell live specimens of *O. virilis* which are many times released into the wild. As of 1990 the known range of *O. virilis* in West Virginia was limited to the Potomac River Drainage in Opequon and Back Creeks, Jefferson and Berkeley Counties and the New (Kanawha) River drainage in Monroe, Summers, Fayette, and Kanawha counties (Jezerinac et al. 1995) (Figure 2). Prior to the discovery of *O. virilis* in West Virginia, Merideth and Schwartz in 1960 located five sites occupied by *O. virilis* in Woodstock Maryland. This population since has expanded to occupy the entire Patapsco River drainage displacing the native crayfish species *C. b. bartonii* and *O. limosus*. In West Virginia this same displacement by *O. virilis* appears to be taking place.

Historically, the range of crayfish *O. limosus* extended from Maine southward into northern Virginia including eastern portions of the eastern panhandle of West Virginia, where *O. limosus*, *C. b. bartonii,* and *O. obscurus* largely comprised the crayfish community. With the relatively recent introduction of *O. virilis* to this portion of West Virginia, a shift in the crayfish community has occurred. A survey of crayfish in 1988 -89 (Jezerinac et al. 1995) reveled only four sites from two streams (Back and Opequon creeks) where *O. limosus* was present. An additional historic *O. limosus* record from Cherry Run in Morgan County was

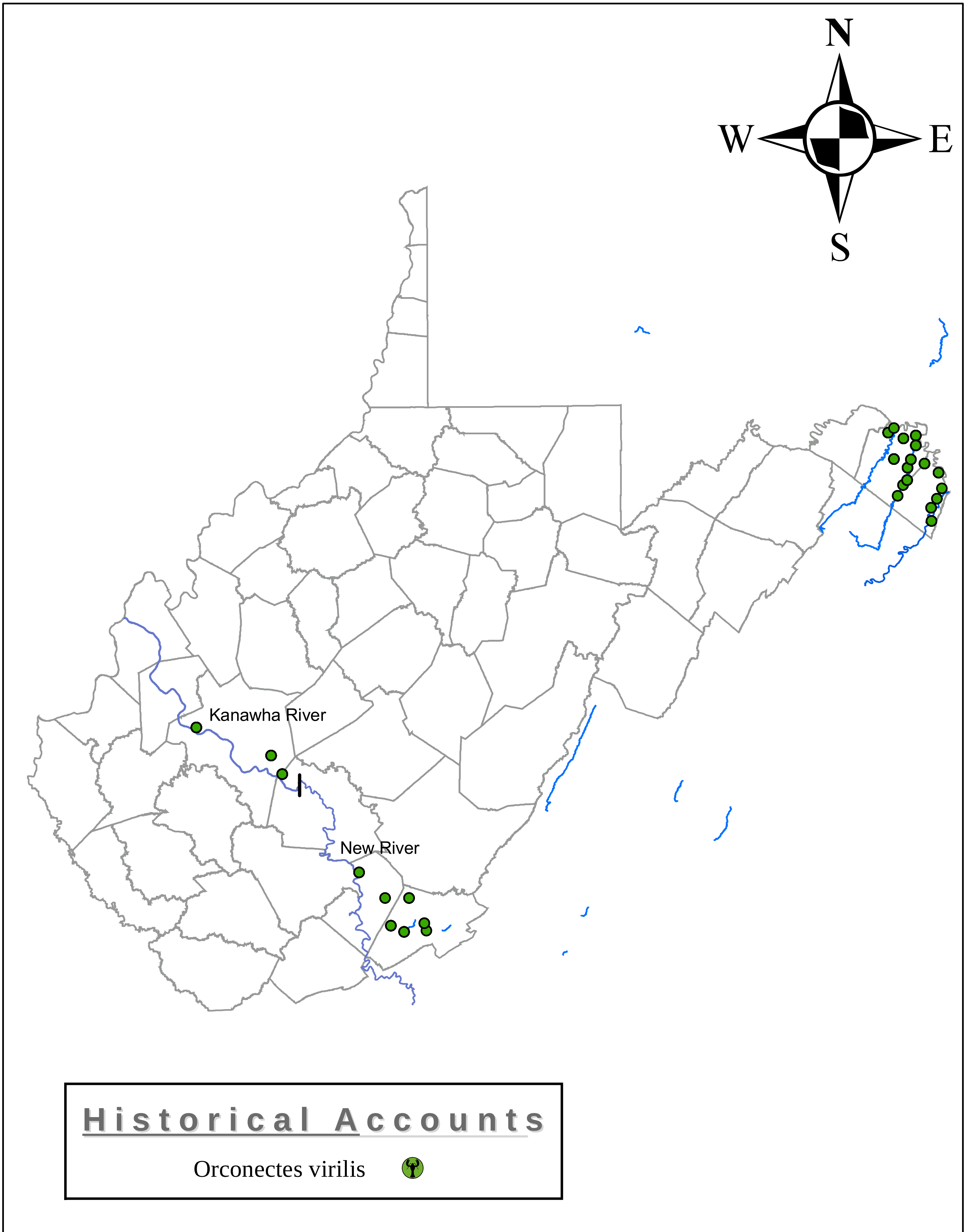

Figure 2

The Crayfishes of West Virginia, Jezerinac et al. 1995 stated by Ortmann in the Crawfishes of the state of Pennsylvania (1906). More recent collections from Cherry Run in 1989 only indicated the presence of *C. b. bartonii*. Only 14 individuals of *O. limosus* were collected from four locations during the 1988 and 1989 surveys (Figure 3). The majority of the collection composed of *O. virilis*, *C. b. bartonii*, and *O. obscurus*. This data along with the accounts of replacement from Maryland called for an extensive survey of the streams within the historic range of *O. limosus* in West Virginia.

2.1 Methods

We used three strategies to determine the crayfish community in tributaries to the Potomac River. Our first strategy involved sampling random and historical stream sites by hand collection (wading and snorkel assisted) and seining. Crayfishes were collected at 27 sites from 18 streams (Figure 3).

Secondly, we used a canoe to sample inaccessible areas of Back Creek during two float trips. Float trip one was approximately 5.4 miles from route 45 West of Glengary to county road 18 East of Shanghai. Float trip two was approximately five miles from county road six to county road nine just west of Hedgesville (Figure 3). Crayfish were sampled by hand, seine, and dip net methods at multiple intervals and at all habitat types during the float trips. Snorkeling and SCUBA also assisted in the collections of deep pools.

Our third strategy was an electrofishing sampling method to estimate crayfish density and determine species composition, similar to that used by Rholl and Orth (1992). At each site along Back Creek (D1, D2, D3), three seine reaches were chosen to represent as many habitat types as possible (riffle, run, or glide) (Table 1). Pools greater than one meter (3 ft) in depth were not sampled due to electrofishing limitations.

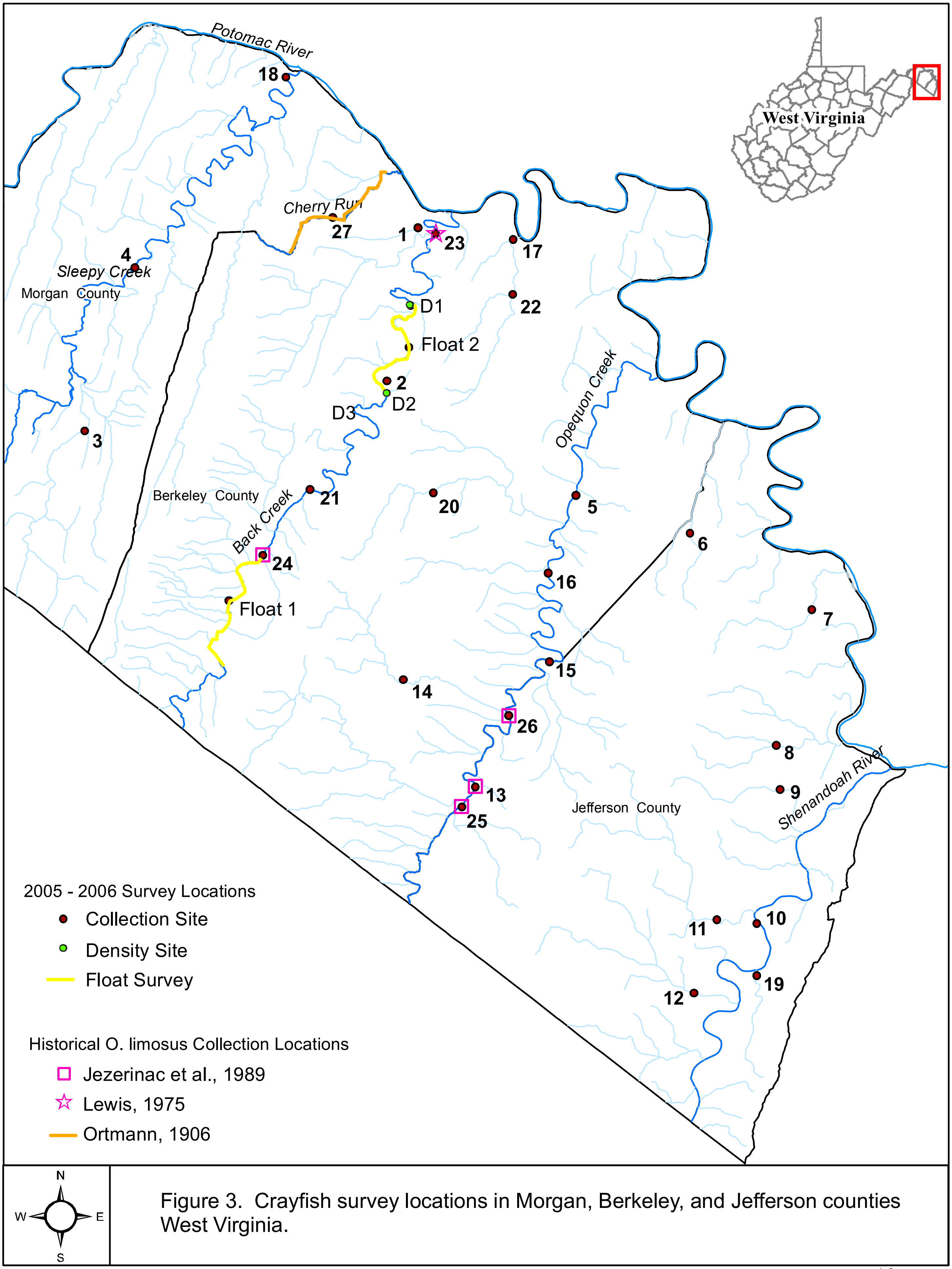

Figure 3. Crayfish survey locations in Morgan, Berkeley, and Jefferson counties West Virginia.

Table 1. Crayfish density survey sites along Back Creek in Berkeley County, West Virginia.

Site	Reach	Easting	Northing
D1	1	756208	4382738
	2	756225	4382741
	3	756188	4382757
D2	1	754783	4377924
	2	754786	4377906
	3	754791	4377940
D3	1	754057	4377263
	2	754024	4377270
	3	754034	4377284

At each reach, a seine (1.2 m × 6 m) was staked to the river bottom perpendicular to stream flow (Figure 4). A reach length of 10 meters was measured upstream from the seine, which designated each sample area to 60 square meters (654 ft^2). Two methods were used to collect crayfish at each stream reach. A kick method was performed by disturbing the substrate and turning rocks vigorously at the farthest upstream point of the sample area and working downstream toward the seine. A backpack electrofishing unit was also used to drive crayfish into the seine (Figure 5). The output power used on the electrofishing unit was four amps. This amount of electrical current appeared to show the greatest reaction from the crayfish from the three sites. We alternated which method was used first at each site to assess the level of effort and efficiency of electrofishing versus rock flipping. Specimens were field identified to species. All specimens were wet weighed using a digital balance (Ohaus Portable Scout Pro Model-SP602) to the nearest 0.01 gram, and the total carapace length was recorded using digital calipers (Mitutoyo Absolute Digimatic Model-500-172-20) to the nearest 0.01mm for each crayfish collected.

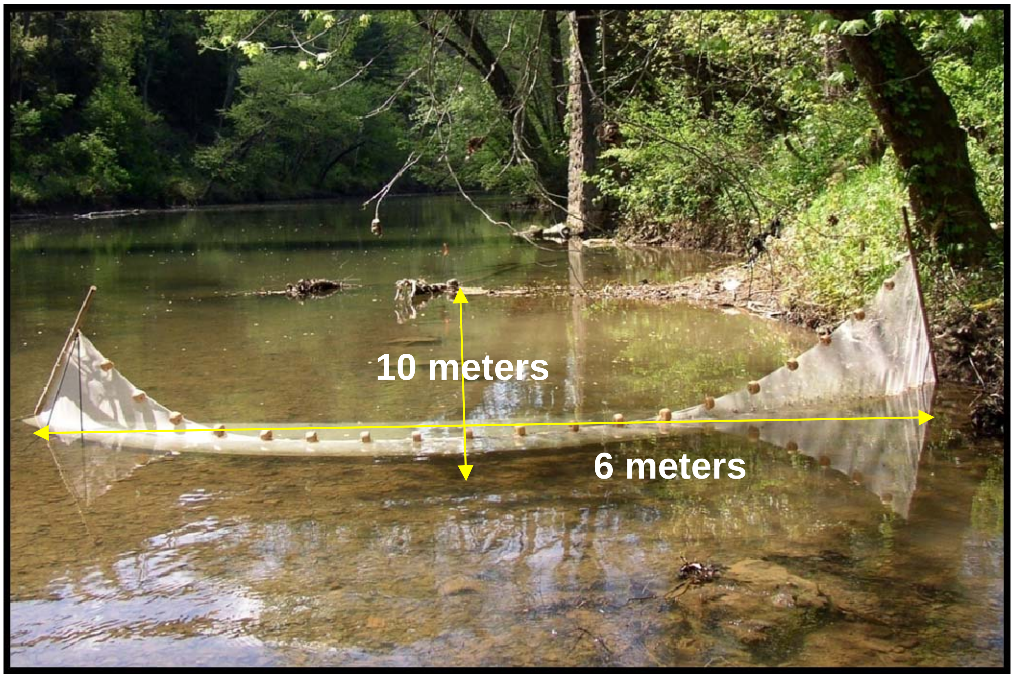

Figure 4. Back Creek density study seine setup, upstream view


Figure 5. Back Creek crayfish density electrofishing collection method

2.2 Results

Twenty seven site samples, two float surveys, and three quantitative sites containing nine seine sub-samples were completed to assess crayfish populations in Morgan, Berkeley, and Jefferson counties West Virginia (Figure 3). Three species of crayfish were collected: *O. virilis, O. obscurus*, and *C. b. bartonii* (Table 2). Re-surveys completed at five of the known historic *O. limosus* sites yielded no spiny cheek crayfish and an abundance of the non-native *O. virilis*.

Site and float surveys yielded 459 crayfish (*O. virilis,* 357; *C. b. bartonii,* 54; *O. obscurus, 48*). *Orconectes virilis* was the most abundant species collected (78%) with *C. b. bartonii* (12%) and *O. obscurus* (10%) accounting for the remaining collections.

The three density sites on Back Creek (Figures 6–8) yielded 142 additional crayfish (1, *C. b. bartonii*; 68, *O. obscurus*; 73, *O.* virilis) from 540 square meters (5812 ft^2) (Table 2). An estimated density of 0.26 crayfish per square meter (10 ft^2) was calculated for Back Creek. *Orconectes virilis* was the most abundant species collected (51%) with *O. obscurus* (48%) and *C. b. bartonii (<1%)* accounting for the remaining collections. The mean carapace length of *Orconectes obscurus* was 20.7 mm. *Orconectes virilis* had a mean carapace length of 29.6 mm. Wet weight as a measure of biomass by species favored *O. virilis* 519.7 grams versus the other two species (C*. b. bartonii* 1.3 grams, *O. obscurus* 146.4 grams). *Orconectes virilis* comprised 78 percent of total collected crayfish biomass (*O. obscurus* = 22%). Seventy-seven crayfish were collected by the kick sampling technique and 65 individuals were collected as a result of using the electrofishing technique. Density site summary data is located in Table 3. Habitat metrics and scores for density sites are located in Table 4.

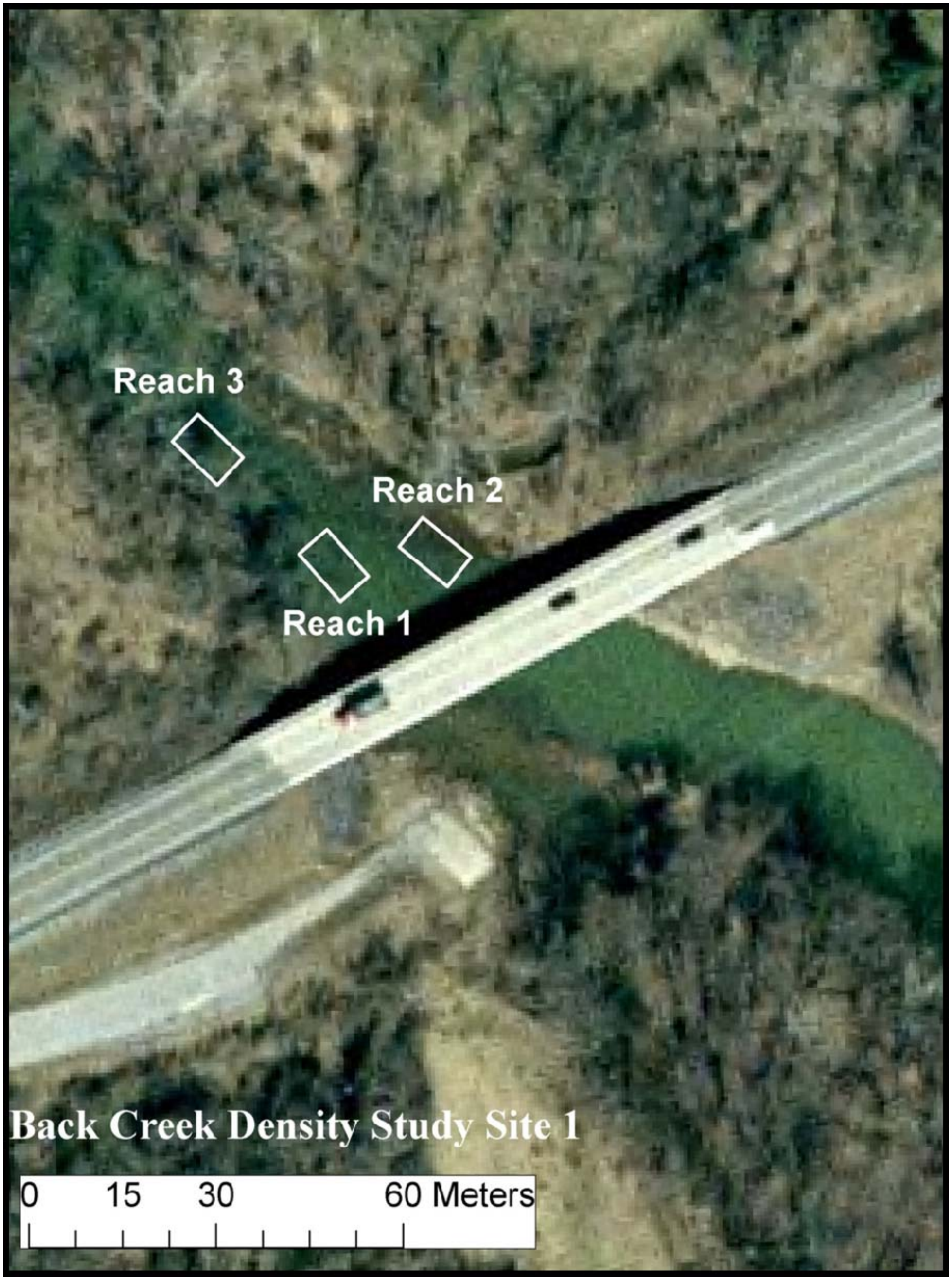

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Figure 6. Crayfish denstiy study Site 1 on Back Creek, Berkeley County, West Virginia

Figure 7. Crayfish denstiy study Site 2 on Back Creek, Berkeley County, West Virginia

Figure 8. Crayfish denstiy study Site 3 on Back Creek, Berkeley County, West Virginia

Table 2. Crayfish species summary table for Back Creek density sites

Species	**Number (n)**	**Mean Carapace Length (mm)**	**Biomass (g)**	**% Biomass**	**% Density**	**Females**	**Males**	**Form I Males**	**Form II Males**
C. b. bartonii	1	NA	1.3	0.002	0.007	1	0	0	0
O. obscurus	68	20.7	146.4	0.219	0.479	29	39	1	38
O. virilis	73	29.62	519.7	0.779	0.514	19	54	0	54
Totals	**142**		**667.4**			**49**	**93**	**1**	**92**

Table 3. Back Creek density site summary data

Site - Reach	**Biomass (g)**	**Area (m^2)**	**Number (n)**	**Density /m^2**	**Habitat Score**	**D 50**	**Mean Carapace Length (mm)**	***# O. virilis***	***# O. obscurus***	***# C. b. bartonii***
D1 - Reach 1	13.5	60	6	0.100	145	17.5	20.998	4	2	0
D1 - Reach 2	2.4	60	2	0.033	145	35	19.050	0	2	0
D1 - Reach 3	0.8	60	1	0.017	145	79.5	16.460	0	1	0
D2 - Reach 1	70.5	60	19	0.317	141	17	26.331	16	3	0
D2 - Reach 2	137	60	13	0.217	141	16	32.209	12	1	0
D2 - Reach 3	3.6	60	2	0.033	141	24	20.435	0	1	1
D3 - Reach 1	292.6	60	75	1.250	127	41.5	52.419	32	43	0
D3 - Reach 2	143.9	60	22	0.367	127	*23	28.376	9	13	0
D3 - Reach 3	3.1	60	2	0.033	127	45.5	20.080	0	2	0
TOTALS	**667.4**		**142**					**73**	**68**	**1**

*Substrate composed of high percentage of woody debris

Table 4. Habitat metrics and scores for Back Creek density survey sites in Berkeley County, West Virginia.

Metrics	D1	D2	D3
Epifaunal Substrate	16	15	13
Pool Substrate	18	13	17
Pool Variability	14	14	13
Sediment Deposition	16	9	9
Channel Flow	17	15	17
Channel Alteration	12	16	14
Channel Sinuosity	16	17	18
Bank Stability LB	9	7	7
Bank Stability RB	7	8	5
Vegetative Protection LB	2	5	2
Vegetative Protection RB	1	4	4
Riparian Vegetative Zone LB	10	8	4
Riparian Vegetative Zone RB	7	10	4
Total Score	**145**	**141**	**127**

2.3 Discussion

Impacts to known populations of *O. limosus* from the introduction of *O. virilis* were suggested during the 1988 and 1989 surveys (Jezerinac et al. 1995). Present data confirms that *O. limosus* is on the brink of extirpation from West Virginia and may be at risk of displacement by invasive crayfishes throughout the Eastern United States. During this study, documented *O. limosus* populations were re-surveyed. Back and Opequon Creeks were targeted due to historic occurrences of *O. limosus*. Crayfish collection sites along a stream are regularly determined by ease of access, however another approach was warranted to access areas that were reasonably unaltered and the occurrence of bait bucket introductions theoretically would be limited. A canoe enabled collectors to float remote areas of Back Creek with limited access to locate extant *O. limosus* populations. Additional small headwater (< 4 ft wide) streams typical of *C. b. bartonii* were also assessed as they may act as refugia to *O. limosus*. Float trip and stream collection sites yielded 459 crayfish. The numbers of *O. virilis* (357) were alarming compared to that of the other species (54 and 48 respectively). This data warranted an additional quantitative survey to estimate species density and composition.

Three sub-samples were completed at each density seine site location. Sites were thoroughly electrofished, large rocks were overturned, and substrate was disturbed to flush all crayfish into the seine. Visual inspection of the reach was completed after each survey method was completed and no additional crayfish were observed. One-hundred forty-two crayfish were collected from 9 reach sites, resulting in a estimated density of 0.26 crayfish per square meter (10.7 ft^2). The quantitative seine / electrofishing survey supports our original collection results. *Orconectes limosus* was absent from all of the Back Creek density sites. An additional concern was the number and size of *O. virilis* compared to the other species. *Orconectes obscurus* composed only 48 % of crayfish in the quantitative density study, while *O. virilis* comprised 51 %. *Orconectes obscurus* is smaller in size (mean carapace length of 20.7 mm) than *O. virilis* which had a mean carapace length of 29.6 mm. Crayfish size has been shown to be directly related to fish predation (i.e. a larger crayfish is less likely to be preyed upon then smaller crayfish by fish) (DiDonato, GT, Lodge, DM 1993).

The presence of *O. obscurus* also may contribute to competition that would impact the existence of *O. limosus* in West Virginia. *O. limosus* and *C. b. bartonii* have very similar ranges and are likely compatible with each other in terms of community structure and environmental niches. The Eastern Panhandle of West Virginia is on the outer edges of *O. limosus* range. *O. obscurus* may be just outside its native range for this portion of West Virginia. The interaction between *O. obscurus* and *O. limosus* from this portion of the state is unclear. *Orconectes obscurus* is native to West Virginia; however it may be an intrawatershed transfer into Back and Opequon creeks. The native ranges of *O. limosus* and *O. obscurus* (Hobbs 1989) appear mostly separate with little overlap. *Orconectes obscurus* may have been introduced into this region prior to the introduction of *O. virilis*. Although not as large or perceived as aggressive as *O. virilis*, sheer competition may have weakened the *O. limosus* populations. It is uncertain if this is the case, more research is needed to confirm the interaction of *O. obscurus* and *O. limosus*. This type of unknown interaction does not downplay the threat *O. virilis* is having on native crayfishes; it adds an additional layer of imbalance to the ecosystem that many times is overlooked. When species are transferred from one watershed to another the potential for negative impacts are still great.

If *O. limosus* is still present in West Virginia it is likely holding on in deep pools of Back or Opequon Creeks. Jezerinac et al. in the Crayfishes of West Virginia (1995) does expand on the fact that *O. limosus* seems to prefer non-typical crayfish habitat, and was collected in detritus, sediment laden substrate, and burrows in the clay bottom which may provide a temporary refuge for them to exist. Pools were under sampled during the density portion of the Back Creek survey due to electrofishing limitations, and inefficacy of seining due to lack of flow in pools. We did utilize snorkeling and SCUBA equipment at a few of the deepest pools, however visibility was limited, and crayfish that were captured all resulted in *O. virilis*. Time was also spent targeting deposition areas and leaf packs however only *O. virilis* was present. Areas with clay substrates were sampled; one burrow in a clay bank was excavated at 18 inches deep with a female *O. virilis* present. In all of our efforts we were unable to collect a single *O. limosus* from West Virginia. These findings bring us to believe that *O. limosus* is on the brink of extirpation from the state of West Virginia due to the introduction of the non-native crayfish *O. virilis*.

3.0 Status and trends of the crayfish community in the New River Gorge National River, West Virginia.

The New River Gorge National River (NRGNR) includes approximately 70,000 acres park land and includes 53 miles of free flowing New River between Hinton and Fayetteville West Virginia (Figure 1). Crayfishes here in the New River function as a keystone species and are an integral part of the aquatic ecosystem, making up a major food item in the river. This balance has over the years been interrupted due to the introduction of the non-native species *O. virilis*. The existence of *O. virilis* in the New River began from the impoundment of the Bluestone Reservoir which is located in Hinton, West Virginia. A lack of knowledge about invasive aquatic species resulted in the addition of *O. virilis* as a forage food to help jumpstart the lakes freshwater fishery, by the West Virginia Division of Natural Resources and National Parks Service. The exact movement of *O. virilis* from the reservoir to river is unknown. Evidence does strongly support bait bucket introduction by fisherman as a likely culprit (Nielson and Orth 1988; Roell and Orth 1992). During this time aquaculture of bait was at its peak. Crayfish made up a significant bait fishery that existed in the New River between Bluestone Dam and Sandstone Falls (Nielsen and Orth 1988). Annual harvest by anglers and commercial bait catchers was about five percent of annual production (Roell and Orth 1992). Overall crayfish production in the New River between Bluestone Dam and Sandstone Falls was about 7.0 grams live weight per square meter per year (Roell and Orth 1992). Half of that production was *C. sciotensis*, with the rest comprised of *O. virilis* and *O. sanbornii*.

There have been six species of crayfishes (*O. sanbornii*, *O. obscurus*, *O. virilis*, *O. spinosus* = O. cristavarius, *C. carinirostris*, and C. sciotensis) recorded from the NRGNR (NPS 1994). Jezerinac in the Crayfishes of West Virginia (1995) lists the previous species lacking *O. obscurus* from the New River. Studies from 1979 on the New River resulted in *O. obscurus* making up 3% of the assemblage (Markham et al. 1980), but were not collected in 1984 or 1985 (Roell and Orth 1992). Jezerinac records two specimens of *O. obscurus* from Piney Creek in Raleigh County near the New River in 1988.

The non-native crayfish species *O. virilis* was introduced to Bluestone Lake prior to 1972 (Edmundson 1974). By 1979 *O. virilis* comprised 90% of five seine sites between Bluestone Dam and Sandstone Falls (Markham et al. 1980). It is likely that *O. sanbornii* was introduced to the New River at a later date from an adjacent watershed, as none were collected in the 1979 samples. By 1983-1985, *O. virilis* was the predominant crayfish in the 1.1 km below Bluestone Dam (Roell and Orth 1992). Non-native crayfish were likely introduced to the New River by anglers as discarded or escaped bait (Miller 1997). Introduction of non-native crayfish into areas inhabited by native species (e.g. Hill and Lodge 1999), along with the restricted ranges of most crayfish, are major factors in 50% of U.S. and Canadian crayfish being in need of conservation recognition (Taylor et al. 1996).

Several other crayfish species have been collected near the NRGNR. The West Virginia Natural Heritage Program (NHP) lists *C. chasmodactylus* as a species of special concern. Although Jezerinac and others (1995) considered *C. chasmodactylus* restricted to the Greenbrier River basin, this species has been reported from the Bluestone (Hobbs 1989) and East Rivers (James 1966). *Cambarus longulus* is known from the New River basin in Virginia; however it is restricted in West Virginia to the James River drainage and has only been recorded from Monroe County. *Cambarus veteranus*, also a NHP species of special concern, is known from the upper Bluestone River Basin, but not from other streams in the vicinity of the parks. *Cambarus robustus* is common in tributaries downstream of Kanawha Falls it is not known throughout most of the New River Basin, although a disjunct population is known from the Greenbrier River Basin. *Cambarus neterius* is endemic to the Greenbrier River Basin, specifically the karst system associated with General Davis Spring near Lewisburg. *Cambarus bartonii cavatus* is listed as rare upstream from Kanawha Falls, and is found primarily above 1,500 feet of elevation (Jezerinac et al. 1995). This species is a secondary burrower and is found in roadside ditches and small headwater streams that may be intermittent. *Cambarus dubius* is a primary burrower that is known from the New River drainage. This species has three color morphs within the state. The red claw black body form is present within the New River National Park. This species is found along seeps and springs also in and around roadside ditches (Jezerinac et al. 1995).

The last major surveys of crayfish within the New River Gorge National River occurred in 1985. Due to the changes in community structure noted from earlier studies throughout West Virginia, and the definite possibility of species introductions by anglers, it is important for National Parks Service to assess the status of the crayfish community, and to document any changes that have occurred.

3.1 Objectives

Major tributaries that flow into the New River and the main-stem were targeted to represent the crayfish community and document species distribution. Additional branches and creeks were also examined to get widespread coverage of the area. Twenty nine stream sites where visited, 16 of those sites were in the New River mainstem or just upstream from the mouth of a tributary. The remaining 13 sites were on tributaries or branches of tributaries that flow into the New River (Figure 9). This study also focused on primary burrowing crayfishes. This portion of the project focused on finding burrowing crayfishes and previously known sightings of crayfish chimneys and burrows. An additional 17 sites located around low lying fields, ponds, wetlands, road side ditches, small streams, seeps, and springs were examined.

3.2 Methods

Crayfish collection methods varied among habitats and environmental conditions. Hand collection was the preferred method in small streams with optimal visibility and low velocity. Sites where conditions were unfavorable of hand collection such as low visibility or high velocity during rain events were sampled using D-frame nets. The D-frame net was positioned downstream of large flat rocks or groups of boulders. The rocks were lifted or disturbed, flushing sediment and any crayfish into the downstream net (Figure 10). This was the most productive method for high water sampling of small streams. Large seines were used in larger streams and where grass beds were present. Sampling completed on the New River mainstem and in deep pools required snorkel and SCUBA equipment (Figure 11). Two divers worked in tandem overturning boulders to capture crayfish. Catch-per-unit effort (CPUE) was calculated by for each site. Morphometric data was recorded for all individuals collected except juveniles and a few damaged specimens. Each crayfish collected was sexed, reproductive condition recorded and measured. All specimens were wet

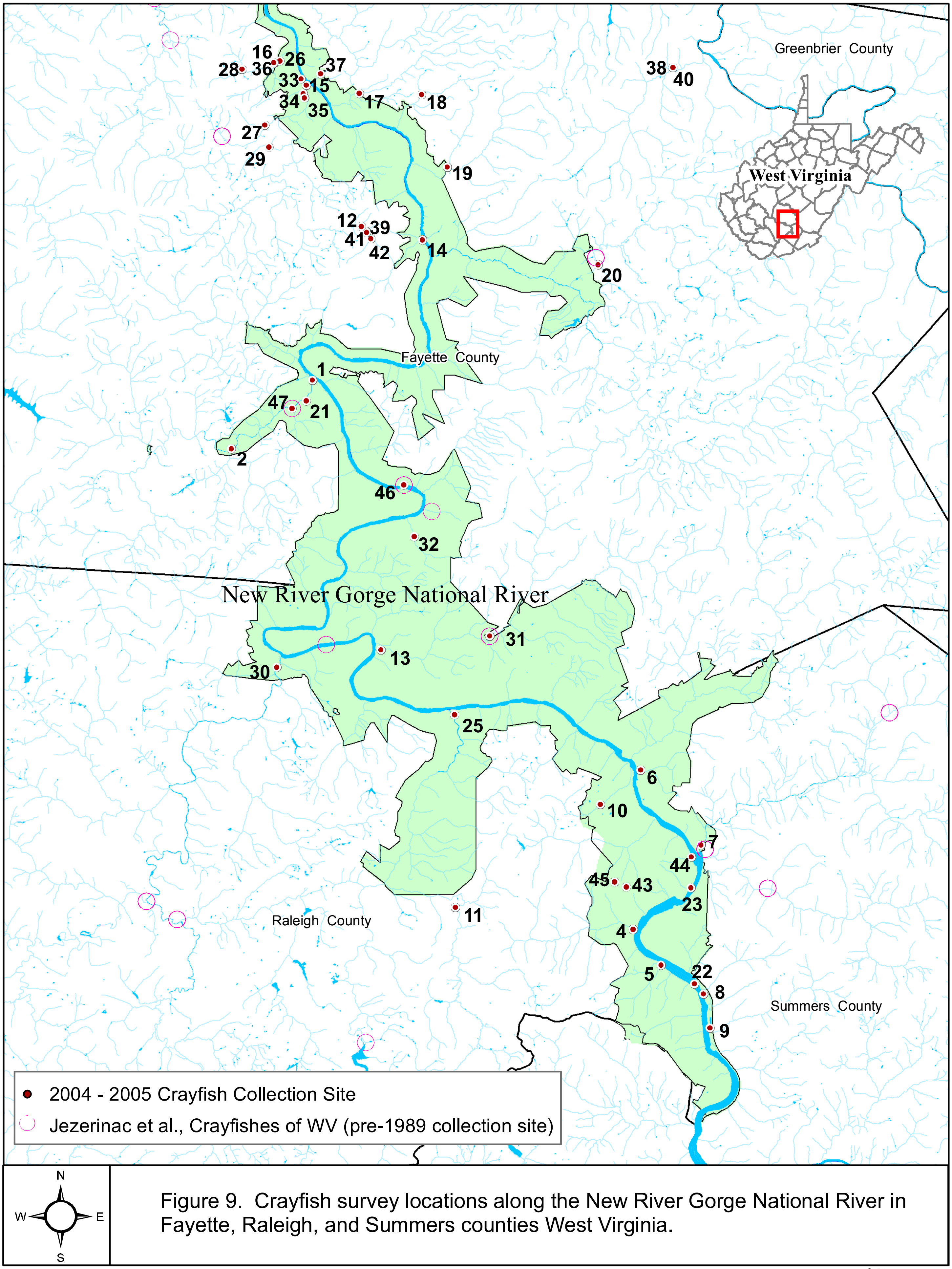


Figure 9. Crayfish survey locations along the New River Gorge National River in Fayette, Raleigh, and Summers counties West Virginia.

Figure 10. Collecting crayfish using a D-frame net in high gradient swift water streams

Figure 11. Divers in full SCUBA gear in New River Gorge National River, West Virginia

weighed using a digital balance (Ohaus Portable Scout Pro Model-SP602) to the nearest 0.01 gram, and length measurements were recorded using digital calipers (Mitutoyo Absolute Digimatic Model-500-172-20) to the nearest 0.01mm for each crayfish. Measurements taken include: Carapace length, Carapace width, Areola length, Areola width, Postorbital ridge width, Rostral width, Rostral length, Acumen length, Chela length, Dactyl length, Chela palm length, Chela width, and Chela thickness (Table 5). Tubercles were also recorded on the mesial and dorsolateral margins of the chela's palm, and finally the status of the crayfishes right and left chela was recorded numerically (1 = normal, 2 = regenerated, or 3 = absent). Each crayfish was weighted in grams on a digital scale and the Orconectids gonopod length and mesial processes length were measured.

Burrowing crayfish were collected using multiple methods. The preferred method was to locate active crayfish burrows with fresh mud located at the burrows entrance. The burrows opening was widened by hand or with the aid of a hand trowel. Burrows within a foot of the water table were pumped by thrusting a fist into the burrow. Water also can be poured into deeper burrows to achieve similar results. The pumping action forces water and changes the pressure throughout the burrow. Crayfish were captured by hand when they came to the water's surface to investigate. Other preferred methods including using pipe traps, mist net traps, and night spotting with headlamps. When all other options failed, excavation by shovel was many times the only way to collect deep burrowed crayfish.

As a test, a three-foot-long fiber optic scope was used to observe crayfish in shallow burrows (Figure 12). The lighted end of the scope was placed down the shaft of a burrow to visually inspect for a crayfish. Crayfish were easily identified using this method due to the

Table 5. New River Gorge National River crayfish morphometric summary data

	O. sanbornii	*O. virilis*	*O. cristavarius*	*C. carinirostris*	*C. sciotensis*	*C. b. cavatus*
Total number specimens (n)	5	39	9	106	134	6
*Number Adults (n)	4	32	8	58	88	3
Number Juveniles (n)	1	7	1	48	46	3
Biomass (g)	28.2	434	37	562.6	1118.8	14.3
% Biomass	1.28%	19.77%	1.69%	25.63%	50.97%	0.65%
Mean Carapace Length	29.54	37.36	23.94	31.21	33.16	26.30
Mean Carapace Width	14.29	18.47	12.52	16.01	17.40	13.02
Mean Areola Length	7.54	12.55	8.81	11.50	11.50	9.21
Mean Areola Width	2.03	1.88	1.94	2.79	3.35	1.58
Mean Postorbital Width	6.98	8.52	6.64	7.98	8.52	6.37
Mean Rostral Width	3.56	4.35	46.51	4.17	4.05	3.36
Mean Rostral Length	9.46	10.06	8.91	6.39	7.45	6.15
Mean Acumen Length	3.69	3.23	3.31	1.94	2.40	1.61
Mean Chela Length	21.68	23.93	15.32	22.43	28.81	16.02
Mean Dactyl length	12.20	16.21	9.05	14.69	18.33	9.61
Mean Palm Length	7.13	6.64	8.53	6.84	8.74	5.47
Mean Chela Width	8.66	9.24	5.99	10.26	11.91	7.35
Mean Chela Thickness	5.27	5.56	3.61	6.38	7.23	4.96
Mean Gonopod Length	7.665	13.82	11.39	NA	NA	NA
Mean Mesial Process Length	2.55	6.46	5.49	NA	NA	NA
Mean Weight	7.05	14.00	4.63	9.87	13.01	4.77

*All morphometric data is based on adults only distinct coloration of burrowing species. The scope proved to be useful in some cases however it regularly became visually obstructed with dirt and mud.

Figure 12. Using fiber optic scope to search crayfish burrows

3.3 Results and Discussion

Crayfish surveys completed in 2004 yielded 299 individuals (106, *C. carinirostris*; 6, C. b. cavatus; 134, *C. sciotensis*; 9, *O. cristavarius*; 5, *O. sanbornii*; 39, *O. virilis*) from 29 sites distributed from Fayetteville south to the Bluestone Dam in Hinton. Collection site coordinates, WVDEP stream quality data, and raw crayfish data is located in Appendix A (Tables 6-9). *Cambarus carinirostris* was located throughout the NRGNR, and was most abundant north of the town of Thurmond. Of the 106 *C. carinirostris* specimens, 64 females and 42 males were collected. Out of the 42 males 10 were first form and 32 were second form in their reproductive status. *Cambarus b. cavatus* had the smallest distribution and was only collected from House Creek near Fayetteville. Of the 6 *C. b. cavatus* specimens collected from house creek, 4 were second form males and 2 were females. *C. sciotensis* was the most abundant species collected throughout the park; however their densest populations were south of Thurmond in the lower elevations. Of the 134 *C. sciotensis* specimens, 72 females and 62 males were collected. Out of the 62 males 23 were first form and 39 were second form in their reproductive status. Out of the 15 males only two specimens were at first form reproductive status. Nine *O. cristavarius* specimens were collected, 5 were female and 4 were second form males. *Orconectes sanbornii* was collected from the New River and a few tributaries just downstream of the Bluestone Dam. Five *O. sanbornii* specimens were collected, two females and three second form males. Of the 39 *O. virilis* specimens, 24 females and 15 males were collected.

The West Virginia Department of Environmental Protection (DEP) produced water quality data from the New River drainage within the vicinity of the crayfish collection sites (Appendix A; Table 8). Three parameters were examined with regard to our crayfish data. A linear regression was used to diagnose each case. The first test compared the West Virginia Stream Condition Index (WVSCI) score to the catch per-unit effort (CPUE) score. The next comparison was between CPUE and organism density. The last test was a comparison of CPUE and habitat score. No definitive correlations could be made from any of the three tests.

The initial hypothesis was that there may be some significance between these parameters, however due to varying collecting conditions over the course of the study; CPUE data may not reflect the normal value during normal environmental conditions. Stream habitat variation also could reflect the low significance values.

A comparison of regenerated versus non-regenerated chela (claw) data was also examined. Crayfish were classified into three groups: (1) representing normal chela, (2) representing regenerated chela, and (3) representing no chela present. The three most abundant species collected were examined (*C. carinirostris, C. sciotensis,* and *O. virilis*). The status of chela in both cambarid species was similar. Approximately 3.5% and 9.7% of chela were regenerated in *C. carinirostris* and *C. sciotensis* respectively, while *O. virilis* resulted with 23.5% of chela regenerated. Approximately 3 percent of cambarid chela was absent, while 29.4 % of *O. virilis* chela were missing. This data could suggest that cambarids retain their chela better then orconectids, or that the aggressive nature of *O. virilis* results in a more confrontational species and increases its chances to lose a claw. Collectors did observed *O. virilis* holding its ground more often than the other species. When lifting large rocks, *O. virilis* would normally stay in place with its claws open and in a defensive posture (i.e. holding its ground). *O. carinirostris* and *O. sciotensis* were more likely to retreat with a flip of their abdomen to be swept away with the current. More observations and specimens of these and other species are needed to determine if behavior is related to chela status.

3.4 Species Distribution

The distribution of crayfish from the NRGNR was mostly unknown, with only a few sparse records available. Each species collected during the 2010 - 2011 survey were mapped to show their current distribution within the National Park. Species distribution maps are provided in Appendix B.

3.4.1 Orconectes virilis

The distribution of *O. virilis* in the new river suggests that it is mostly confined to the main-stem of the New River. It was however collected from the mouths of numerous tributaries and recently molted large females were observed upstream a few hundred meters. Below Bluestone Dam fisherman were observed with bait buckets full of *O. virilis* that were hand caught in the area. Jezerinac et al. (1995) also states that *O. virilis* is likely to be distributed throughout the New River due to bait bucket introductions. *O. virilis* was the predominate orconectes species collected from the New River. In a 2005 survey of the Kanawha River, researchers discovered *O. virilis* at multiple locations. It is likely that this species has extended its range from the initial introduction in the Bluestone Reservoir downstream into the Kanawha possible as far as the Ohio River. This species has been recorded to expand its range in other parts of West Virginia and is likely to do the same here.

3.4.2 Orconectes sanbornii

Orconectes sanbornii has historically only been present in the southern portion of the park (Hinton). *O. sanbornii* was believed to be introduced around 1979. By 1983-1985, they were the predominant crayfish in the 1.1 km (0.68 mi) below Bluestone Dam (Roell and Orth 1992). *O. sanbornii* in 2004 was collected just below the Bluestone Dam and one specimen at the mouth of Brooks Branch. *Orconectes virilis* is now the predominate crayfish below the Bluestone Dam; however it was not collected from the northern half of the park.

3.4.3 Orconectes cristavarius

Orconectes cristavarius is found throughout southern West Virginia. This species was originally identified as *O. spinosus* however recently (Taylor, et al. 2000) separated the species and now it is *O. cristavarius*. *O. cristavarius* was found again in Lick Creek from a previous record from 1988. This species may have been originally introduced into West Virginia waters from somewhere else and is potentially expanding its range at the cost other native species. Quote from Jezerinac the Crayfishes of West Virginia: “In 1947, Hobbs and

Wilson collected *O. sanbornii* from Briar Creek in the Guyandotte Drainage from Logan County. In 1953 Hobbs and Combs also captured *O. sanbornii* from Huff Creek in Logan County. When sites in the vicinity were later visited in 1988 and 1989 only *O. spinosus* was found." The low numbers of *O. cristavarius* in the New River may be a result of competition with *O. virilis*.

3.4.4 Orconectes obscurus

O. obscurus was not collected within the park, however a 1979 survey identified O. obscurus as comprising 3% of the crayfish assemblage in the New River (Markham et al 1980), but were not collected in 1984 or 1985 (Roell and Orth 1992). During this study O. obscurus was not collected either.

3.4.5 Cambarus bartonii cavatus

C. b. cavatus was only collected from House Creek in Fayette County within the park. The low occurrence of *C. b. cavatus* is likely due to its range which is the upper Kanawha River drainage. Jezerinac (1995) stated that "*C. b. cavatus* is rare above Kanawha falls." This subspecies may also be hard to find due to its reputation as a secondary burrower which may be found in roadside ditches, springs, and in very small first order streams. The presence of *C. b. cavatus* in house creek helps evaluate the stability of that population.

The 2005 burrower survey also located a population of *C. b. cavatus*. Both of these collections were made near the top of the gorge and in a roadside ditch (Co. Rd. 82) with flowing water. This species is likely more abundant than previously thought, however it prefers small streams from springs and seeps that are normally under sampled.

3.4.6 Cambarus carinirostris

The distribution of *C. carinirostris* appears to be widespread throughout the New River watershed. It was originally only known from one location within the National Park, however recent data suggests it is found throughout the park. *C. carinirostris* was collected from the main stem as well as the surrounding tributaries. The densest populations were found in the northern higher elevations (Fayetteville), where it was the dominant species. It was collected in the lower southern portion of the park (Hinton); however C. sciotensis was abundant and appeared to be the dominant cambarid.

3.4.7 Cambarus sciotensis

The distribution of *C. sciotensis* is widespread throughout the new river watershed. This species was collected from the main stem as well as the surrounding tributaries. The densest populations were found in the southern lower elevations (Hinton), and also appeared to be the dominant cambarus species in the New River. It was collected in limited numbers from the upper northern (Fayetteville) sections of the National Park; however *C. carinirostiris* is abundant and appears the dominant cambarid there.

3.4.8 Cambarus robustus

Cambarus robustus is historically recorded from one site within the New River drainage. It was however not found in any samples from the 2004 survey. Jezerinac states that this species disappears above the Kanawha falls until re-appearing in the Greenbrier River. *C. robustus* is also easily confused with *C. sciotensis* which is known from sites within close proximity of the one historically recorded site.

3.4.9 Cambarus dubius

Cambarus dubius was historically recorded from only two places within the park by Stocker in 1988. Due to this species being a primary burrowing crayfish it was not collected in our 2004 stream samples. *Cambarus dubius* has three color morphs known from West Virginia: orange or red body form, blue body form, red claw black body form. Of the three forms the red claw black body form resides in the park. The 2005 burrower survey helped confirm the species and color morph present in the National Park. This species is a primary burrower and was found mostly in road side ditches where a seep or spring was present. *Cambarus dubius* was found at 11 sites that stretch from Fayetteville or the northern portion of the National Park to Hinton the southern section of the park. *Cambarus dubius* is likely to be found throughout the park and surrounding areas.

3.5 Conclusion

The crayfish community appears intact throughout the NRGNR. The density of crayfish in the New River is high, although some orconectes species appear to be in decline. This decrease in numbers of orconectes species may be due to the occurrences of *O. virilis* in such high numbers. The presence of non-native crayfish in West Virginia is in need of additional monitoring. The reduction of native species seems apparent in the NRGNR and if the continuation of bait bucket introduction is not regulated, West Virginia's crayfish diversity may diminish.

4.0 Invasive crayfishes of the Ohio / Kanawha River drainage, West Virginia, with examination of large river collection techniques

Crayfish collections from West Virginia have mostly come from wadeable rivers, small steams, and lakes. Large rivers are generally under sampled because they are harder to access and require specialized equipment and experience to effectively sample them. The Kanawha River in West Virginia begins where the New River flows over Kanawha Falls. The river then flows west through three US Army Corps of Engineers controlled locks and dams, where it finally empties into the Ohio River. Crayfish records for this area are limited, and most come from boat ramps, tributaries, and backwater floodplain areas. No collections have ever been documented from the bottom of the main channel of the Kanawha River.

During this study, a series of trial crayfish collection methods were implemented in the main stem of the Kanawha River over the span of 5 field seasons (2004 – 2007). Many of the methods were abandoned, while others seem to be very practical. SCUBA accounted for the basis of most of the methods discussed in later sections. The ability to research the mainstem of large rivers has increased our knowledge of the crayfishes that reside there tremendously. In the Kanawha River drainage two non-native crayfishes (*O. virilis* and *O. rusticus*) have been historically documented (Jezerinac et al. 1995). Previous chapters discussed the impacts *O. virilis* is having on native crayfishes in West Virginia, and supports the efforts to locate additional populations.

Orconectes rusticus is not native to West Virginia, but has been historically recorded from Four Pole Creek (Cabell County), from Beech Fork Lake (Wayne County), and a single collection from the Kanawha River (Putnam County) (Jezerinac et al. 1995) (Figure 13).

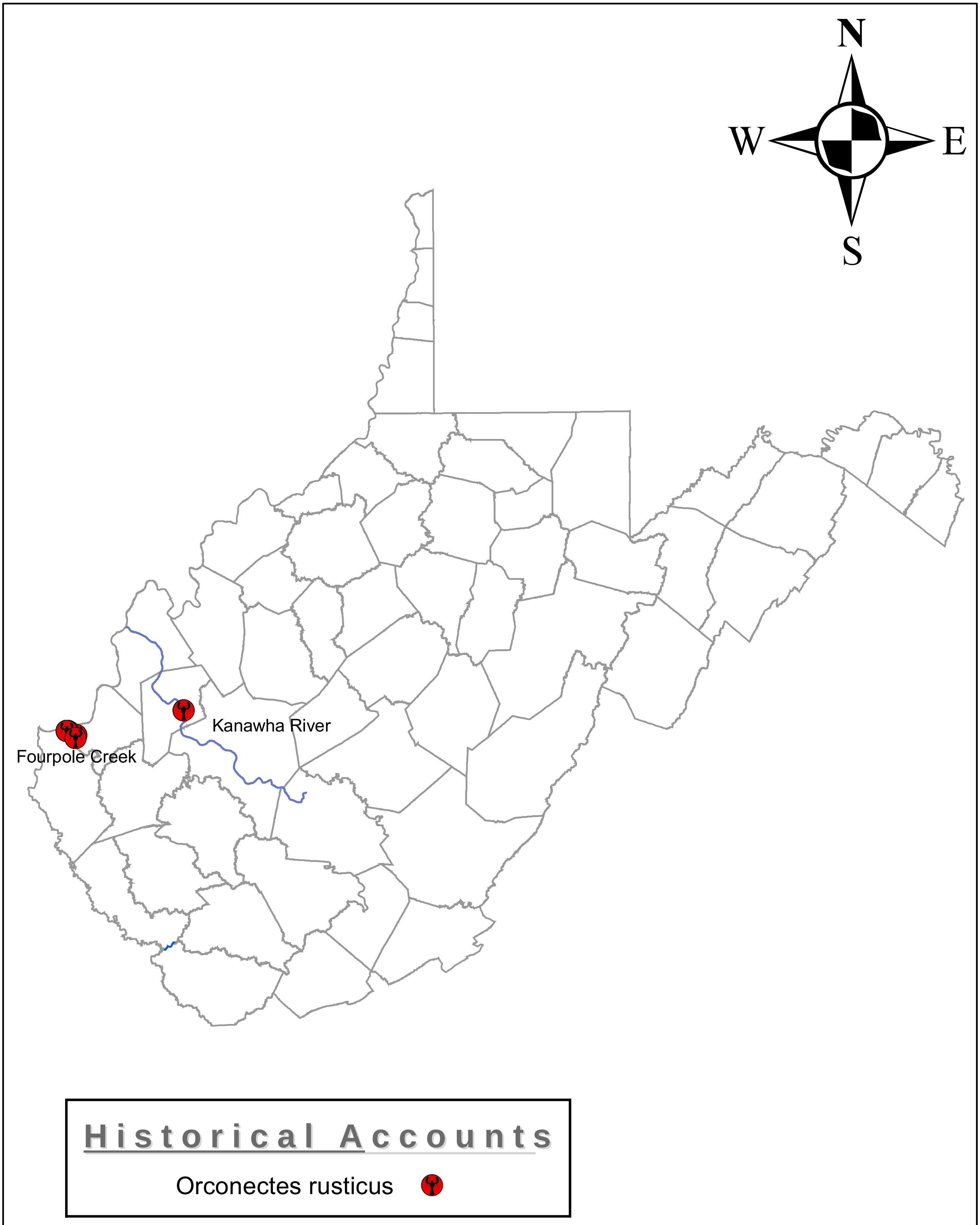

N
W
E
S
Kanawha River
Fourpole Creek
Historical Accounts
Orconectes rusticus

Figure 13

Orconectes rusticus has been shown to displace native crayfish species such as *O. propinquus* and *O. virilis*, in lotic habitats in Ohio (Jezerinac et al. 1995) and Illinois (Taylor and Redmer 1996). Also, the impact of *O. rusticus* has been studied in northern Wisconsin lakes where the native species is *O. virilis*. Within a few years of establishment *O. virilis* and *O. propinquus* had been reduced or completely eliminated by *O. rusticus* (Lodge et al. 1986; Olsen et al. 1991). *Orconectes rusticus* is determined to be superior to many species by chemosensory responses to food and consumption rates of food (Olsen et al. 1991; Willman et al. 1994). They are recorded to have faster growth rates (Hill et al. 1993), and out-compete native species for shelter and food (Hill and Lodge 1994). Also, *O. rusticus* has been shown to have some differential susceptibility to fish predation (DiDonato and Lodge 1993; Garvey et al. 1994). This species has been observed amplexing with native species and there have been genetically confirmed hybridizations (Taylor et al. 2000). The previously discussed *O. virilis* threats to native crayfish species in West Virginia may be exceeded by the expanse of *O. rusticus*.

4.1 Objectives

Determine the current distribution of *O. rusticus* and *O. virilis* in the Kanawha River mainstem. Examine selected tributaries of the Kanawha River for invasive crayfish species. Acknowledge additional locations where invasive crayfish are present and may present a future problem. Determine the feasibility and use of multiple large river crayfish collection techniques.

4.2 Methods

Collections of crayfishes described from this chapter were completed using multiple methods. The effectiveness and outcome of each method will be further discussed in the discussion section of this chapter.

4.2.1 Density Seine Sites

Three locations surrounding Hurricane Creek, a tributary of the Kanawha River in Putnam County were sampled to estimate the efficiency of electrofishing versus rock flipping for collecting crayfish. This method was used in Back Creek and detailed collection methods are described in Chapter 1 methods (Section 2.1). Hurricane Creek is narrower than Back Creek sampled from Chapter One so the seine was stretched across the entire stream. At each site, three reaches were chosen to be sampled, totaling nine seine reaches. Pools were defined as any section of stream with a depth over 1.5 meters (4.9 ft) of water, and were unable to be sampled due to backpack electrofishing limitations.

4.2.2 River Bank and Backwater Collections

Bank and backwater collections were sampled by hand, seine, dip net, and with the aid of snorkeling gear along the Kanawha River (Figure 14). Shallow rocky outcrops and point bars were targeted along the river for ease of collecting. Hand collections were completed by locating large rocks, woody debris, or other objects that may act as refuge for crayfish. The structures were slowly lifted to reveal any crayfish. A mask and snorkel with the aid of a small net were used in shallow water and drop offs to the main channel. Small burrows were excavated by hand usually resulting in a crayfish. Collectors also used breath holding techniques to swim underwater to reach burrows and collect specimens.

Figure 14. Using snorkeling gear to assess the river bank for crayfish

4.2.3 Minnow Trap

A series of minnow traps was placed along the Kanawha River mainstem. The sites were chosen based on river bank morphology. Large rock outcrops and point bars on the river banks were targeted due to the likelihood of more cover resulting in more crayfish. Chicken livers were placed inside of the traps to bait the crayfish. Each trap was tethered to a log, rock, or root mass by a 3.6 meter (12 ft) nylon rope and weighted with small rocks to keep them positioned on the river bottom. The traps were left alone for 24 hours prior to being retrieved.

4.2.4 Floating Turbidity Fence Exclusion

A floating turbidity fence/curtain was used to exclude sections of river bank along the Kanawha River mainstem (Figure 15). The fences were originally designed to control sediment from in-stream construction projects. The dimensions of fence used on the Kanawha River were 1.5 meters (5 ft) in height and 30.4 meters (100 ft) in length, with large floating foam blocks along the upper edge. The bottom edge of the fence was fixed with a heavy chain line and was additionally anchored to the river bottom at the upstream section of the reach by a 4. kilogram (10 lb) anchor. The fence was slowly placed into the water from the boat heading down stream until it was completely deployed. Once the fence was lying parallel to the river bank, it was positioned against the bank to confine any crayfish to the sampling area. The area between the floating turbidity fence and water's edge was designated sampling area. The fence was secured at multiple intervals to keep it abutted to the substrate. Researchers then placed a block seine at the downstream opening to capture any crayfish trying to escape. Once the seine and floating fences were in place, collectors began using different collection techniques to find which was more effective. This was done using a multiple pass depletion method. Snorkeling, seining, and electrofishing were completed along the 30.4 meter (100 ft) reach. Crayfish were collected separately for each method and time recorded to later examine time efficiency.

Figure 15. Floating turbidity exclusion fence setup along the Kanawha River, West Virginia

4.2.5 SCUBA Hand Collection

Deep water sites over four feet in depth were completed with the aid of SCUBA. The diver would locate rocks, logs, and other cover objects. The structures would be slowly lifted in a way that would reduce disturbing soft sediments on the bottom. The diver would visually look or place his/her hand into the shallow depressions to feel for the presence of crayfish. The diver would grab the crayfish by its carapace and place it into a small mesh bag with a drawstring. Wide mouth bottles were also used as containers for underwater collections. Bottom intervals were timed and divers recorded the number of crayfish that escaped while collecting.

4.2.6 Perpendicular Bank Transects

Transects that extended from the bank toward the river channel were used to assess crayfish in the Kanawha River. A diver would hold one end of a 19 millimeter (0.75 in) rope line and manually carry it out to 30.4 meter (100 ft) toward the middle of the river while a researcher on the bank would feed out the line. Once the transect rope was placed the diver would return up the line toward the bank placing two pound lead weights every 6 meters (20 ft) to keep the rope in place. A diver would start from the river bank and proceeded along one side of the rope collecting crayfish out to 30.4 meter (100 ft), and then turn around and collect on the opposite side of the rope. The diver would search an area of 1 meter (3.2 ft) on each side of the rope collecting crayfish as they proceeded. The total area searched would equal 200 square meters (2152 ft^2). This method was also completed using two divers, each searching a single side of the transect rope. The transect was also deployed from a boat by driving up to the river bank and fastening a large 6.8 kilogram (15 lb) anchor to one end of the rope and placing it at the water's edge. The boat was then driven in reverse toward the middle of the channel, while researchers fed the rope line from the front of the boat placing two pound lead weights at equal intervals. Once the rope line was tight a 9 kilogram (20 lb) anchor tied to the end was tethered to an additional rope and lowered to the river bottom. The final rope was tied off to the boat. Two divers would jump into the river and descend along the tag line to the anchor. Once at the anchor each diver would choose a side and move along the transect rope collecting crayfish 1 meter (3.2 ft) out until reaching the river bank. Crayfish were collected using hand collection methods described previously in the scuba hand collection method section.

4.2.7 Anchor Pivot Transects

Pivot transects were completed at single point locations in the mainstem Kanawha River. A large anchor was lowered from the boat to the substrate. Once the anchor and boat became stable a diver in SCUBA gear would descend down the anchor line to the substrate. The diver would connect an underwater hand reel marked in one meter increments to the anchor. The diver would position themselves directly one meter downstream from the anchor. The diver would then proceed to move in a circular pattern around the stationary anchor searching for crayfish within the one meter area. Once the diver made a full revolution and was repositioned one meter downstream of the anchor. The diver would loosen the reel and move two meters downstream of the anchor. The diver would continue the circular searches until reaching five meters beyond the anchor. Crayfish were collected by hand or with the aid of a small dip net.

4.2.8 Ultra-Surber Sampler

A one square meter surber-sampler was fabricated to collect crayfish in the Kanawha and Ohio Rivers (Figure 16). The frame was constructed from 1 inch diameter round aluminum tubing, welded to form a one meter square with 1 foot long posts on each of the four corners. Sheets of 500 micron mesh netting were used for the collection bag, while 0.25 inch mesh was used along the sides to keep crayfish from escaping.

The ultra-surber was taken to the river bottom by a diver and placed on the substrate with the bag opening facing upstream. The diver would slowly remove all large cover objects making sure to corral all crayfish into the net opening. Once the area was fully disturbed and all the crayfish were accounted for, the diver would reposition the ultra-surber to another location. After a specified number of samples were taken, the diver would surface with the sampling equipment (Figure 17).

Figure 16. Ultra-Surber large river benthic sampler

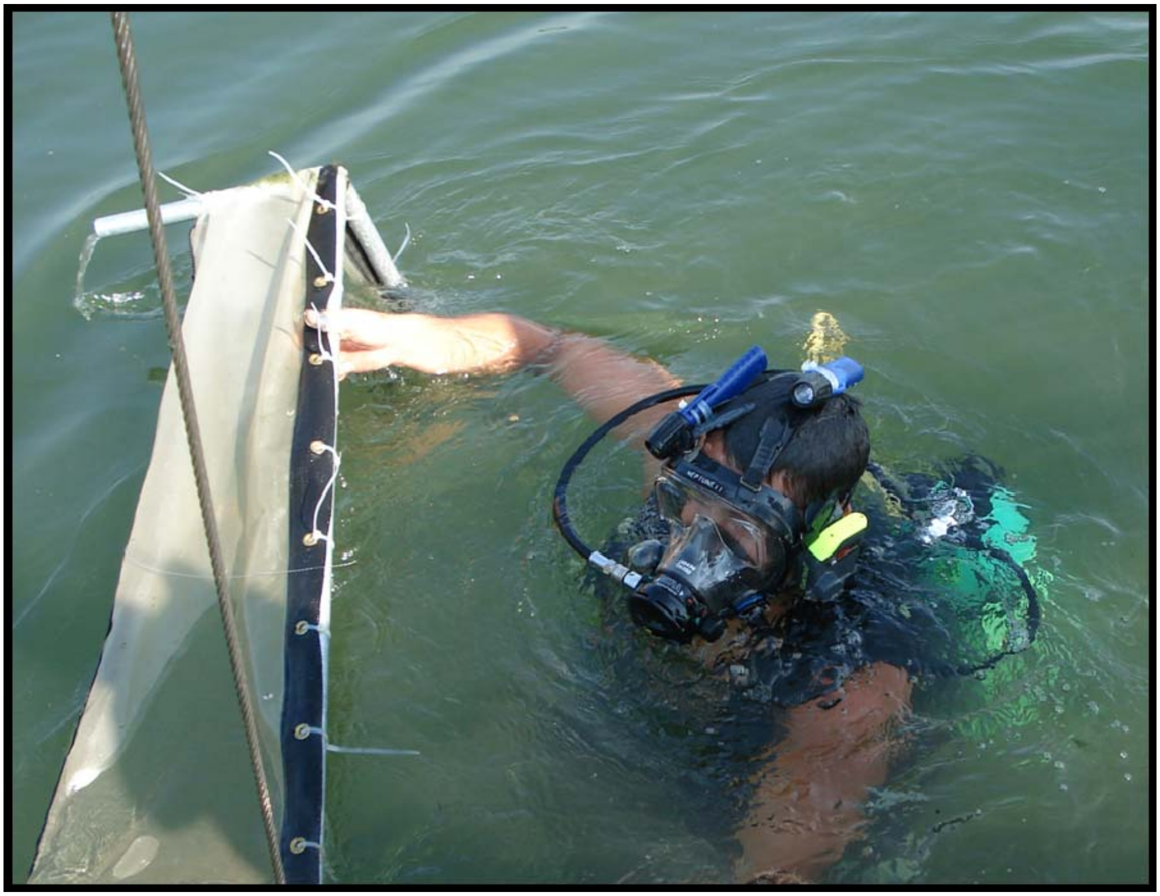


Figure 17. Ultra-Surber brought to the surface by a diver

4.2.9 Large River Transect Array

Sampling crayfish on the river bottom was completed using transects connected to a central anchor point. The anchor array consisted of a large anchor with four, 5-inch diameter tubes surrounding it (Figure 18). Each tube contained a single 10 meter rope line that was then connected to a 6 pound weight. The large array was lowered into the river until it reached the bottom. A diver descended down the line to the transect array and pulled out each rope line in four cardinal directions with river flow (upstream, downstream, left of flow, and right of flow). The diver collected crayfish from one meter on each side of each transect rope, resulting in a total of 80 square meters. At the endpoint of each transect rope; an ultra-surber sample was taken. After all the samples were completed, the diver(s) placed the transect ropes and weights in their corresponding tube and surfaced.

During the dives, a surface team recorded data on the divers through surface to subsurface communication gear. The divers could communicate with each other and the team on the surface. At all collection locations, geo-coordinates were taken from an onboard Garmin GPS depth sounder.

Figure 18. Large river dive transect array

4.2.10 Missouri Modified Benthic Trawl

The use of a benthic trawl to sample crayfish from large rivers was evaluated (Figure 19). A Missouri-type 8 foot wide trawl rig was the standard trawl employed during these surveys. The trawl is manufactured from 0.05 inch diameter nylon twine with 0.75 inch bar mesh and was lined with 1/8 in ace-style mesh. Two otter or trawl boards were connected, one on each side of the rig. These were connected to the boat with 0.625 inch diameter 100 foot in length twisted nylon tow lines. The bottom of the trawl opening is fashioned with a trawl chain that is 1.75 inch in length by 1 inch in height by 0.25 inch diameter. The top or float line of the trawl is completed with float buoys to help keep the rig opened while deployed.

The trawl was towed from Marshall University's electrofishing boat, and was attached to two hard points on the front of the boat. A towline of various lengths was used depending on water depth. A small float was attached to the end of the codpiece with a braided nylon rope that was adjusted to be no longer than the maximum depth to be sampled. In the event the trawl was snagged or had to be disconnected from the boat, the float marked the location of the trawl, facilitating recovery.

The trawl was deployed by first placing the boat in reverse on a downstream course. The codpiece float or tag line was then let out from the bow of the boat. The trawlers would proceed by placing the cod end of the net in the water until the net was fully expanded. The otter boards were then hand fed into the water and held in position until the rig was fully opened and operational. A single researcher would lower the towlines simultaneously as the boat continued to move at a downstream rate approximately 1 to 2 meters per second greater then flow. The driver would call out the depth and when the rig was felt on the bottom each tow line was cinched off to a hard point on the bow of the boat. The driver would mark the beginning position on a Garmin GPS depth sounder, and recorded position, water temperature, depth, and the length of tow line. Relative approximate depths, distances to shore, date, time, and trawl site information were also recorded. After the predetermined trawl time (1 – 5 min) passed the net was brought aboard and the cod end was untied, dumping all the catch into a large plastic bin to be processed. In the event a snag was irretrievable by the surface. A diver would descend down the tow line in SCUBA gear to untangle and retrieve the net.

Figure 19. Eight foot wide Missouri modified benthic trawl on the front of the electrofishing boat ready to be deployed

4.3 Results

A total of eight species from two genera were collected in 2004 and 2005 from the Kanawha River drainage. Eighteen locations (Figure 20) were sampled in total, distributed throughout the Kanawha River including a single site just upstream in the mouth of the Elk River, one site in the Ohio River, and two sites directly above Kanawha Falls. Four species (*O. rusticus*, *O. virilis*, *O. cristavarius*, and *C. robustus*) were collected from the Kanawha River mainstem while *C. sciotensis* was collected above Kanawha Falls and *O. sanbornii* was collected from just upstream in the Elk River. Two additional species *Cambarus thomai* and *C. b. cavatus* were recorded from one of three seine sites in the Hurricane Creek watershed.

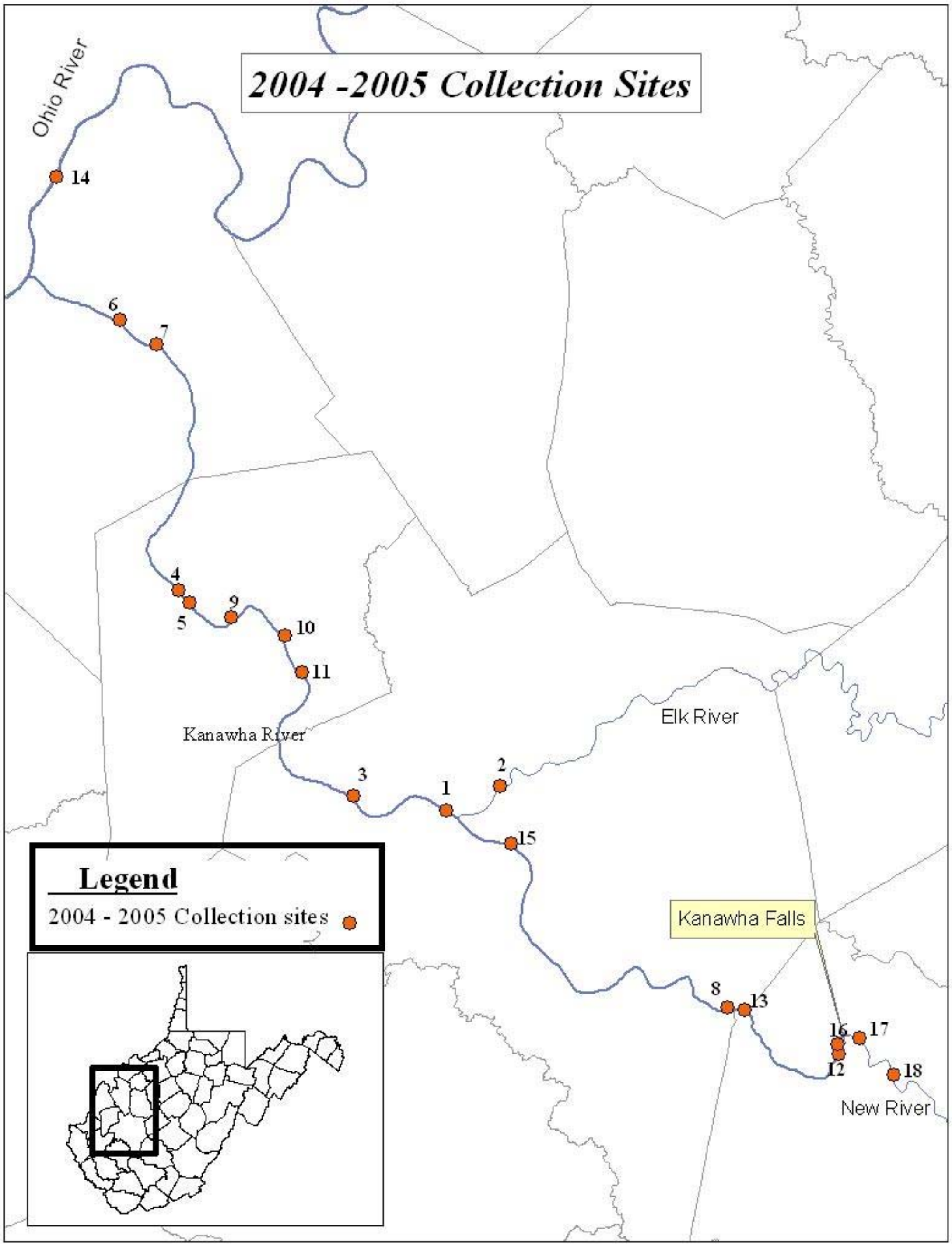


Figure 20. Crayfish collection sites along the Kanawha River West Virginia (2004 – 2005).

The results from the 18 collection sites are as follows: Two *O. virilis* (1, female; 1, Form I male) and ten *O. rusticus* (2, females; 5, Form I males; 3, Form II males) were collected from site one on the Kanawha River. There were six *O. sanbornii* (3, females; 3 Form I males) collected from site two upstream in the Elk River. Also a single *O. rusticus* form one male and one *O. virilis* female was collected. Three *O. virilis* (2, females; 1, Form I male) and two *O. rusticus* (1, female; 1, Form II male) were collected near a boat ramp along the Kanawha River at site three. Four *O. rusticus* form one males were collected on the Kanawha River at site 4. Six *O. rusticus* (3, females; 3, Form I males) were collected from site five on the Kanawha River. Eight *O. rusticus* (3, females; 4, Form I males; 1, juvenile) were collected from the Kanawha River at site 6. There were five *O. rusticus* (3, females; 2, Form I males) captured at site 7 on the Kanawha River. Three *O. rusticus* (1, female; 2, Form I males) were collected on the Kanawha River from site 8. Six *O. rusticus* (2, females; 1, Form II male; 3, juveniles) were collected from site 9 on the Kanawha River. Six *O. rusticus* (2, females; 2, Form I males; 1, Form II male; 1, juvenile) were collected from site ten on the Kanawha River. A singe female *O. rusticus* was collected along the Kanawha River at site 11. Three crayfishes were collected from site 12 on the Kanawha River. Two first form male *O. rusticus* and a single female *O. virilis* was collected. Two *O. rusticus* (1, female; 1 Form I male) were collected from site 13 on the Kanawha River. A single first form male *O. rusticus* was captured at site 14 on the Ohio River near the Gaven Power Plant. Two *O. rusticus* (1, female; 1, Form I male) were collected on the Kanawha River at site 15. Site 16 crayfish collections from just below Kanawha Falls resulted in the collection of four species. A single *O. virilis* second form male was collected. A single female *O. cristavarius* was collected. Two female *Cambarus robustus* were collected. Fourteen *O. rusticus* (5, females; 9, Form II males) were collected. Two sites above Kanawha Falls in the New River were sampled for crayfish. Four *O. virilis* (3, females; 1 Form II male) were collected from site 17. Sixteen crayfish were collected from site 18. Eleven were *O. virilis* (6, females; 2, Form I males; 3, Form II males) while five were identified as *C. sciotensis* (3, females; 1, Form I male; 1, Form II male).

The density seine collection results from the three Hurricane Creek are as follows (Figure 21-23): Reach one from site one resulted in a total collection of 17 crayfish. *C. b. cavatus* (1 second form male), *C. robustus* (6 females; 1 Form II male), *O. sanbornii* (1, inberry female; 7, Form II males), and *O. virilis* (1, Form I male) made up the species composition. The eletrofishing method resulted in the collection of 14 specimens while kick method yielded 8 individuals. Reach two from site one resulted in a total of 42 crayfish. The species that were collected include *C. robustus* (13, females; 7, Form II males) and *O. sanbornii* (3, females, 2, Form I males; 17, Form II males). A total of 16 crayfish were collected by electrofishing method while 26 were collected from the kick method. Reach three from site 1 resulted in the collection of 17 crayfishes. The two species collected were *C. robustus* (2 females; 1 Form II male) and *O. sanbornii* (5, females with one being inberry; 9, Form II males). The electrofishing method resulted in the collection of five crayfish while kick method returned 12 individuals.

Reach one from site two yielded 14 crayfishes. Three female *C. robustus*, four *O. virilis* (1 female with young; 1, Form I male; 2, second form males), and seven *O. sanbornii* (4 females [2 inberry]; 1, Form I male; 2, Form II males) were collected. Nine crayfish were collected by the kick method and 5 were from the electrofishing technique. Reach two from site two yielded 16 specimens. Eight crayfish were collected by electrofishing, and eight

Figure 21. Crayfish density study Site 1 on Hurricane Creek, Putnam County, West Virginia

Figure 22. Crayfish density study Site 2 on Hurricane Creek, Putam County, West Virginia

Figure 23. Crayfish density study Site 3 on Hurricane Creek, Putnam County, West Virginia

were collected using the kick method. Three *C. robustus* females, ten *O. sanbornii* (4 females [2 inberry]; 1, Form I male; 5 Form II males) and three *O. virilis* (2, Form I males; 1, Form II male) specimens were collected. Reach three from site two yielded six *O. sanbornii* (2, females; 4, Form II males) and a single second form male *O. virilis*. Two crayfish were collected by kick method while the remaining five were collected by electrofishing method.

Reach one from site three on hurricane creek yielded eight crayfish. A single *C. robustus* inberry female was collected and seven *O. sanbornii* (1, female; 6, Form II males). Reach two from site three yielded four crayfish. Three *O. sanbornii* (1, female; 1, Form I male; 1, Form II male), and a single *C. thomai* second form male was collected. Two specimens were collected by kick method while two were collected by electrofishing. The *C. thomai* was flushed from an undercut bank by electrofishing. Reach three from site three resulted in a single female *C. robustus* and 16 *O. sanbornii* (6, females; 1, Form I male; 9, Form II males) collections. Eight crayfish were collected by electrofishing method while 9 were collected by kick method.

Sixty-three crayfish were collected from diving collection methods in the mainstem of the Kanawha River. The mainstem surveys yielded a single second form male *O. virilis* and while all other collections were *O. rusticus* (44, females; 18, Form II males). *Orconectes rusticus* had a mean carapace length of 23.04 mm and a mean weight of 3.334 grams. This data was collected by various methods and combinations of methods. A frequency of carapace lengths of *O. rusticus* from the Kanawha River ranged from 20 to 30 mm. Age one *O. rusticus* typically range between 23 to 36 mm (Taylor and Schuster, 2004). This might suggest that *O. rusticus* does not get as large in the large riverine environment as they do in lentic environments. It also suggests that the majority of the crayfish in the river are in the 1 to 2 year age class.

4.4 Discussion

Prior to our collections, the distribution of *O. virilis* from the New/Kanawha River drainage was only known directly below Bluestone Dam in Hinton, WV (Jezerinac, et al. 1995). *Orconectes rusticus* appeared to be restricted to a single collection site from Black Betsy, West Virginia along the Kanawha River. Also, an established population was recorded from Beech Fork Lake (Wayne County, WV) and Four Pole creek in Huntington (Jezerinac, et al., 1995).

From this study, we have a new view on the current distribution of *O. rusticus* and *O. virilis* from the New/Kanawha drainage. The data from the initial 18 sites along the Kanawha River suggested *O. rusticus* and *O. virilis* were the most abundant species present, and aside from the collections in tributaries just below Kanawha Falls they were the only species present in the mainstem Kanawha. We initially expected *O. virilis* to be abundant in the Kanawha mainstem based on prior knowledge of historical data from the New River. Further investigation using sampling methods assessing the actual channel of the river concluded that *O. rusticus* was the dominate species present in the Kanawha River. *Orconectes virilis* was only found along the river banks near boat ramps, areas heavily fished, backwater areas, and mouths of tributaries flowing into the Kanawha River. The abundance of *O. virilis* in these shallow habitats makes them more likely to be caught as bait and transferred by fisherman. The sample sites along the river that appeared to be heavily fished had a high occurrence of *O. virilis*. We believe that *O. rusticus* is out competing *O. virilis*, but due to a constant reintroduction of *O. virilis* to heavily fished areas, they remain.

The eighteen sites along the Kanawha River yielded 111 crayfish of 6 species within two genera. The most abundant species was *O. rusticus*, which comprised 66 percent of all collections with a total collection of 73 individuals. *Orconectes rusticus* was collected from all sites visited on the Kanawha River during this survey. *Orconectes virilis* composed 21 percent of the collection (n = 23), most of which were collected upstream of Kanawha Falls. *Orconectes sanbornii* composed 5 percent (n = 6) of collections, all of which were collected in the Elk River. One specimen of *O. cristavarius* was collected directly below Kanawha Falls. *Orconectes cristavarus* is native to the New River and was rarely collected upstream in the NRGNR (Chapter II) where *O. virilis* is the dominate orconectid species.

Three *Cambarus robustus* individuals were collected below Kanawha Falls. Five specimens of *C. sciotensis* were collected from the New River just above Kanawha Falls. *Cambarus sciotensis* is common in the upper New River and appears restricted to above the fall. The barrier idea was acknowledged by Jezerinac et al. (1995) in that it appeared *C. robustus* was found primarily below Kanawha Falls which acted as a natural barrier for the species. Naturally, it would be expected that Kanawha Falls would be a barrier to *O. rusticus* given the current data on its distribution from only below the falls; however with bait bucket introductions as common as they appear, it will likely overcome this natural barrier. With *O. rusticus* being a more dominate crayfish species then *O. virilis* (Capelli 1982); it could easily reach the New River Gorge National River and alter the current crayfish community.

Orconectes virilis and *O. rusticus* were both collected upstream in the Elk River near Mink Shoals along with *O. sanbornii*. The Upper Elk River drainage is also inhabited by the Elk River Crayfish (*Cambarus elkensis*). This is an endemic species only found in the Slaty Fork, Upper Elk River drainage of West Virginia. Currently there is no real threat to this area from invasive crayfishes, though if either species (*O. virilis* or *O. rusticus*) continues their advancement up the Elk River there may be some concern in the future. The Elk River is an extremely popular fishing location and increased transfer of bait could speed up the process of expansion.

Many anglers I have spoken to have no idea about non-native crayfish or the problem with transferring bait to other streams. Some fisherman I observed had collected bait from a stream near their home and traveled up to 20 miles to use as bait in the New River. I have observed anglers catching bait in small streams in northeastern West Virginia that were planning on using the crayfish in the Shenandoah River. All of the crayfish they had in their possession were *O. virilis*. Many fisherman who use crayfish around the Huntington area use Fourpole creek as their preferred source, due to ease of access and the abundance of crayfish (*O. rusticus*). *Orconectes rusticus* appears to be displacing the native *O. sanbornii* in Fourpole Creek. During an educational survey completed in 2003 of fourpole creek, no native *O. sanbornii* were collected, and only two *C. b. cavatus* were found. The crayfish community was dominated by *O. rusticus*. This species also was collected in the surrounding tributaries and continues to be the dominate species in Beech Fork Reservoir, which is believed to be a bait-bucket introduction (Jezerinac et al. 1995).

Other populations of *O. virilis* and *O. rusticus* within the state have been identified recently. Areas of Stonewall Jackson Lake in West Virginia have *O. virilis* as the dominate species. In the lake, *O. virilis* is taking on a secondary burrowing role, digging into the clay banks due to the lack of rocky shoreline and structure. One large female *O. virilis* was burrowed 2 feet horizontally into the clay bank. *Orconectes virilis* was also collected from 70 feet in deep in Summersville Lake (collected by Dr. Tom Jones, Marshall University). I collected *O. rusticus* from Barbourville Lake (2007) while conducting research on freshwater mussels. *Orconectes virilis* also was collected during a fish culvert project completed in 2003 in Hurricane Creek, Putnam County. We recently re-sampled three streams in the Hurricane creek watershed. The data confirmed *O. rusticus* was absent from each of the samples, however *O. virilis* was present at sites 1 and 2, although the majority of specimens collected were *O. sanbornii* (n = 93).

4.5 Sampling Technique Discussion

Over the past few years we have also discovered that sampling bank habitat and easy access spots such as boat ramps, bridge pull offs, tributary mouths, and backwater areas do not effectively characterize the crayfish community of the water body. We began using traditional collection methods to sample shallow water bank collections and used snorkeling equipment to collect crayfish near rocky out crops and structures on the banks. We then placed minnow traps in the Kanawha River. The traps were baited and placed in areas that we believed to be optimal areas for crayfish (large rocks, debris, structures, etc.). We caught crayfish, but the time that went into placing the traps and returning to the traps the next day was not feasible. Also we hand collected in areas where traps had been deployed and we could catch more crayfish by hand in the time it took to use the traps.

Seining was used to estimate species density and composition from small streams, however we wanted to explore methods to assess similar parameters in a large river setting. The use of a large floating turbidity fence seemed like a possible option. The idea was to use it as a barrier to seclude a section of river bank. Then using multiple pass depletions with different collection methods we hoped to find the most efficient method to collect crayfish from large river bank habitats. This could only be used in shallow waters and this was before we had observed the abundance of specimens in the deeper portion of the channel. We spent considerable efforts to use the floating turbidity fence but its size and weight made it near impossible to manipulate. This method was quickly abandoned and other methods were implemented.

The use of SCUBA to collect crayfish was something that we had conducted many times during other aquatic surveys (i.e. freshwater mussel surveys). Hand collection underwater can be challenging given the conditions. Visibility, flow, depth, substrate composition, and experience all play a role in the efficiency of collecting crayfish underwater by hand. Mesh bags with draw strings were used to contain crayfish while diving, however while placing a new specimen in the bag another would escape. We tried using wide mouth bottles to keep our collections in. The bottles were preferred over the bags in most instances. A screw on cap and the rigid bottle allowed less effort to find the opening and less of a chance for a crayfish to escape. We dove 100-meter (328-ft) transects perpendicular to flow from the bank while searching for crayfish one meter on each side of the rope line. We realized that because substrate composition is linear with stream flow we were moving in and out of habitat types.

At some of our sites we observed all the crayfish in a one meter swipe of substrate while the rest of the river bottom was sand or sometimes even bedrock. We then decided to try sampling using pivot searches. This technique allowed us to sample similar habitat or substrate. Pivot searches were preferred over the perpendicular transects because of the reduced time. The problems we found with using a pivot search was that in low flow situations, which are very common in sections of the Ohio and Kanawha Rivers, fine sediments get stirred up on the bottom making visibility near zero. Collections could still be completed, but we estimated that our CPUE efficiency decreased. When diving in low visibility conditions the current aids the diver as to where they are in position to the riverbank and the anchor. This method did work and was considered a viable option because we had a known area to search and in good conditions we felt confident in our results.

To quantitatively sampling the river bottom the Ultra-Surber sampler was created. A 1 meter square framed sampler was used to sample crayfish and other organisms on the bottom of the river. The mesh sides kept most of the fleeing crayfish from escaping. This finally provided the best way to sample the bottom quantitatively. In conjunction with the Ultra-Surber, a unique transect array was also built to aid in the systematic sampling of large river crayfishes. This transect array gave us the ability to deploy it at a centroid point into known habitat or substrate types from tow behind sonar data. Unlike the pivot searches we could begin to sample and compare transect collections to square meter surber samples. Each 10 meter transect was searched for crayfish, while and Ultra-Surber samples were completed at the ends of each transect. This resulted in 4 square meters of quantitative sampling area per deployment. With the transect array we had the ability to classify substrate composition at each transect and determine the reliability of our side scan sonar data.

The final method described in the methods section was the use of a Missouri modified benthic trawl. While doing research on the Ohio and Kanawha river darter community, crayfish were caught as by-catch in the nets. The crayfish along with macroinvertebrates, snails, mussels, and other aquatic organisms were regularly caught in the net. The majority of our trawling was completed during the daytime hours, and since we believed crayfish to be most active at night, we concluded that trawling at night might be an effective way to assess crayfishes in large rivers. After completing 5 pools on the Ohio River and a few pools on the Kanawha River we concluded that the number of crayfish we were catching was not sufficient to continue with trawling as a viable crayfish collection method.

Continued trial and error using a combination of the methods described above will eventually result in an acceptable protocol for sampling crayfish in large rivers. Collections from Pittsburgh, Pennsylvania to Cairo, Illinois (981 miles) on the Ohio River were completed during the summer of 2007. Many of the methods described were used in conjunction with this trip. The results suggest *O. obscurus* is the dominant crayfish species from Pittsburg PA, to Marietta, Ohio where a shift in species composition moves toward *O. rusticus.* From Marietta south to below Newport, Indiana the dominant species appears to be *O. rusticus*. Once the river reaches the Smithland Pool another shift occurs that seems to bring in three additional species including *O. placidus, O. pardolotus,* and *C. rusticiformis*.

5.0 Appendix A: New River Gorge National River Crayfish Study Data

Site	Date	County	Location	UTMN	UTME
1	7/19/2005	Fayette	Co Rd 25	4199733	492971
2	8/13/2005	Fayette	Co Rd 82 Road side spring	4213511	493494
3	8/13/2005	Fayette	Co Rd 82 Road side spring	4213300	492686
4	8/13/2005	Fayette	Co Rd 82 Road side ditch	4212686	492770
5	8/13/2005	Fayette	Co Rd 82 Road side ditch	4212519	492827
6	8/2/2005	Fayette	Co Rd 82 near rafting outfiters	4214069	491789
7	8/2/2005	Fayette	Co Rd 82 near rafting outfiters	4213992	491556
8	10/14/2005	Fayette	Bank of Bracken Creek	4213787	508251
9	9/30/2005	Fayette	Co Rd 9	4210456	491340
10	9/30/2005	Fayette	Co Rd 9	4207127	495200
11	9/30/2005	Fayette	Co Rd 9	4206890	495432
12	9/30/2005	Fayette	Co Rd 9 unnamed stream	4206623	495613
13	10/4/2005	Raleigh	Co Rd 26	4179481	506300
14	10/4/2005	Raleigh	Co Rd 26 below waterfall	4180737	509027
15	10/4/2005	Raleigh	Co Rd 26 around pond	4179695	505819
16	7/19/2005	Fayette	Co Rd 25	4196317	496984
17	7/19/2005	Fayette	Co Rd 25	4199523	492298

Table 6. NRGNR burrowing crayfish collection sites

SiteNumber	Date	County	Stream	Directions	NearestStream	Easting83	Northing83
1	6/14/2004	Fayette	Dunloup Creek		Dunloup Creek	493170	4200696
2	6/14/2004	Fayette	Dunloup Creek		Dunloup Creek	489764	4197831
3	6/14/2004	Summers	Trib New River	Below Bluestone Dam	New River	510252	4166052
4	6/15/2004	Raleigh	Fall Creek		Fall Creek	506579	4177707
5	6/15/2004	Raleigh	Kates Branch		Kates Branch	507758	4176209
6	6/15/2004	Summers	Meadow Creek		Meadow Creek	506907	4184364
7	6/15/2004	Summers	Lick Creek		Lick Creek	509428	4181245
8	6/15/2004	Summers	Owens Branch		Owens Branch	509542	4175002
9	6/15/2004	Summers	Brooks Branch		Brooks Branch	509797	4173575
10	6/16/2004	Raleigh	Sewell Branch		Sewell Branch	505223	4182921
11	6/16/2004	Raleigh	Pinch Creek		Pinch Creek	499139	4178625
13	6/16/2004	Fayette	Laurel Creek		Laurel Creek	496038	4189405
14	6/16/2004	Fayette	Coal Run		Coal Run	497778	4206566
15	6/17/2004	Fayette	Wolf Creek		Wolf Creek	492905	4213032
16	6/17/2004	Fayette	Marr Branch		Marr Branch	491559	4213979
17	4/17/2004	Fayette	Fern Creek		Fern Creek	495125	4212707
18	4/17/2004	Fayette	Short Creek		Short Creek	497739	4212645
19	4/17/2004	Fayette	Keeney Creek		Keeney Creek	498812	4209606
20	4/18/2004	Fayette	Floyd Creek		Floyd Creek	505127	4205528
22	7/12/2004	Raleigh	New River	Below Brooks Falls	New River	509158	4175417
23	7/13/2004	Raleigh	New River	Below Sandstone Falls	New River	509020	4179441
24	7/23/2004	Summers	New River	Below Bluestone Dam	New River	510234	4166284
25	7/22/2004	Raleigh	Glade Creek		Glade Creek	499117	4186693
27	10/15/2004	Fayette	House Creek		House Creek	491169	4211363
28	10/15/2004	Fayette	Trib Marr Branch		Marr Branch	490219	4213704
30	10/15/2004	Raleigh	Piney Creek		Piney Creek	491679	4188673
31	10/15/2004	Fayette	Laurel Creek		Laurel Creek	500587	4189975
32	10/15/2004	Fayette	Slater Creek		Slater Creek	497419	4194146
39	10/15/2004	Fayette	Un-Named Creek	Co Rd 9, just east of Gatewood	Coal Run	495410	4206926

Table 7. NRGNR stream crayfish collection sites

SiteNumber	Stream	CPUE_VALUE	Habitat_Score_Total	WVSCI_Benthos_Score	Organisms_per_Sq_m_(WVSCI)
17	Fern Creek	2.36	145	71.1	636.67
28	Trib Marr Branch	3.636	101	32.98	6725
31	Laurel Creek	4.09	167	84.8	1085
23	New River	5	138	78.82	311.76
4	Fall Creek	5	144	78.35	331.82
11	Pinch Creek	7.105	144	85.67	570.59
30	Piney Creek	7.5	153	67.83	602.94
32	Slater Creek	7.5	141	83.85	360
1	Dunloup Creek	7.5	140	65.78	662.5
6	Meadow Creek	8.18	154	75.21	2280
7	Lick Creek	10	140	77.76	1166.67
2	Dunloup Creek	10.5	145	59.97	3216.67
9	Brooks Branch	13.5	61	18.71	294.44
16	Marr Branch	15	101	32.98	6725
19	Keeney Creek	15	176	77.24	1100
15	Wolf Creek	15	139	40.71	1875
13	Laurel Creek	19.28	146	75.1	950
20	Floyd Creek	26.66	108	53.94	32
25	Glade Creek	30	184	87.44	1485.71

Table 8. West Virginia Department of Environmental Protection Agency (WVDEP) stream quality data at selected NRGNR crayfish collection sites.

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
281	8	Orconectes virilis	Female		29.91	14.61	9.84	1.14	6.58	3.49	8.29	2.78	17.7	10.56	4.12	6.18	3.44	5	4			5.9	1	2	
282	8	Orconectes virilis	Female																						Juv
283	9	Orconectes virilis	Female		50.05	23.95	17.11	1.34	10.66	5.49	13.42	5.46										24.7	3	2	
284	22	Orconectes virilis	Male	Form II	52.86	26.27	17.98	2.34	12.36	5.88	14.78	3.77	50.52	38.99	10.2	16.82	9.67	6	4	22.96	9.25	38.9	2	2	
285	22	Orconectes virilis	Male	Form II																					Juv
286	22	Orconectes virilis	Male	Form II																					Juv
287	22	Orconectes virilis	Male	Form II																					Juv
288	22	Orconectes virilis	Female																						Juv
289	23	Orconectes virilis	Male	Form II	35.62	16.97	11.71	1.51	8.39	4.45	9.91	3.18	25.57	16.06	6.41	10.14	5.79	6	5	14.36	6.68	11.2	1	1	
290	23	Orconectes virilis	Male	Form I	42.46	20.99	14.24	1.18	9.99	4.83	12.57	4.41	31.77	21.3	8.71	13.79	8.15	7	6	17.68	7.54	19.9	1	1	
291	24	Orconectes virilis	Female		38.71	19.46	12.82	0.97	8.81	4.47	10.52	3.73	27.72	18.15	7.43	11.96	7.15	6	5			14.4	1	1	
292	24	Orconectes virilis	Male	Form I	40.3	19.78	13.32	19.75	9.5	4.97	10.83	3.55			8.55	13.46	7.78	6	6	15.62	8.47	14.6	3	2	
293	24	Orconectes virilis	Female		43.03	21.9	14.4	1.7	9.85	5.3	11.15	3.52										16.4	3	2	
294	24	Orconectes virilis	Female		35.83	17.24	11.93	1.19	8.24	4.66	10.16	3.78	22.23	14.12	6.51	8.8	5.11	6	5			9.9	1	1	
295	24	Orconectes virilis	Female		31.22	15.69	10.07	1.39	7.15	3.85	9.14	3.14	18.33	11.85	5.08	7.41	4.08	6	5			7.7	1	1	
296	24	Orconectes virilis	Male	Form II	23.62	12.23	7.96	0.75	5.28	2.84	7.01	1.86	13.38	9.26	4.64	5.29	3.09	6	6	8.1	4.72	3.2	1	1	
297	24	Orconectes virilis	Male	Form II	24.27	11.75	7.28	1.53	5.89	2.2	7.69	2.71	14.03	8.78	4.38	5.5	2.82	6	5	7.85	3.94	3	1	1	Recently Molted
298	24	Orconectes virilis	Female																				1	1	Juv
299	24	Orconectes virilis	Female																				1	1	Juv

* 1 = normal chela; 2= regenerated chlea; 3 = chela absent

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
261	1	Orconectes virilis	Female		45.73	22.21	15.2	1.18	10.27	5.03	12.8	4.24	28.91	19.57	7.43	11.28	6.72	3	3			19.2	2	3	
262	3	Orconectes virilis	Female		55.3	30.03	20.44	0.93	12.65	7.39	12.65	2.62	38.43	31.72	9.94	15.38	8.4	5	4			40.9	3	2	
263	3	Orconectes virilis	Female		55.03	27.4	19.91	1	11.94	5.76	13.26	3.8										33.8	3	3	
264	3	Orconectes virilis	Female		35.97	18.31	11.73	1.04	8.35	4.23	9.81	3.78	23.25	14.94	7.02	9.74	5.89	7	5			9.7	1	1	
265	3	Orconectes virilis	Female		34.98	16.71	11.16	1.41	8.44	4.18	10.02	3.21	16.66	13.49	4.73	6.98	3.72	5	4			9	1	1	
266	3	Orconectes virilis	Female		25.77	12.28	8.44	0.76	6.02	3.06	7.28	2.35										3.7	3	3	
267	3	Orconectes virilis	Female		23.98	11.09	7.8	0.84	5.74	2.66	6.92	2.27	13.19	8.58	4.38	4.66	2.85	7	5			2.6	1	1	
268	3	Orconectes virilis	Female		22.95	10.46	7.69	0.99	5.35	2.66	6.48	2.21	11.24	6.87	4.02	4.45	2.55	6	5			2.7	1	1	
269	3	Orconectes virilis	Male	Form II		17.54	12.15	1.04	8.23	3.45			23.82	15.85	7.34	10.32	6.33	6	5	14.24	6.24	11	1	1	rostrum damaged
270	3	Orconectes virilis	Male	Form II	29.12	14.24	9.56	0.96	6.84	3.44	7.77	2.85								12.13	5.23	5.2	3	3	
271	3	Orconectes virilis	Female		31.03	15.1	10.33	1.57	7.33	3.71	9.06	2.93										6.4	3	3	Recently Molted
272	4	Orconectes virilis	Female		51.06	28.8	18.11	1.76	11.42	5.65	11.85	2.32										30.4	2	2	
273	4	Orconectes virilis	Male	Form II	42.4	20.22	14.8	1.33	9.63	5.21	10	2.42								16.71	7.66	15.5	2	3	
274	4	Orconectes virilis	Female		44.35	22.74	15.27	1.43	10.82	5.53	11.16	3.78	34.67	22.88	9.41	14.57	8.31	5	4			24.1	1	1	
275	4	Orconectes virilis	Female																				1	1	Recently Molted
276	4	Orconectes virilis	Male	Form II	35.11	16.63	11.6	1.65	7.36	3.42	9.04	3.27	23.32	13.86	6.34	9.4	5.18	5	4	11.79	6.82	9.7	1	1	
277	5	Orconectes virilis	Male	Form II	32.05	15.33	9.97	1.33	7.21	4	9.46	3.25	20.08	13.5	5.72	7.19	4.06	6	6	12.29	5.58	6.6	1	3	
278	8	Orconectes virilis	Male	Form II	32.06	15.49	10.71	1.26	7.22	3.78	8.57	2.77	20.26	12.57	5.99	8.25	4.76	6	5	12.12	5.36	7.9	1	1	
279	8	Orconectes virilis	Female		41.36	20.46	13.7	1.88	8.71	4.93	11.1	3.87	28.23	18.67	8.05	2.06	7.05	7	6			16.8	1	1	
280	8	Orconectes virilis	Female		34.79	16.8	11.7	1.05	7.82	4.19	9.1	3.02	23.1	14.99	6.42	9	4.95	6	6			9	1	2	

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
241	31	Cambarus sciotensis	Male	Form II	23.7	11.8	7.69	2.12	6.47	2.7	5.01	1.51	15.99	10.84	5.5	6.88	4.34	7	7			3.6	1	1	
242	31	Cambarus sciotensis	Female																				1	1	Carapace Damaged
243	31	Cambarus sciotensis	Male	Form II																			1	1	Juv
244	31	Cambarus sciotensis	Female																				1	1	Juv
245	31	Cambarus sciotensis	Male	Form II																			3	1	Juv
246	31	Cambarus sciotensis	Female																				1	1	Juv
247	1	Orconectes cristavarius	Female			13.24	9.37	1.47	7.14	3.69			14.31	8.41	5.39	5.78	3.69	6	5			5	1	2	Damaged Rostrum
248	1	Orconectes cristavarius	Male	Form II																			1	1	juv
249	2	Orconectes cristavarius	Female		22.01	9.85	6.77	1.63	5.54	2.8	6.95	2.88	10.12	5.54	4.16	3.85	2.47					2.3	1	1	
250	2	Orconectes cristavarius	Female		25.5	11.64	8.04	1.85	6.55	0.24	7.12	1.57	11.4	6.97	4.64	4.77	2.93					3.9	1	1	
251	2	Orconectes cristavarius	Male	Form II	26.02	10.93	8.46	1.95	5.8	3.19	8.86	3.47	15.11	9.7	6.06	6.14	3.54			9.89	6.17	3.4	1	1	
252	7	Orconectes cristavarius	Male	Form II	31.64	14.51	10.37	2.02	7.32	3.6	10.06	3.84	20.45	13.28	629	6.99	4.27	7	6	12.73	5.64	6.6	1	1	
253	7	Orconectes cristavarius	Male	Form II	29.44	13.4	9.1	2.12	6.57	351	9.92	3.93	19.08	10.71	6.62	7.16	4.18	8	8	11.54	4.67	5.3	1	1	
254	7	Orconectes cristavarius	Female		29.97	13.38	9.37	2.54	7.22	3.76	9.69	3.77	16.46	9.04	5.8	6.72	3.88	8	7			5.6	1	1	
255	7	Orconectes cristavarius	Female		2.97	13.19	8.98	1.97	7.01	3.78	9.77	3.72	15.66	8.72	6.6	6.51	3.89	9	8			4.9	1	2	
256	3	Orconectes sanbornii	Male	Form II	27.71	12.9	9.26	2.04	6.52	3.19	8.91	3.18	21.06	11.34	6.32	8.15	5.25	9	8	8.2	2.77	5.1	1	1	
257	3	Orconectes sanbornii	Male	Form II	22.77	10.62	7.65	1.24	5.58	2.76	7.48	2.97	16.48	9.26	5.62	6.24	4.1	9	8	7.13	2.33	2.9	1	1	
258	9	Orconectes sanbornii	Male	Form II																			3	1	juv
259	24	Orconectes sanbornii	Female		36.16	18.75	12.26	2.7	8.55	4.49	11.78	4.61	27.03	16.42	9.32	11.05	6.03	8	7			12.2	1	1	
260	24	Orconectes sanbornii	Female		31.5	14.89	0.97	2.13	7.27	3.79	9.66	3.98	22.14	11.76	7.27	9.18	5.69	8	8			8	1	1	

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
221	24	Cambarus sciotensis	Female		46.6	25.26	16.94	4.72	11.53	5.17	9.51	3.66	43.88	28.71	13.32	19.1	11.3	8	6			33.2	1	1	
222	24	Cambarus sciotensis	Male	Form I	36.96	19.83	13.88	3	8.62	3.82	7.61	2.58	41.63	23.5	11.77	16.26	9.98	6				16.2	1	2	
223	24	Cambarus sciotensis	Male	Form I	43.35	23.5	15.58	3.75	10.13	4.89	9.13	3.15	51.89	32.43	14.46	20.98	11.72	7	5			30.5	1	1	
224	24	Cambarus sciotensis	Male	Form I	39.48	20.56	13.52	3.44	9.67	4.75	8.75	2.82	44.26	24.67	13.17	18.43	10.36	7	4			18.3	1	2	
225	24	Cambarus sciotensis	Female		36.22	18.77	12.51	2.74	8.71	4.46	8.17	2.17	30.04	18.56	9.22	12.87	8.33	7	6			14.9	1	1	
226	24	Cambarus sciotensis	Male	Form I	31.18	16.88	10.59	2.12	7.91	3.89	7.29	2.05	29	18.71	9.46	12.42	7.7	6				11.4	1	1	
227	24	Cambarus sciotensis	Male	Form I	34.83	18.2	12.63	3.38	9.4	4.28	7.64	2.3	36.41	22.46	11.24	14.93	9.21	6	5			15.1	1	1	
228	24	Cambarus sciotensis	Male	Form I	30.84	16.06	1.25	2.66	7.94	3.71	6.95	2.6	26.08	15.66	8.12	10.54	6.68	6	6			8.6	1	1	
229	25	Cambarus sciotensis	Female		27.99	13.89	9.48	2.36	7.23	3.39	6.29	2.11	14.41	10.56	4.53	4.67	3.18	5				4.8	1	1	
230	25	Cambarus sciotensis	Male	Form II	33.33	17.06	11.61	2.83	8.61	4.2	7.2	2.19										7.9	2	2	
231	25	Cambarus sciotensis	Male	Form II	26.93	13.27	9.33	2.62	6.93	3.33	5.93	1.84	18.14	11.61	6.94	8.26	5.36	7				5.4	1	1	
232	25	Cambarus sciotensis	Female																				1	1	juv
233	30	Cambarus sciotensis	Male	Form II	27.84	14.35	9.68	3.3	7.39	3.36	6.69	1.47	19.85	13.08	5.61	8.17	5.04	5				6.5	1	1	
234	30	Cambarus sciotensis	Male	Form I	46.85	24.81	17.33	3.59	10.5	5.21	9.23	2.73	47.42	32.73	10.22	18.99	9.98	5	3			26.6	1	2	
235	30	Cambarus sciotensis	Male	Form I	41.14	21.26	14.25	3.98	10.45	5.09	9.47	2.76	34.26	26.22	7.8	13.73	7.12	4	2			20.5	2	2	
236	31	Cambarus sciotensis	Female		36.09	17.96	12.37	3.64	8.95	4.56	7.63	2.38	27.5	17.02	8.63	12.53	7.59	8	6			12.5	2	1	
237	31	Cambarus sciotensis	Male	Form II	35.44	17.5	11.37	4.42	9.11	4.37	7.12	2.18	27.12	18.31	8.27	12.17	7.32	7	6			13.1	1	1	
238	31	Cambarus sciotensis	Female		34.38	17.86	11.64	3.62	8.94	4.61	7.59	2.77	27.65	16.81	9.15	12.01	7.32	8				12.9	1	1	
239	31	Cambarus sciotensis	Female		28.73	14.74	10.01	3.83	7.31	3.57	5.96	1.94	19.84	11.87	6.96	9.18	5.71	6	5			6.9	1	1	
240	31	Cambarus sciotensis	Male	Form II	25.09	12.36	8.02	2.39	6.45	2.76	5.75	1.97	19.02	10.77	5.84	7.16	4.51	7				4.2	1	1	

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
201	22	Cambarus sciotensis	Male	Form II																					Juv
202	22	Cambarus sciotensis	Female																						Juv
203	22	Cambarus sciotensis	Female																						Juv
204	22	Cambarus sciotensis	Female																						Juv
205	22	Cambarus sciotensis	Female																						Juv
206	22	Cambarus sciotensis	Female																						Juv
207	23	Cambarus sciotensis	Female		47.35	24.2	16.82	4.52	12	5.26	10.56	2.99	43.13	33.13	9.2	14.39	7.76	6	5			28.8	1	1	
208	23	Cambarus sciotensis	Male	Form I	46.49	25	16.88	3.7	11.69	5.03	9.59	3.21	51.4	31.53	14.97	20.73	11.35	6	5			34.3	1	1	
209	23	Cambarus sciotensis	Male	Form I	41.78	20.59	14.72	3.21	10.38	5.13	9.38	2.77	42.61	28.9	9.18	14.64	8.14	4	3			20.9	1	1	
210	23	Cambarus sciotensis	Female		39.68	21.22	13.75	3.79	10.1	4.86	9.23	2.62	35.44	22.78	10.74	14.73	8.8	7	5			18.9	1	1	
211	23	Cambarus sciotensis	Female		39.01	20.51	13.94	4.37	10.03	4.35	8.18	2.32	36.02	22.39	11.18	14.96	9.19	8	6			19.2	1	1	
212	23	Cambarus sciotensis	Male	Form II	33.07	16.93	11.52	2.89	8.29	4.05	7.56	2.18	27.61	17.27	8.41	11.94	7.46	7	6			10.8	1	1	
213	23	Cambarus sciotensis	Female		27.59	14.16	9.56	2.56	7.37	3.32	6.45	1.58	20.72	12.65	6.76	8.95	5.73	8	6			6.7	1	1	
214	23	Cambarus sciotensis	Female		28.74	14.43	9.49	2.95	7.17	3.77	6.43	2.33	20.32	13.31	6.51	8.92	5.6	8	7			6.4	1	1	
215	23	Cambarus sciotensis	Male	Form I	43.86	23.31	16.13	4.36	11.74	4.94	9.08	2.63	52.45	28.96	16.64	19.9	11.97	8	6			31.3	1	1	
216	23	Cambarus sciotensis	Female		36.91	19.33	12.92	3.65	9.24	4.42	8.25	2.22	30.96	18.74	9.75	12.95	8.29	7	6			15.5	1	1	
217	24	Cambarus sciotensis	Male	Form II																			1	1	Juv
218	24	Cambarus sciotensis	Female																				1	1	Juv
219	24	Cambarus sciotensis	Male	Form II																			1	1	Juv
220	24	Cambarus sciotensis	Female																				1	3	Juv

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
181	13	Cambarus sciotensis	Female		26.47	13.07	9	3.38	6.83	3.23	6.51	2.45	18.91	12.09	6.07	7.68	5	7				5	1	1	
182	13	Cambarus sciotensis	Male	Form II	27.7	13.81	9.51	2.85	7.48	3.87	6.89	2.45	20.32	12.96	6.52	8.24	5.32	7				5.9	1	1	
183	13	Cambarus sciotensis	Female																				1	1	juv
184	13	Cambarus sciotensis	Female																				1	1	juv
185	14	Cambarus sciotensis	Male	Form II	23.93	11.58	0.83	2.92	6.43	3.39	5.28	1.94	17.07	10.07	5.75	7.27	4.62	5	0			3.7	1	1	
186	14	Cambarus sciotensis	Male	Form II	20.11	9.74	6.41	2.07	5.26	2.49	5.37	2.02	13.87	8.94	4.78	5.28	3.56	5	4			2	1	1	
187	14	Cambarus sciotensis	Male	Form II																			1	1	Juv
188	14	Cambarus sciotensis	Female																				1	1	Juv
189	14	Cambarus sciotensis	Female																				1	1	Juv
190	15	Cambarus sciotensis	Female		34.04	17.09	12.08	3.36	8.47	4.02	8.52	2.98	25.51	15.82	8.08	11.52	6.79	6	4			10.6	1	1	Recently Molted
191	15	Cambarus sciotensis	Male	Form II	36.6	19.83	12.85	3	9.12	4.17	7.81	2.1										10.5	3	1	Recently Molted
192	15	Cambarus sciotensis	Female		26.45	14.25	9.32	2.73	6.69	3.15	6.12	2.1	18.81	11.18	5.55	7.6	5.13	5	3			5.1	1	1	
193	15	Cambarus sciotensis	Male	Form II																			1	1	Recently Molted
194	15	Cambarus sciotensis	Female		23.98	11.42	8.06	2.31	6.44	3.38	6.64	2.19	14.67	9.82	5.23	6.42	4.21	6				3.6	1	1	
195	15	Cambarus sciotensis	Female		24.12	11.68	8.74	2.52	6.04	2.89	6.09	1.73	15.52	9.02	5.03	6.56	4.11	6	5			3.2	1	3	
196	15	Cambarus sciotensis	Male	Form II	26.07	12.65	9.21	2.62	6.68	3.32	5.93	1.94	17.87	11.14	5.87	7.68	5	5				4.9	1	1	
197	22	Cambarus sciotensis	Male	Form I	46.23	24.75	15.71	3.05	11.05	5.2	10.28	3.3	58.7	37.47	17.07	22.15	13.34	8	6			39.2	1	1	
198	22	Cambarus sciotensis	Male	Form I	43.01	23.39	15.5	3.73	11.57	4.5	8.82	2.28	51.03	31.22	15.07	20.55	11.79	7	5			29.1	1	1	
199	22	Cambarus sciotensis	Male	Form I	38.11	19.52	13.53	3.17	9.5	4.42	7.75	1.99	40.16	29.19	8.79	15.08	8.1	4	3			17.3	1	1	
200	22	Cambarus sciotensis	Male	Form I	36.29	19.56	13.31	3.82	9.09	4.24	7.65	2.06	39.69	23.47	11.5	15.59	9.3	7	6			16.8	1	1	

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
161	11	Cambarus sciotensis	Female		37.4	20.21	12.76	4.72	9.57	4.67	8.51	3.16	29.8	18.48	9.8	13.3	7.57	7				14.6	1	1	
162	11	Cambarus sciotensis	Male	Form II	29.51	14.37	9.77	3.07	7.42	3.66	7.12	2.29	22.33	13.82	6.81	9.83	5.77	7				6.8	1	1	
163	11	Cambarus sciotensis	Male	Form II	30.65	14.91	10.1	3.92	7.68	3.72	7.32	2.68	23.31	15.21	7.56	10.46	6.2	8				7.9	2	1	
164	11	Cambarus sciotensis	Male	Form II	27.27	13.86	9.1	3.56	6.85	3.43	6.23	2.46	19.43	11.56	6.66	8.83	5.31	6				5.5	1	1	
165	11	Cambarus sciotensis	Male	Form II	27.07	13.66	8.71	2.65	7.03	3.13	6.51	2.17	19.19	12.52	6.41	8.99	5.27	9				5.8	1	1	
166	11	Cambarus sciotensis	Female																				1	1	juv
167	11	Cambarus sciotensis	Female																				1	1	juv
168	11	Cambarus sciotensis	Female																				1	1	juv
169	11	Cambarus sciotensis	Male	Form II																			1	1	juv
170	11	Cambarus sciotensis	Male	Form II																			1	1	juv
171	11	Cambarus sciotensis	Male	Form II	30.17	15.23	10.51	2.97	7.49	3.51	6.9	2.77	22.6	14.9	7.22	9.36	5.85	5				7.4	2	1	
172	11	Cambarus sciotensis	Male	Form II	30.31	15.09	10.49	3.5	7.68	3.83	6.61	2.45	21.57	14.48	7	9.39	5.69	6				7.7	2	1	
173	11	Cambarus sciotensis	Male	Form II																			1	1	juv
174	11	Cambarus sciotensis	Male	Form II	27.94	13.78	9.57	3.37	7.25	3.57	6.64	2.46	18.03	12.47	6.15	8.15	4.8	5				5.4			
175	11	Cambarus sciotensis	Female		26.6	12.94	9.67	3.18	6.87	3.04	6.22	2.42	18.64	11.68	5.4	7.87	5.03	5				4.8	2	1	
176	11	Cambarus sciotensis	Male	Form II	26.23	12.5	8.56	2.57	6.68	3.3	6.52	1.99	15.99	10.86	5.56	7.51	4.66	6				4.2	1	1	
177	11	Cambarus sciotensis	Female																						Juv
178	13	Cambarus sciotensis	Female		4.3	24.66	16.51	4.06	10.79	5.6	9.06	2.57	41.74	28.39	12.74	17.78	10.62	8				30.1	1	1	
179	13	Cambarus sciotensis	Female		30.9	16.43	11.17	3.23	8.02	3.75	6.54	1.79	22.81	13.78	7.45	9.73	6.04	8				8.4	1	1	
180	13	Cambarus sciotensis	Female		25.33	13.12	8.01	2.81	6.65	3.35	5.43	2.15	17.11	10.4	5.1	7.52	4.75	7				4.7	1	1	

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
141	7	Cambarus sciotensis	Male	Form I	42.16	21.47	14.64	3.81	10.23	4.3	9.23	3.05	45.28	29.09	12.98	19.45	11.48	7				19	1	3	
142	7	Cambarus sciotensis	Male	Form II	31.81	16.04	10.71	2.54	8.08	4.35	6.99	2.15	25.44	16	7.99	10.77	6.65	6				9.5	1	1	
143	7	Cambarus sciotensis	Male	Form II	33.67	17.5	11.64	2.99	8.8	4.26	7.31	2.71	28.74	17.34	9.69	12.93	7.73	7				11.9	1	1	
144	7	Cambarus sciotensis	Female		37.63	20.58	13.1	3.57	9.57	4	7.62	2.51	32.99	22.05	10.37	1.21	8.15	7				15.7	2	1	
145	7	Cambarus sciotensis	Female		32.08	16.83	11.31	3.34	8.16	4.17	6.81	2.2	23.87	15.07	8.05	10.75	6.68	8				9.9	1	1	
146	7	Cambarus sciotensis	Female																				1	1	juv
147	7	Cambarus sciotensis	Female																				1	1	juv
148	7	Cambarus sciotensis	Male	Form II																			1	1	juv
149	7	Cambarus sciotensis	Female		37.35	19.74	13.01	4.47	9.31	4.77	8.19	2.36										18.2	2	2	inberry
150	8	Cambarus sciotensis	Female		36.67	18.84	13.37	2.6	8.35	4.13	7.55	2.42	31.78	20.29	10.31	13.12	8.21	7	4			15.4	1	1	
151	8	Cambarus sciotensis	Female		35.02	18.39	11.8	3.25	8.24	3.59	7.3	2.12	28.71	16.8	8.29	12.58	7.54	7				12.6	1	1	
152	8	Cambarus sciotensis	Male	Form I	33.43	17.47	11.52	3.53	8.17	3.92	7.76	2.29	29.7	19	9.37	13.15	7.97	7				12.4	1	1	
153	8	Cambarus sciotensis	Female																						Juv
154	9	Cambarus sciotensis	Female		40.15	21.35	13.97	5.09	10.47	5.36	8.66	2.91	33.41	23.61	10.65	15.64	9.25	7				20.5	2	1	
155	9	Cambarus sciotensis	Female		36.13	19.66	12.24	4.54	9.47	5.16	8.4	2.83										11.9	2	3	
156	9	Cambarus sciotensis	Male	Form II	34.76	18.05	12.36	4.19	8.99	4.85	7.03	2.72	28.88	17.78	8.16	12.46	7.43	7				11.5	1	1	
157	9	Cambarus sciotensis	Male	Form II	19.89	9.21	6.83	2.7	5.36	2.71	5.01	1.7	11.86	7.22	3.37	4.24	2.8	6				1.9	1	1	
158	9	Cambarus sciotensis	Male	Form II																					Juv
159	11	Cambarus sciotensis	Male	Form II	33.45	16.64	11.01	4.3	8.69	3.62	7.85	2.64	26.55	16.37	8.21	11.76	7.15	7				10	2	1	
160	11	Cambarus sciotensis	Female		35.76	17.91	12.11	4.27	9.25	4.46	8.1	2.73	29.59	19.83	8.97	13.26	7.77	8				13.5	1	1	

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
121	2	Cambarus sciotensis	Male	Form II	23.53	11.31	8.81	2.21	6.2	2.91	5.33	2.4	14.96	9.48	4.11	6	3.76	6				3.4	1	1	
122	4	Cambarus sciotensis	Female		35.08	18.72	11.94	3.11	9.06	4.61	7.31	2.48	28.73	18.51	9.95	13.49	8.01	7				13.4	2	1	
123	4	Cambarus sciotensis	Female		40.01	20.78	13	3.76	9.99	4.79	8.27	2.53										17.4	2	2	
124	4	Cambarus sciotensis	Male	Form I	33.09	17.47	11.19	4.1	8.21	4.16	7.26	2.76	26.43	16.59	8.58	11.47	7.3	6	5			10.5	1	1	
125	4	Cambarus sciotensis	Female																						Juv
126	4	Cambarus sciotensis	Female																						Juv
127	4	Cambarus sciotensis	Female																						Juv
128	4	Cambarus sciotensis	Female																						Juv
129	5	Cambarus sciotensis	Female		35.42	18.42	12.83	3.72	8.84	3.64	7.24	2.84	26.84	17.88	8.95	11.99	6.88	7				13.3	1	1	
130	5	Cambarus sciotensis	Female																						Juv
131	5	Cambarus sciotensis	Female																						Juv
132	6	Cambarus sciotensis	Male	Form I	46.93	24.6	17.12	4.61	11.65	5.41	10.12	2.98	53.17	32.12	15.93	23.32	12.78	7	6			39.1	1	1	
133	6	Cambarus sciotensis	Female		37.77	20.08	12.86	3.34	9.81	4.75	8.08	2.27	32.57	19.78	11.13	14.47	8.74	8	6			17.1	1	1	
134	6	Cambarus sciotensis	Female																						Juv
135	6	Cambarus sciotensis	Female																						Juv
136	6	Cambarus sciotensis	Female																						Juv
137	6	Cambarus sciotensis	Female																						Juv
138	6	Cambarus sciotensis	Female																						Juv
139	7	Cambarus sciotensis	Male	Form I		19.98	13.05	3.72	9.68	4.03			35.76	25.47	8.25	14.36	7.81	7				14.9	1	2	
140	7	Cambarus sciotensis	Male	Form I	34.21	18.07	12.46	3.84	9.47	4.66	7.06	1.91	33.06	20.6	10.54	14.85	8.35	5	4			12.6	2	1	

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
101	39	Cambarus bartonii carinirostris	Male	Form I	38.09	19.18	13.77	2.58	9.18	4.6	6.14	1.77	35.38	21.33	9.68	15.15	9.04	4				17.1	1	1	
102	39	Cambarus bartonii carinirostris	Male	Form I	43.17	22.9	15.9	3.51	10.67	5.27	7.07	2.18	41.85	27.13	10.07	17.12	9.91	6				25.6	1	1	
103	39	Cambarus bartonii carinirostris	Male	Form I	34.74	17.95	12.95	2.61	8.58	4.67	6.52	1.95	28.57	19.59	6.97	11.22	6	5				12.1	1	1	
104	39	Cambarus bartonii carinirostris	Female		26.9	13.69	9.06	2.64	6.92	3.85	5.38	1.97	17.46	12.61	5.88	8.56	5.51	5				5.8	1	1	
105	39	Cambarus bartonii carinirostris	Male	Form II																			1	1	Juv
106	39	Cambarus bartonii carinirostris	Male	Form II																			1	3	Juv
107	27	Cambarus bartonii cavatus	Male	Form II	25.51	13.13	9.16	1.2	6.49	3.57	6.16	1.63	15.98	9.8	5.79	7.13	5.04	4	5			4.6	1	1	
108	27	Cambarus bartonii cavatus	Male	Form II	25.23	11.9	9.13	1.92	6.06	3.08	5.93	1.64	14.86	8.56	5.23	6.92	4.72	5				4.2	1	1	
109	27	Cambarus bartonii cavatus	Male	Form II	28.16	14.02	9.33	1.63	6.56	3.43	6.36	1.56	17.22	10.46	5.4	8.01	5.11	5	4			5.5	1	1	
110	27	Cambarus bartonii cavatus	Male	Form II																					juv
111	27	Cambarus bartonii cavatus	Female																						juv
112	27	Cambarus bartonii cavatus	Female																						juv
113	1	Cambarus sciotensis	Male	Form I	39.58	21.46	14.18	3.25	9.79	4.55	8.73	2.26	44.01	28.18	13.12	16.79	10.01	7	6			22.2	1	1	
114	1	Cambarus sciotensis	Female		34.06	17.63	11.8	3.56	8.25	3.58	7.47	2.65	27.99	17.05	9.28	11.59	7.63	7	6			10.3	1	3	
115	1	Cambarus sciotensis	Female		24.13	11.78	7.67	2.39	5.99	2.54	6.06	1.78	15.72	9.47	5.8	6.44	4.18	7	7			3.4	1	1	
116	1	Cambarus sciotensis	Male	Form II	26.57	13.05	8.5	2.28	6.3	3.34	6.4	2.11	16.58	10.54	6.16	7.61	4.93	8	7			4.8	1	1	
117	1	Cambarus sciotensis	Male	Form II	29.74	14.45	9.64	3.41	7.44	3.37	7.12	2.36	21.63	13.19	7.16	9.27	5.79	8	7			6.4	1	1	
118	1	Cambarus sciotensis	Female																				1	3	juv
119	1	Cambarus sciotensis	Female																				1	3	juv
120	1	Cambarus sciotensis	Female																				1	1	juv

ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
81	19	Cambarus bartonii carinirostris	Female																				1	1	juv
82	19	Cambarus bartonii carinirostris	Female																				1	1	juv
83	19	Cambarus bartonii carinirostris	Female																				1	1	juv
84	20	Cambarus bartonii carinirostris	Female		38.07	19.64	14.02	2.89	9.44	5.15	6.89	1.83	28.5	18.58	9.35	13.86	8.59	7				17	1	1	
85	20	Cambarus bartonii carinirostris	Male	Form II	34.7	17.84	12.82	2.56	8.46	4.5	7.27	2.14	24.4	14.07	8.31	11.51	7.29	6				11	1	1	
86	20	Cambarus bartonii carinirostris	Male	Form II	22.68	10.89	7.9	2.22	5.69	2.98	5.3	1.08	13.12	8.27	5.32	6.45	4.04	6				3.1	1	1	
87	28	Cambarus bartonii carinirostris	Female		34.95	17.38	12.65	2.95	8.61	4.13	6.98	1.86	25.59	16.16	8.15	11.75	7.09	7				12.2	1	1	
88	28	Cambarus bartonii carinirostris	Male	Form I	32.17	16.66	11.39	3.01	8.11	4.21	5.97	1.73	24.85	16.49	7.79	11.69	7.33	7				10.4	1	1	
89	28	Cambarus bartonii carinirostris	Female		31.24	16.27	10.95	2.61	7.68	4.2	6.07	1.92	20.59	13.82	6.72	10.39	6.8	6				9.1	1	1	
90	28	Cambarus bartonii carinirostris	Male	Form II	31.7	16.18	11.44	2.7	7.2	3.88	5.38	1.62	21.6	14.79	6.71	10.52	6.69	5	4			8.9	1	1	
91	28	Cambarus bartonii carinirostris	Female		31.29	15.65	10.57	2.4	7.38	4.01	6.31	1.43										7.2	2	3	
92	28	Cambarus bartonii carinirostris	Female		30.06	15.1	10.64	2.85	7.74	3.58	6.5	1.86	20.23	13.75	6.4	10.01	6.24	6				7.3	1	1	
93	28	Cambarus bartonii carinirostris	Male	Form II	23.38	10.97	8.06	3.17	6.08	3.13	5.82	1.76	14.69	9.73	4.3	6.48	4.29	5				3.3	1	1	
94	28	Cambarus bartonii carinirostris	Female																				3	1	Juv
95	28	Cambarus bartonii carinirostris	Male																				1	1	Juv
96	28	Cambarus bartonii carinirostris	Female																				1	1	Juv
97	28	Cambarus bartonii carinirostris	Female																				3	1	Juv
98	30	Cambarus bartonii carinirostris	Male	Form II	30.87	16.15	11.28	2.28	7.89	4.08	6.18	1.92	19.61	15.34	5.7	9.05	5.62	5				7.5	1	3	
99	32	Cambarus bartonii carinirostris	Female																						
100	32	Cambarus bartonii carinirostris	Female																						

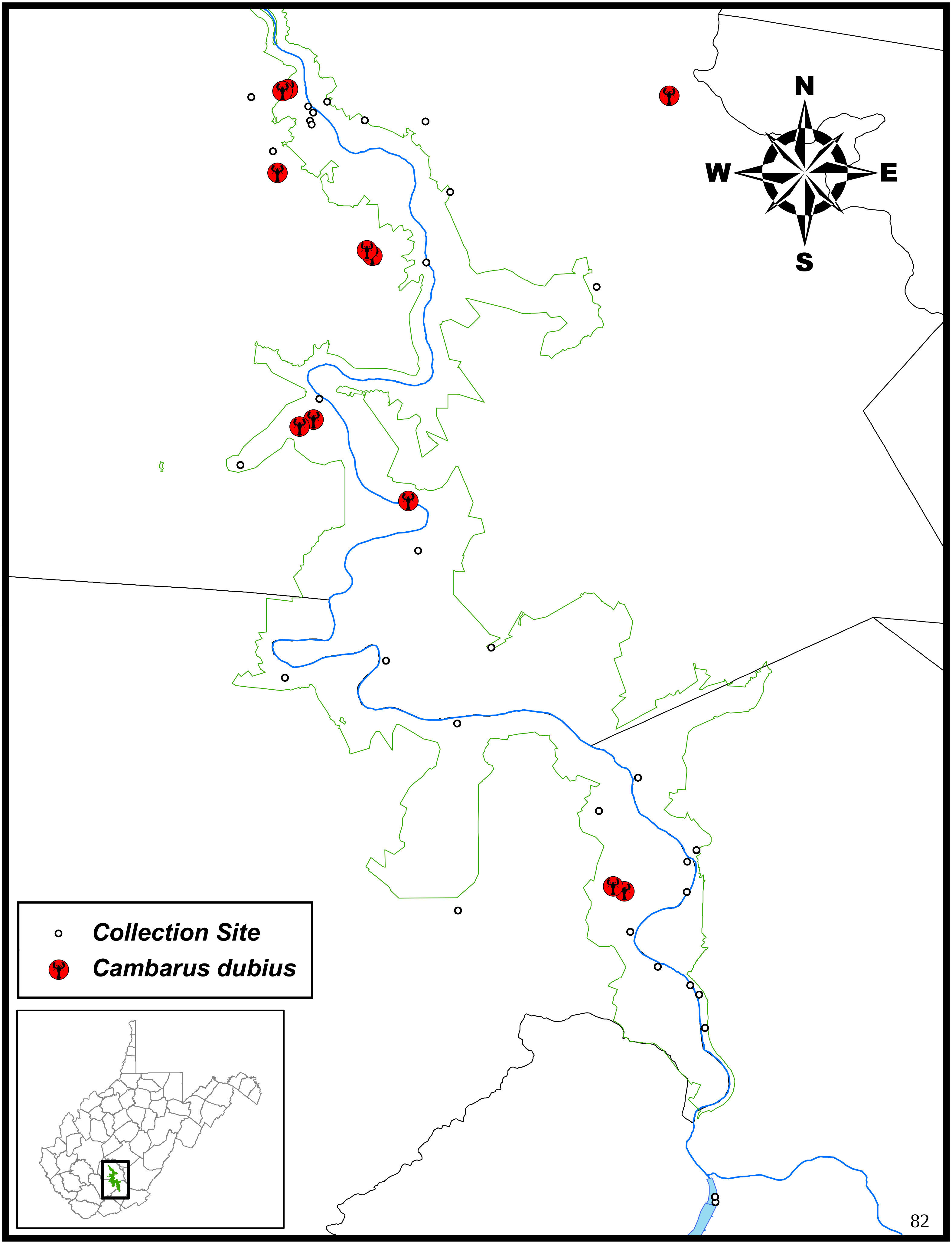
ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
61	17	Cambarus bartonii carinirostris	Male	Form II																					Juv
62	17	Cambarus bartonii carinirostris	Female																						Juv
63	17	Cambarus bartonii carinirostris	Female																						Juv
64	17	Cambarus bartonii carinirostris	Female																						Juv
65	17	Cambarus bartonii carinirostris	Female																						Juv
66	17	Cambarus bartonii carinirostris	Female																						Juv
67	17	Cambarus bartonii carinirostris	Male	Form II	26.28	12.36	9.45	2.68	6.36	3.47	6.12	2.25	15.93	9.58	5.15	7.19	4.65	6	0			4.4	1	1	
68	17	Cambarus bartonii carinirostris	Male	Form II	23.13	10.95	8.08	2.12	6.09	3.27	5.21	1.65	13.56	8.54	4.76	5.62	3.83	7	0			3	1	1	
69	17	Cambarus bartonii carinirostris	Female		25.55	12.01	8.57	2.32	6.44	3.09	5.82	1.73	15.61	9.24	4.85	6.94	4.5	5	0			4.2	1	1	
70	17	Cambarus bartonii carinirostris	Female		27.72	13.47	9.71	2.28	7.08	3.85	6.43	1.89	15.83	10.27	5.25	7.23	4.75	5	0			5.6	1	1	
71	17	Cambarus bartonii carinirostris	Female		25.23	11.61	8.9	2.73	6.64	3.4	5.88	2.25	15.05	9.85	5.26	6.53	4.36	6	0			3.6	1	1	
72	17	Cambarus bartonii carinirostris	Female		24.22	11.56	8.4	2.23	6.63	3.55	6.28	1.83	13.14	8.94	4.4	6.03	4	5	0			3.5	1	1	
73	18	Cambarus bartonii carinirostris	Female		37.4	19.67	14.15	3.13	8.89	5.41	7.18	2.42	24.48	16.8	8.09	13.27	8.12	5				15.2	1	1	
74	18	Cambarus bartonii carinirostris	Female		23.67	12.1	8.18	2.04	6.11	3.33	4.84	1.15	13.45	8.44	4.64	6.45	4.21	5				3.6	1	1	
75	18	Cambarus bartonii carinirostris	Male	Form II	23.88	11.87	8.5	2.41	6.13	3.33	5.05	1.68	15.22	8.7	5.09	6.4	4.09					3.6	1	1	
76	19	Cambarus bartonii carinirostris	Male	Form I	36.05	17.6	13.26	2.96	8.62	4.72	6.78	2.37	30.65	21.77	8.57	12.72	7.68	5				14.5	1	1	
77	19	Cambarus bartonii carinirostris	Female		33.75	16.25	11.88	2.82	8.86	4.64	7	1.87	22.66	14.6	8.32	11.15	6.99	5				11.1	1	1	
78	19	Cambarus bartonii carinirostris	Male	Form I	32.54	16.77	11.8	2.92	8.44	4.44	7.35	2.37	26.28	17.44	7.49	11.97	7.5	6				10.5	1	1	
79	19	Cambarus bartonii carinirostris	Male	Form II	27.32	13.65	9.34	2.41	7.25	3.57	6.23	1.71	18.49	11.66	6.56	8.63	5.54	7				5.6	1	1	
80	19	Cambarus bartonii carinirostris	Female		25.67	12.08	8.65	2.08	6.53	3.79	5.52	1.69	17.1	10.52	6.16	7.75	5.12	5				4.6	1	1	

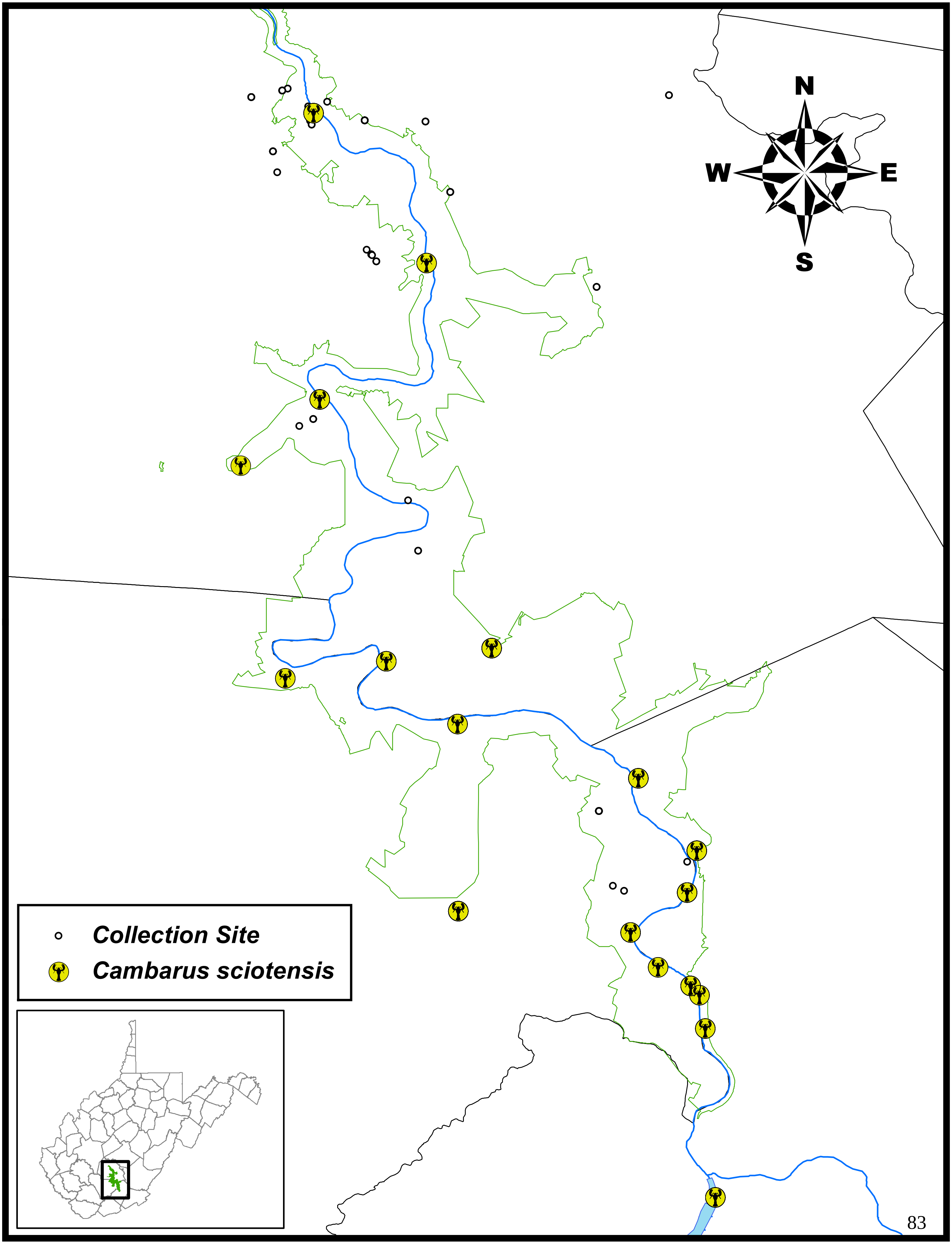
ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
41	14	Cambarus bartonii carinirostris	Male	Form II																			1	3	Juv
42	14	Cambarus bartonii carinirostris	Female																				3	1	Juv
43	14	Cambarus bartonii carinirostris	Male	Form II																			1	1	Juv
44	14	Cambarus bartonii carinirostris	Female																				1	1	Juv
45	16	Cambarus bartonii carinirostris	Female		35.07	18.26	12.78	3.22	8.79	4.5	6.62	1.86	22.27	14.4	6	10.75	6.92	6	4			13.1	1	1	
46	16	Cambarus bartonii carinirostris	Male	Form I	39.22	20.76	14.71	3.6	9.43	4.65	7.12	1.82	31.85	18.2	9.92	14.73	8.73	7	4			17.4	1	1	
47	16	Cambarus bartonii carinirostris	Male	Form I	40.49	21.36	15.37	2.54	9.87	4.91	8.19	1.93	31.41	20.82	9.44	14.99	9.13	7	3			19.3	1	1	
48	16	Cambarus bartonii carinirostris	Male	Form II																					Juv
49	16	Cambarus bartonii carinirostris	Male	Form II																					Juv
50	16	Cambarus bartonii carinirostris	Male	Form II																					Juv
51	16	Cambarus bartonii carinirostris	Male	Form II																					Juv
52	16	Cambarus bartonii carinirostris	Female																						Juv
53	16	Cambarus bartonii carinirostris	Female																						Juv
54	17	Cambarus bartonii carinirostris	Female		38.56	19.64	14.12	3.85	9.54	4.69	7.65	1.95	30.2	18.7	9.02	13.57	8.57	8	0			16.9	1	1	
55	17	Cambarus bartonii carinirostris	Female		41.9	21.27	15.92	3.4	9.93	5.07	8.18	2.05	31.2	21.15	8.5	13.08	7.9	6	0			19.6	1	1	
56	17	Cambarus bartonii carinirostris	Female		36.14	18.06	13.32	3.45	8.5	4.63	7.22	2.5	24.32	15.47	7.58	11.53	7.36	8	0			12.8	1	1	
57	17	Cambarus bartonii carinirostris	Female		38.2	19.41	13.85	2.9	8.99	4.82	7.68	2.91	26.89	17.72	9.3	12.94	8.1	7	0			16	1	1	
58	17	Cambarus bartonii carinirostris	Male	Form I	43.91	22.11	16.52	3.47	10.58	5.79	8.55	2.57	38.02	25.06	10.25	17.31	10.04	6	0			25.6	1	1	
59	17	Cambarus bartonii carinirostris	Male	Form I	38.97	20.7	14.54	4.07	9.35	4.81	7.69	2.49	32.33	20.9	9.94	14.67	9.04	5	0			16.4	1	1	
60	17	Cambarus bartonii carinirostris	Male	Form II																					Juv

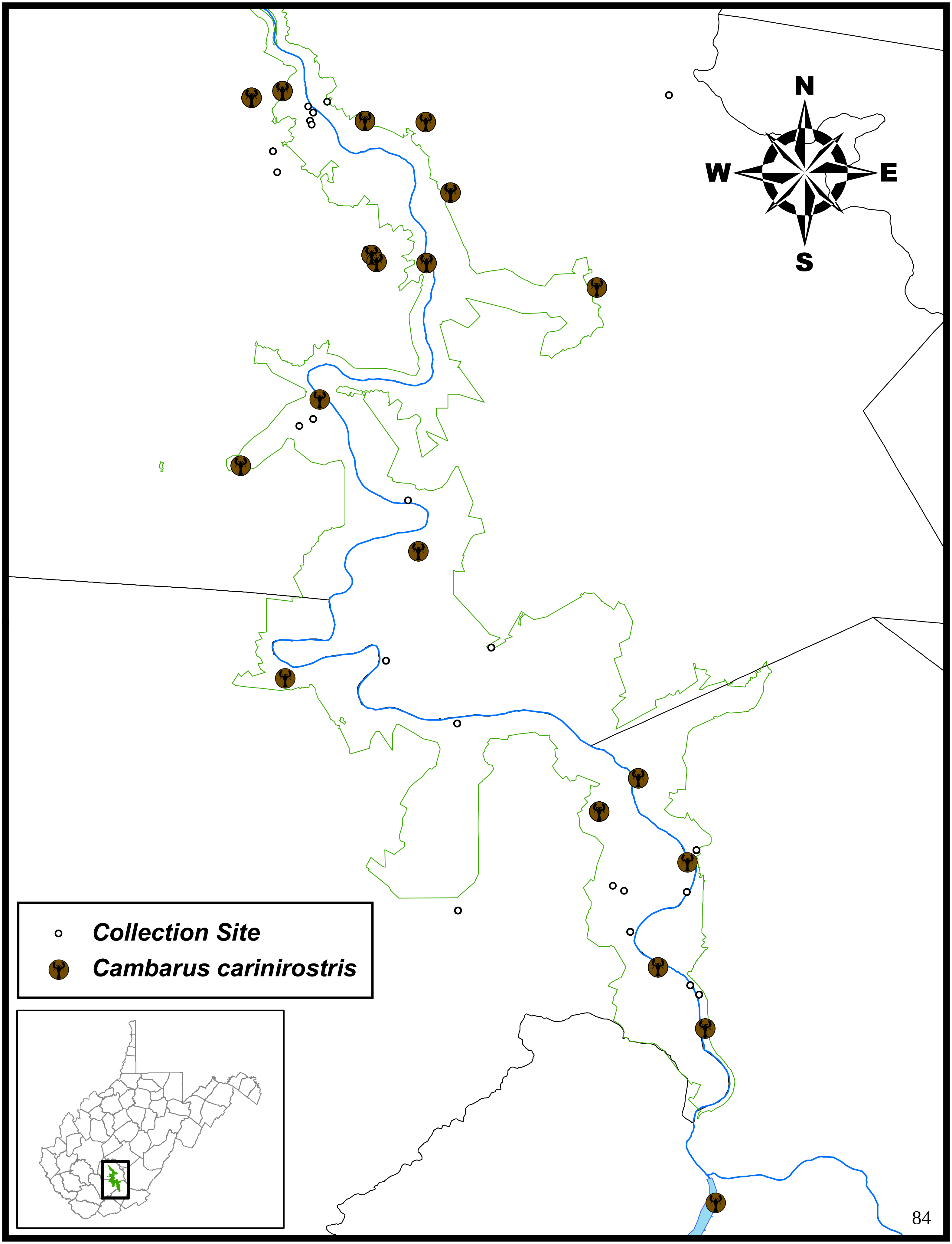
ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
21	10	Cambarus bartonii carinirostris	Female		3.82	18.47	13.39	3.29	9.04	5.02	6.91	2.51										13.3	2	2	
22	10	Cambarus bartonii carinirostris	Female		29.39	14.83	11.01	2.99	7.64	3.99	6.08	1.34	20.85	12.58	6.53	9.73	6.06	5				7.5	2	1	
23	10	Cambarus bartonii carinirostris	Male		34.27	16.92	12.83	2.86	8.55	4.3	6.48	2.2	21.26	15.53	5.5	9.3	5.54	4				10.6	1	1	
24	10	Cambarus bartonii carinirostris	Male		30.31	15.04	10.91	2.63	7.77	4.19	6.21	1.92	18.68	13.74	4.78	8.18	4.93	5				7.9	1	1	
25	10	Cambarus bartonii carinirostris	Male		26.54	12.35	9.16	2.87	7.22	3.62	4.84	1.81	17.64	10.91	5.45	7.65	4.8	6				4.7	1	1	
26	10	Cambarus bartonii carinirostris	Male	Form II																					Juv
27	10	Cambarus bartonii carinirostris	Male	Form II																					Juv
28	10	Cambarus bartonii carinirostris	Male	Form II																					Juv
29	10	Cambarus bartonii carinirostris	Female																						Juv
30	10	Cambarus bartonii carinirostris	Female																						Juv
31	10	Cambarus bartonii carinirostris	Female																						Juv
32	10	Cambarus bartonii carinirostris	Female																						Juv
33	10	Cambarus bartonii carinirostris	Female																						Juv
34	10	Cambarus bartonii carinirostris	Female																						Juv
35	10	Cambarus bartonii carinirostris	Female																						Juv
36	14	Cambarus bartonii carinirostris	Male	Form II	36.93	19.25	13.7	3.13	9.07	5.06	7.26	1.83	31.52	19.41	8.99	14.19	8.86	6	0			13.7	1	1	
37	14	Cambarus bartonii carinirostris	Male	Form II																			1	1	Juv
38	14	Cambarus bartonii carinirostris	Female																				1	1	Juv
39	14	Cambarus bartonii carinirostris	Female																				1	1	Juv
40	14	Cambarus bartonii carinirostris	Female																				1	2	Juv

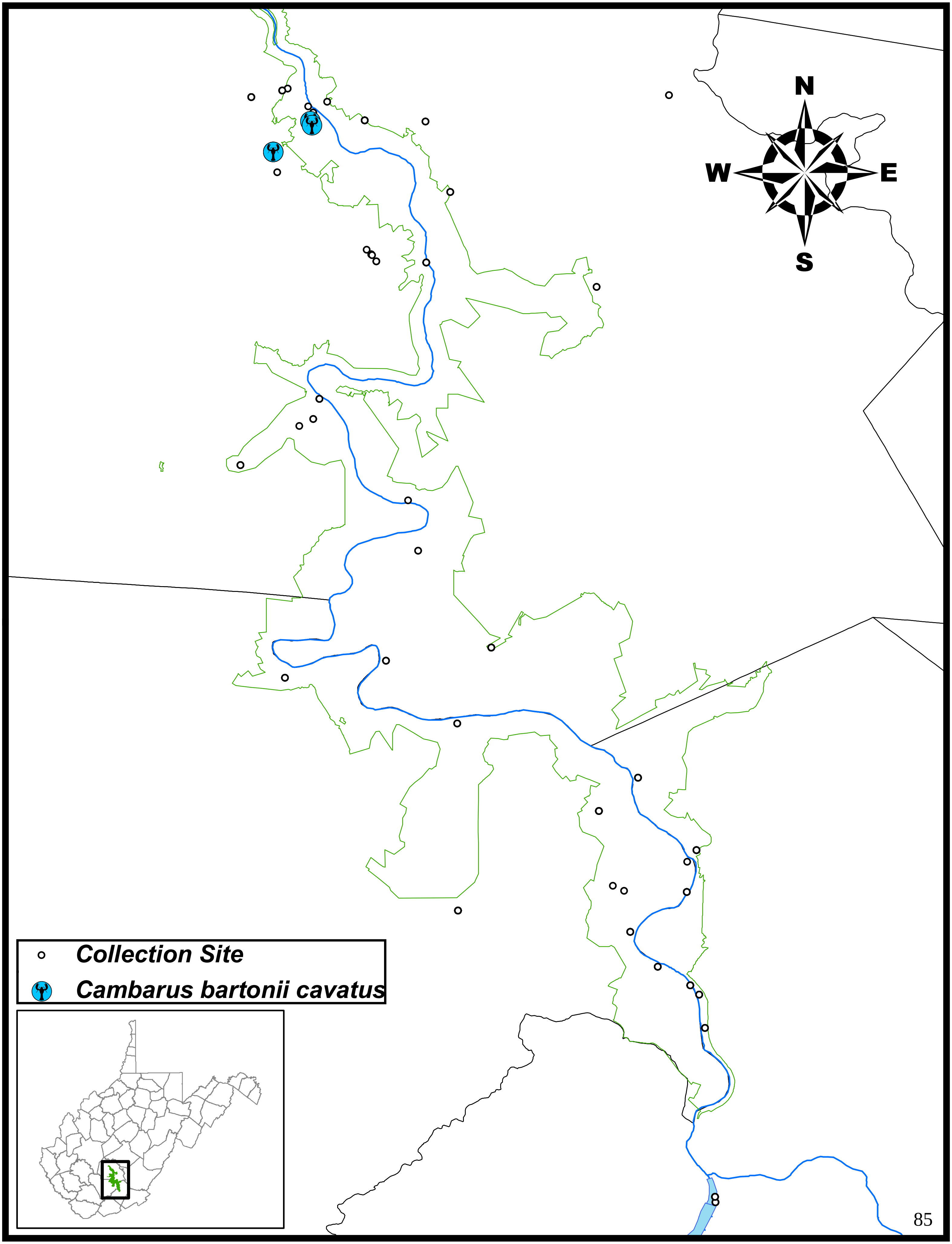
ID	Site	Species	Gender	Reproductive Condition	Carapace Length	Carapace Width	Areola Length	Areola Width	Postorbital Width	Rostral Width	Rostral Length	Acumen Length	Chela Length	Dactyl Length	Palm Length	Chela Width	Chela Thickness	Tubericals Mesial	Tubercles Dorsolateral	Gonopod Length	Mesial Process Length	Weight (g)	*Right Chela	*Left Chela	Comments
1	1	Cambarus bartonii carinirostris	Female																				2	2	juv
2	2	Cambarus bartonii carinirostris	Female		29.01	13.87	10.9	2.3	6.87	3.81	6.51	2.39	17.09	11.51	5.38	7.76	5.14	5				5.9	1	1	
3	2	Cambarus bartonii carinirostris	Male	Form II	31.55	15.65	11.37	2.79	7.92	4.08	6.53	2.15	20.11	14.8	6.23	8.95	5.84	6				8.5	1	1	
4	2	Cambarus bartonii carinirostris	Female		27.73	14.02	9.9	2.7	7.32	3.51	5.9	2.71	15.06	10.29	6.39	8.08	5.15	6				6	1	1	
5	2	Cambarus bartonii carinirostris	Female		28.59	14.05	9.6	3.02	7.52	4.23	6.36	2.24	18.36	11.79	6	8.12	5.23	6				5.9	1	3	
6	3	Cambarus bartonii carinirostris	Male	Form II	27.3	13.89	9.91	1.67	7.21	3.53	5.56		17.5	12.83	4.37	7.76	4.98	4				6	1	1	
7	5	Cambarus bartonii carinirostris	Female		26.78	13.54	9.36	2.48	7.08	3.28	5.34	1.59	18.76	11.99	5.71	8.31	5.44	7				5.7	1	1	
8	5	Cambarus bartonii carinirostris	Male	Form II																		1.6	1	1	juv
9	5	Cambarus bartonii carinirostris	Female																						Juv
10	5	Cambarus bartonii carinirostris	Female																						Juv
11	6	Cambarus bartonii carinirostris	Female		36.57	19.01	13.44	2.81	9.65	4.83	6.59	1.78	27.95	18.04	8.69	13.42	7.85	6	5			14.7	1	1	
12	6	Cambarus bartonii carinirostris	Female																						Juv
13	6	Cambarus bartonii carinirostris	Female																						Juv
14	6	Cambarus bartonii carinirostris	Female																						Juv
15	9	Cambarus bartonii carinirostris	Female		31.04	16.06	10.95	2.24	8.18	3.86	6.18	1.48	23.65	15.05	7.21	11	6.69	6				9.4	1	1	
16	9	Cambarus bartonii carinirostris	Female		20.66	10.24	7.3	2.01	5.71	2.94	4.63	1.77	12.78	7.63	3.5	5.57	3.57	7				2.6	1	1	
17	9	Cambarus bartonii carinirostris	Male	Form II																					Juv
18	10	Cambarus bartonii carinirostris	Female		33.07	16.79	11.97	3.4	8.22	4.5	6.2	1.86	21.46	15.55	5.47	9.42	5.44	5				10.2	1	1	
19	10	Cambarus bartonii carinirostris	Female		30.6	15.52	11.43	2.77	8.18	3.83	5.09	1.54	19.76	14	5.24	8.78	5.55	4				8.2	1	1	
20	10	Cambarus bartonii carinirostris	Female		34.97	17.23	13.26	3.52	9.2	5.04	6.6	1.79	26.35	17.14	8.16	12.36	7.73	5				12.5	1	1	

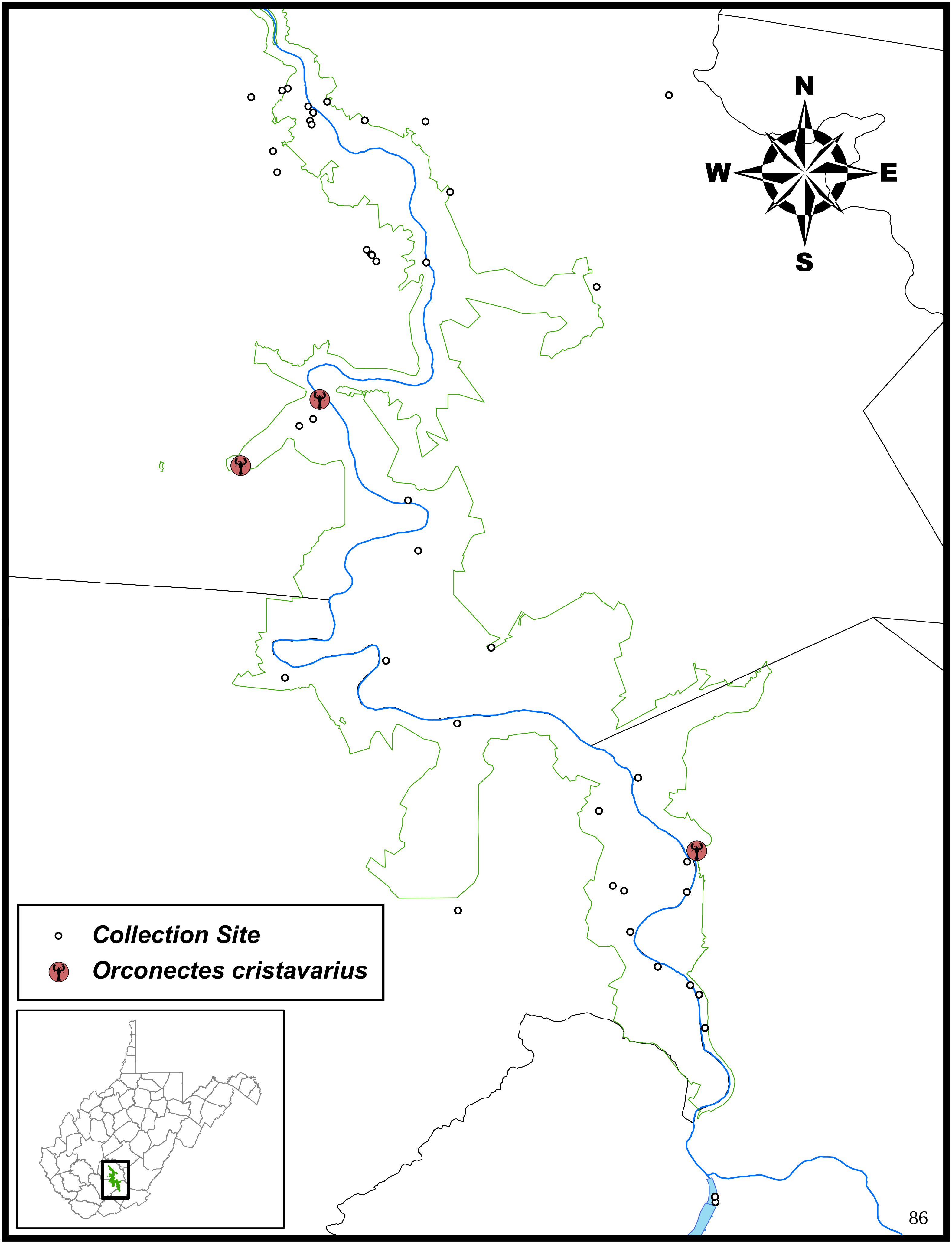
6.0 Appendix B: New River Gorge National River Crayfish Species Distribution Maps

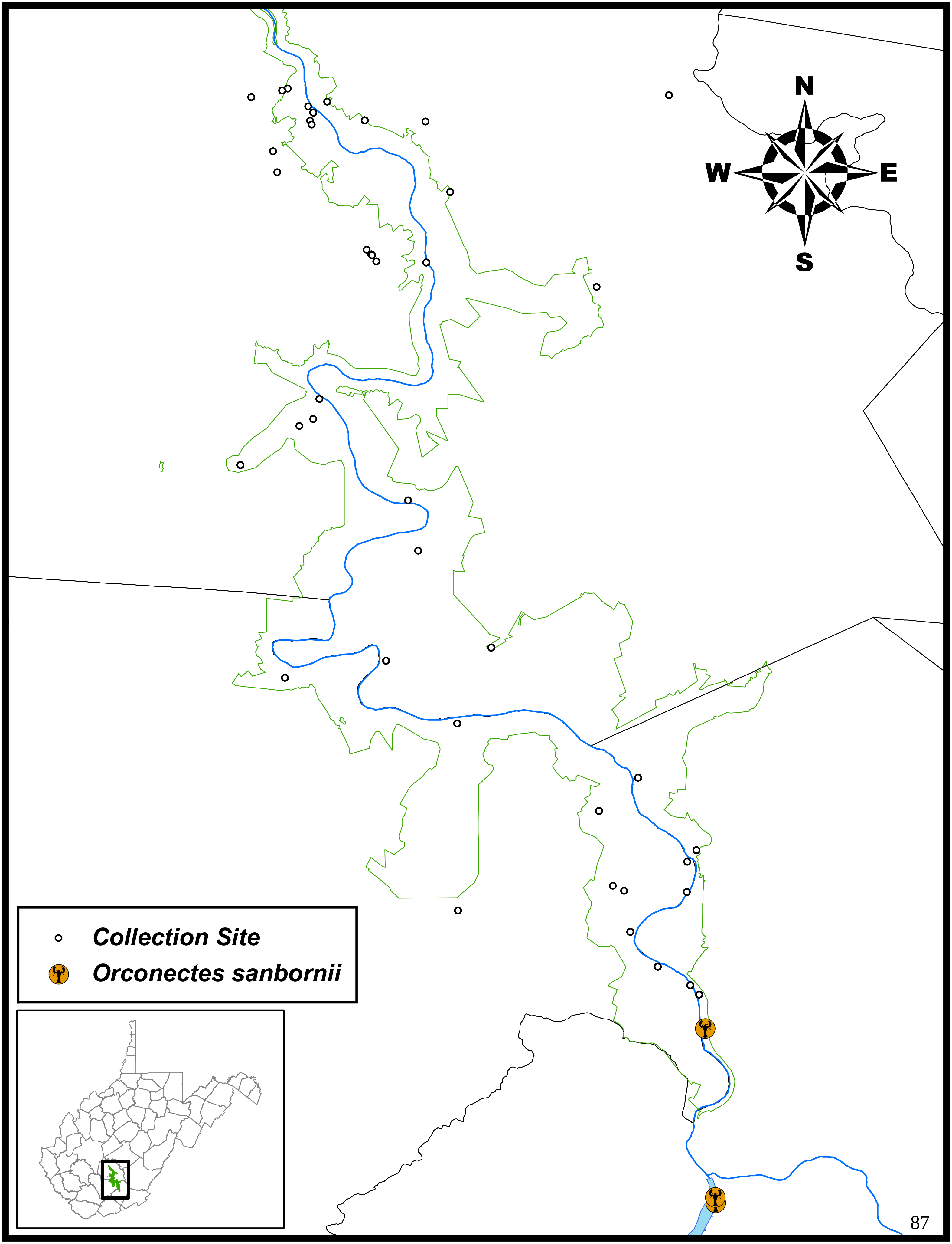

N
W
E
S
Collection Site
Cambarus dubius


N
W
E
S
Collection Site
Cambarus sciotensis

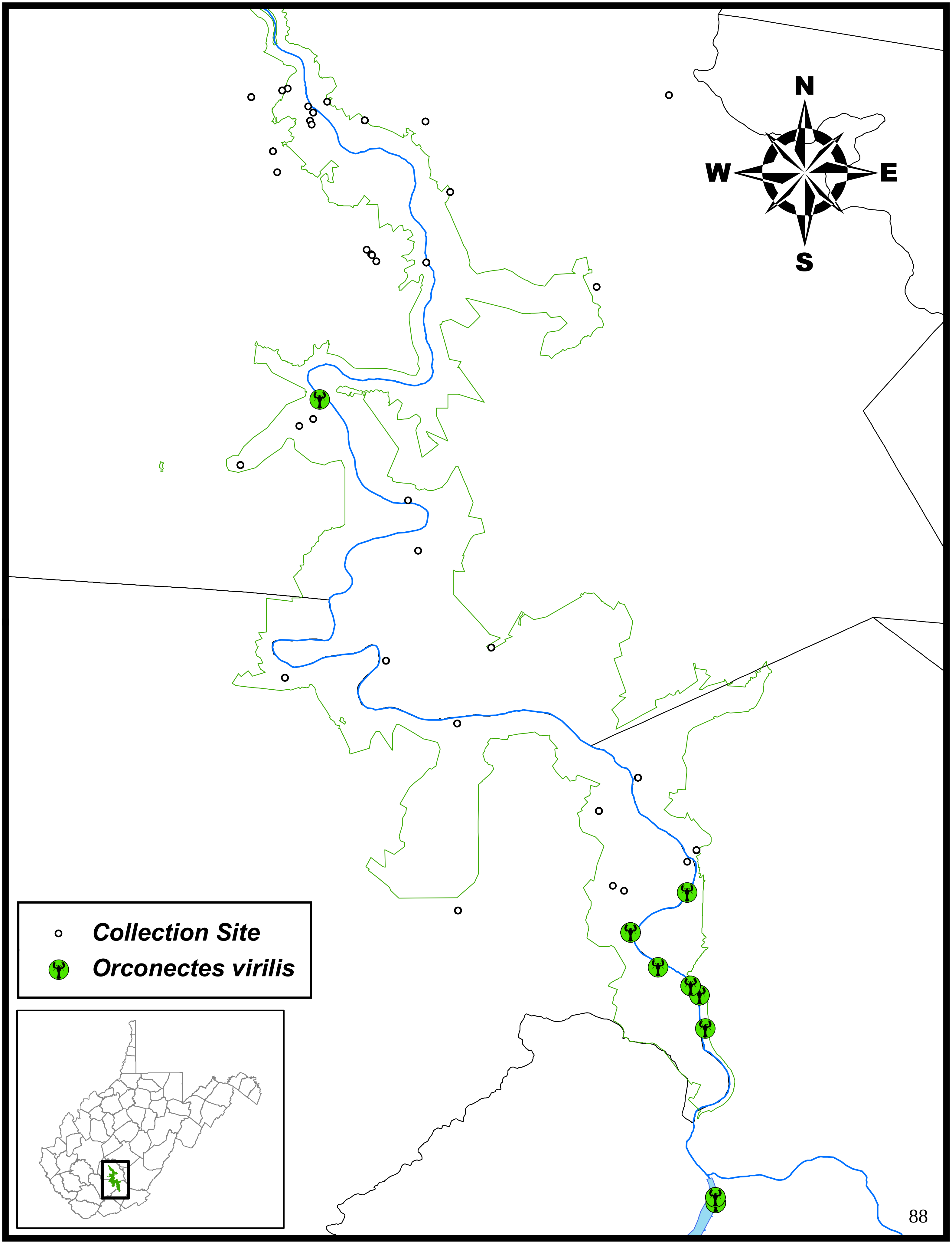

N
W
E
S
Collection Site
Cambarus carinirostris


N
W
E
S
Collection Site
Cambarus bartonii cavatus


N
W
E
S
Collection Site
Orconectes cristavarius



N
W
E
S
Collection Site
Orconectes sanbornii


N
W
E
S
Collection Site
Orconectes virilis

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