

STATE WILDLIFE GRANT PROJECT - FINAL REPORT

Project T2 - 1 - 4

**STREAM CRAYFISHES OF NORTHWEST ARKANSAS WITH EMPHASIS ON THE
STATUS AND DISTRIBUTION OF *ORCONECTES WILLIAMSI***

By

Brian K. Wagner¹, Christopher A. Taylor², and Mark D. Kottmyer¹

¹Arkansas Game and Fish Commission
915 E. Sevier Street,
Benton, AR 72015

²Illinois Natural History Survey
Center for Biodiversity and Ecological Entomology
1816 S. Oak
Champaign, IL 61820

Presented to

The Arkansas Game and Fish Commission

June 28, 2007

APPROVALS:



June 28, 2007

Brian Wagner, Project Coordinator

Date

Steve Filipek, Programs Assistant Chief

Date

Mike Armstrong, Chief of Fisheries

Date

Executive Summary

Orconectes williamsi is a rare stream-dwelling crayfish that is endemic to the upper White River basin of Arkansas and Missouri. This study surveyed a semi-random selection of stream sites in the Arkansas portion of this range in order to characterize the crayfish communities including *Orconectes meeki*, another species of interest; identify co-occurring fishes; and evaluate the status of *O. williamsi* in Arkansas. Collections of a total of 2,372 individual crayfish specimens were made at 68 sites, including 197 *O. williamsi* from 23 sites. *O. meeki* was the crayfish species most commonly associated with *O. williamsi*, occurring at 87% of sites occupied by *O. williamsi*. The fish species most commonly encountered in streams with *O. williamsi*, were *Etheostoma spectabile*, *Campostoma anomalum*, and *Semotilus atromaculatus*. *O. williamsi* was found in the smallest streams sampled, with coarse substrates and no aquatic vegetation. It showed a strong preference for riffle habitats. It is our opinion that the species is somewhat imperiled in Arkansas, and should be considered rare and vulnerable range-wide.



Introduction

Orconectes williamsi (Fitzpatrick 1966) is a stream-dwelling crayfish with a very limited distribution in headwater streams of the upper White River basin in Missouri and Arkansas. Taylor et al. (1996) consider it to be of “special concern” and The Nature Conservancy ranks it as G2, globally imperiled. It occurs in at least four counties in Missouri (Pflieger 1996) and its status in that state was recently reviewed (Westhoff et al. 2005, 2006). Given the lack of distributional and ecological information available to plan for the conservation of this species in Arkansas, a survey in this state is needed in close temporal proximity to the Missouri study to provide a complete picture of range-wide conservation status.

Orconectes meeki is another species of interest. In fact, preliminary results of surveys in Missouri indicate that it was more rare in that state than *O. williamsi* (Westhoff et al. 2005). However, *O. meeki* has a much wider range in Arkansas (Williams 1954, Robison 2002).

The objectives of this study were to determine baseline distribution and habitat information for *Orconectes williamsi*, characterize the crayfish fauna of the upper White River Basin, and document species associations.

Methods

Study Area and Site Selection

This study focused on portions of the Upper White River and Bull Shoals Reservoir basins in northern Arkansas. Based on the National Hydrology Dataset (NHD), these two hydrologic units comprise 7,291 identified stream segments totaling 15,170 km. The Arkansas portion of these units includes parts of Benton, Boone, Carroll, Franklin, Madison, Marion, Newton, Searcy, and Washington counties. Since these areas are largely in private ownership, road access to sampling sites was particularly important. U. S. Census Bureau data on roads in these counties was used to identify stream segments that intersect roads using ArcMap GIS software – this resulted in the identification of 1,924 accessible segments. A semi-random subset of these segments was selected for sampling by generating a random number between 0 and 19 as a start point, and then every 20th segment listed in the pooled list of accessible stream segments was chosen. Since the NHD segments were generally adjacent to one another in order, this reduced selection of clustered sampling sites and provided a fairly uniform distribution of sites. This resulted in selection of 96 stream segments as potential sample sites.

The selected stream segments were mapped on USGS 7.5 minute topographic maps using ArcMap and road accesses identified. Because headwater streams are more numerous and more easily bridged than larger streams, it was acknowledged that site selection was biased toward headwater streams, the habitat for the target species. Some of these headwater streams were intermittent and did not hold water or crayfish when visited for sampling. When this was the case, the site was replaced with a nearby site on a larger stream that was not selected for sampling. Two stream segments selected turned out to be erroneously assigned to the study

basins, and were replaced in the same manner. Distribution data was supplemented with collections including *O. williamsi* from other areas and researchers.

Sampling Methods

All available habitats at sites were intensively sampled in using minnow seines or dip nets appropriately sized to the area being sampled. This was supplemented when possible by approximately 30 person-minutes of visual search and hand capture of crayfish by overturning rock slabs if present.

At each sample site, latitude and longitude coordinates were recorded for the midpoint of the sample area. Other information recorded included water temperature, typical depth and width of pool and riffle habitats, predominant substrate sizes, and notes regarding aquatic vegetation, riparian vegetation, turbidity, and flow class. For this study, habitats were classified as pools if they had slower flow, undisturbed surface, and were the deeper habitats in the sample area; conversely, riffles were habitats with rapid flow, surface disturbance, and relatively shallow water. A sample data sheet is attached as Appendix 1.

Crayfish data were recorded separately for distinct major habitat units (pools vs. riffles) at each site, as applicable. Crayfish were sorted by perceived species, sexed, and measured to the nearest mm carapace length (CL). A series of voucher specimens including males and females of each species were also taken. All voucher specimens were preserved in 70% ethanol, identification to species verified by the second author, and deposited in the collection of the Illinois Natural History Survey or the AGFC Nongame Aquatics Program reference collection.

Results

Ninety-six stream segments were targeted for sampling within the upper White River basin (Beaver Lake and Bull Shoals Lake watersheds). Due to lack of water or access, several sites were deleted or moved, resulting in samples actually being conducted at 68 sites. Sites sampled are mapped in Figure 1. Crayfish species collected are noted in Table 1 and fish species collected are noted in Table 2.

A total of 2,372 crayfish specimens of nine different species were collected within the study area. The most commonly encountered species was *Orconectes neglectus neglectus*, occurring at 63.24% of sites sampled, followed by *O. meeki meeki* (52.94%), *O. williamsi* (33.82%), and *O. ozarkae* (32.35%) (Table 3). Mean lengths and sex distributions by species are displayed in Table 4. Length frequencies of individuals collected (carapace length in mm) are provided in Figures 2 – 5. *Cambarus hubbsi*, *O. longidigitis*, *O. nana*, *O. palmeri longimanus*, *O. virilis*, *Procambarus acutus*, and unidentified *Procambarus* sp. were found at 4 or fewer sites and were excluded from most analyses.

Collections in this study included 197 specimens of *Orconectes williamsi* from 23 sites. *O. williamsi* was also documented by 12 additional specimens from two sites in the Elk River basin and one site in the Mulberry River basin, not included in these analyses.

Crayfish Species Associations

Three species were found to occur at sites with *Orconectes williamsi*, namely *O. neglectus neglectus*, *O. meeki meeki*, and *O. ozarkae* (Table 5). *O. williamsi*'s most common associate was

O. m. meeki, occurring at 36 total sites and 87% of *O. williamsi* sites. *O. n. neglectus*, found at 43 total sites, was present at 26% of sites where *O. williamsi* was found. *O. ozarkae*, found at 22 sites, apparently avoided *O. williamsi* habitat, occurring with it only 4% of the time. Species associations with *O. williamsi* were also examined using the metrics of dominance, constancy, and fidelity (Table 6), as described by Pflieger (1978). *O. williamsi* was barely the dominant species where found, comprising 39.1% of the community compared to 38.5% for *O. meeki*. The least dominant species was *O. ozarkae* (8.5%), being collected with *O. williamsi* at only one site. Constancy results indicated that *O. meeki* (87.0%) and *O. ozarkae* (4.3%) were found most and least often at sites having *O. williamsi*, respectively. Fidelity estimates, incorporating all sampled sites regardless of *O. williamsi*'s presence, were greatest for *O. meeki* (55.6%) and lowest for *O. ozarkae* (4.5%).

O. ozarkae sites always had *O. n. neglectus* (100%), but *O. n. neglectus* was much more widely distributed (twice as many sites, only 50% had *O. ozarkae*). *O. m. meeki* sites most commonly had *O. williamsi* (56%) and often *O. n. neglectus* (36%), but never *O. ozarkae* (0%).

Fish Species Associations

Thirty fish species were found at one or more sites with *O. williamsi* (Table 2). The most commonly associated fish species were *Etheostoma spectabile* (74%), *Camptostoma anomalum* (70%), *Semotilus atromaculatus* (52%), and *Luxilus pilsbryi* (35%). Sites with *O. williamsi* had an average of 4.57 fish species present, whereas those without *O. williamsi* had 7.29 fish species. This difference was statistically significant (t-test, $p=0.0168$).

Habitat Characteristics

Table 7 provides a comparison of selected habitat variable observations from sites with *O. williamsi* and across all sites sampled. *O. williamsi* appears to occupy the smallest streams with coarser substrates and no aquatic vegetation. Most crayfish species collected seemed to prefer pools (Table 8), whereas *O. williamsi* and *O. nana* were usually found in riffles. *O. n. neglectus* and *O. ozarkae* appeared to generally use both habitats.

Discussion

Distribution

Orconectes williamsi was described by Fitzpatrick (1966), who reported it as restricted to three sites in Madison County, Arkansas. Pflieger (1996) reported nine localities from the upper White River basin in Missouri, expanding its known range much further north. While still only reported from 3 published sites in Arkansas, it was also found in additional locations in the vicinity (Henry Robison, pers. Comm.). Recent work by Westhoff et al. (2006) increased its documented range in Missouri to 27 sites, which, when combined with the 23 Arkansas sites documented in this study, provides a much better picture of the global distribution of this Ozark endemic. Its known range includes portions of Barry, Christian, Stone, and Taney counties in Missouri and Benton, Boone, Carroll, Madison, and Washington counties in Arkansas.

Westhoff et al. (2005) and the Missouri Department of Conservation (Bob Distefano, pers. Comm.) consider *Orconectes meeki* to be a much rarer crayfish in Missouri, reporting it from only 4 stream segments during their study. In Arkansas it appears to be more common, as documented by the fact that we found them at 36 sites during this study and that their range in Arkansas includes much of the Ozark portion of the Arkansas and White river basins. Future work is needed to accurately reflect the status of this species, and both of its subspecies, in regions beyond the scope of this study.

Other species collected during this study represented such small segments of their respective ranges that no meaningful distribution inferences can be made from these data.

Species Associations

Orconectes williamsi was found with *O. meeki* more commonly than with any other crayfish, which is consistent with the findings of Fitzpatrick (1966) and Westhoff et al. (2006).

For comparison with the Missouri study by Westhoff et al. (2005), species associations with *O. williamsi* were examined (Table 6) using Pflieger's (1978) metrics of dominance, constancy, and fidelity. Arkansas *O. williamsi* were not as dominant (39.1%) where found, compared to Missouri (56%) populations. We found *O. meeki* (38.5%) to be second in dominance, while it was much less dominant in Missouri (5%). The second in dominance in Missouri was *O. neglectus* (28%), which was much less dominant in Arkansas (13.9%). The dominance of *O. ozarkae* was comparable in the two states (AR – 8.5%, MO – 9%), but in our study the species was represented by a high abundance at a single *O. williamsi* site. *O. virilis* was of low dominance in Missouri (2%) and not represented at Arkansas *O. williamsi* sites. Constancy results indicated that *O. meeki* was found most often at Arkansas *O. williamsi* sites (AR – 87.0%, MO – 17.6%), while *O. neglectus* was most constant in Missouri (AR – 26.1%, MO – 94.1%). *O. neglectus* was only present (n=3) at one *O. williamsi* site in the Boston Mountain Ecoregion, where it appears to be replaced by much higher populations of *O. meeki* than in the Ozark Highlands Ecoregion, where *O. neglectus* is abundant. Fidelity estimates were greatest for *O. meeki* in both states (AR – 55.6%, MO – 75%), indicating that it is the best species associate for indicating suitable habitat within the range of *O. williamsi*.

We also looked at fishes found with *O. williamsi*. Our findings in this area were not surprising, considering that *O. williamsi* was found in the smallest streams sampled – in fact we failed to find them at some previously reported sites because the stream reaches were dry when we

visited! Consistent with this, we found *O. williamsi* sites to be lower than the average fish diversity of sites sampled in the study, and usually having only central stonerollers, orangethroat darters, and creek chubs.

Habitat Use

O. williamsi is reported to inhabit “gravelly headwater creeks, spring branches, and cave streams” (Pflieger 1996). In Fitzpatrick’s (1966) description, he notes that *Orconectes williamsi* was associated with “proportionately very large stones” in pools, while riffles yielded *O. meeki*. This description is not consistent with our findings, which show an association with riffles. Our results are consistent with the findings by Westhoff et al. (2006) that show association with shallow water and high current velocity. It is remotely possible that this discrepancy could be due to seasonal shifts in habitat use - Fitzpatrick collected in January, Westhoff et al. in April through August, and we in October through December.

All three studies support association with cobble or larger substrates and our study and Westhoff et al. concur on a negative association with aquatic vegetation. *Orconectes williamsi* habitat can be characterized as small streams that are well-incised, with coarse substrate, shallow water, fast current, and riparian forest cover sufficient to restrict aquatic vegetation growth. We did, however, note an outlier to this description – collection BKW2004-087 was from a site on Leatherwood Creek that was a concrete-lined roadside ditch in downtown Eureka Springs with limited natural substrate. Crayfish density was low at this site, but *O. williamsi* was the dominant species.

Recommendations

Orconectes williamsi is presently not ranked for conservation status at the state level for Arkansas (www.natureserve.com, accessed 5-29-07). Westhoff et al. (2006) recommend a rank of imperiled (S2), after finding the species at 27 sites in Missouri. This is comparable to the 23 sites we found, and we propose that a rank of imperiled (S2) would also be appropriate for Arkansas. The current global rank of rare (G3) seems appropriate.

Acknowledgements

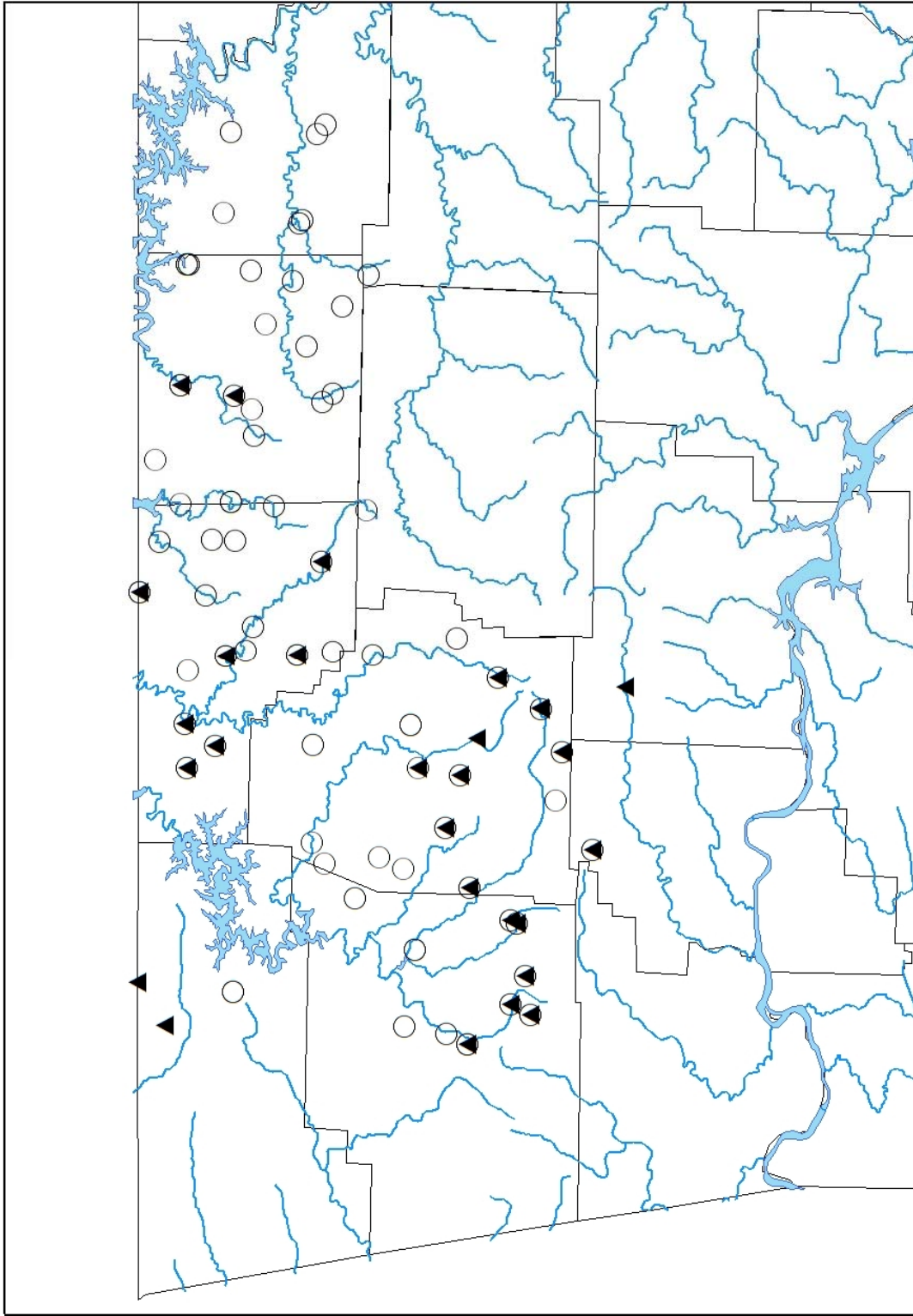
Field assistance was provided by T. Anderson, S. Brown, K. Coffey, F. Leone, R. Limbird, M. Oliver, K. Shirley, and J. Stinnett of the Arkansas Game and Fish Commission; E. Inlander and D. Crosswhite of The Nature Conservancy; and S. Coughlan of Arkansas State University. C. Dillman and J. Ray of Saint Louis University assisted with one of the reported supplemental collections.

Literature Cited

- Fitzpatrick, J. F., Jr. 1966. A new crayfish of the genus *Orconectes* from the headwaters of the White River in Arkansas (Decapoda, Astacidae). Proc. of the Biol. Soc. of Washington. 79:145-150.
- Pflieger, W. L. 1978. Distribution, status, and life history of the Niangua darter, *Etheostoma nianguae*. Missouri Department of Conservation Aquatic Series Report No. 16. Jefferson City. 25 pp.
- Pflieger, W. L. 1996. The Crayfishes of Missouri. Missouri Dept. Cons., Jefferson City. 152 pp.
- Robison, H. W. 2002. Computerization of the Crayfishes of Arkansas. Final Report Submitted to Arkansas Game and Fish Commission, Little Rock. 24 pp and associated database.
- Taylor, C. A., M. L. Warren, Jr., J. F. Fitzpatrick, Jr., H. H. Hobbs III, R. F. Jezerinac, W. L. Pflieger, and H. W. Robison. 1996. Conservation and status of crayfishes of the United States and Canada. Fisheries 21(4): 25-38.
- Westhoff, J. T., J. A. Guyot, and R. J. Distefano. 2005. A survey of the distribution of the imperiled Williams' crayfish (*Orconectes williamsi*) in the upper White River drainage of Missouri: Associations with multi-scale environmental variables. Missouri Department of Conservation, Final Report. Columbia, MO. 90 pp.
- Westhoff, J. T., J. A. Guyot, and R. J. Distefano. 2006. Distribution of the imperiled Williams' crayfish (*Orconectes williamsi*) in the upper White River drainage of Missouri: Associations with multi-scale environmental variables. American Midland Naturalist 156(2): 273-288.

Williams, A. B. 1954. Speciation and distribution of the crayfishes of the Ozark Plateaus and Ouachita Provinces. The Univ. of Kansas Sci. Bull. Vol. 36, Pt. 2, No.12. Pages 803-918.

Figure 1: Map of northwest Arkansas depicting locations included in this report. Open circles indicate sites sampled as part of this study. Circled solid triangles indicate study sites where *O. williamsi* was encountered. Solid triangles alone indicate sites where *O. williamsi* was encountered outside study area through other sampling efforts.



Prepared by Brian Wagner for reference only, 3-8-2007

0 3.75 7.5 15 Miles

Figure 2: *Orconectes williamsi* length frequency.

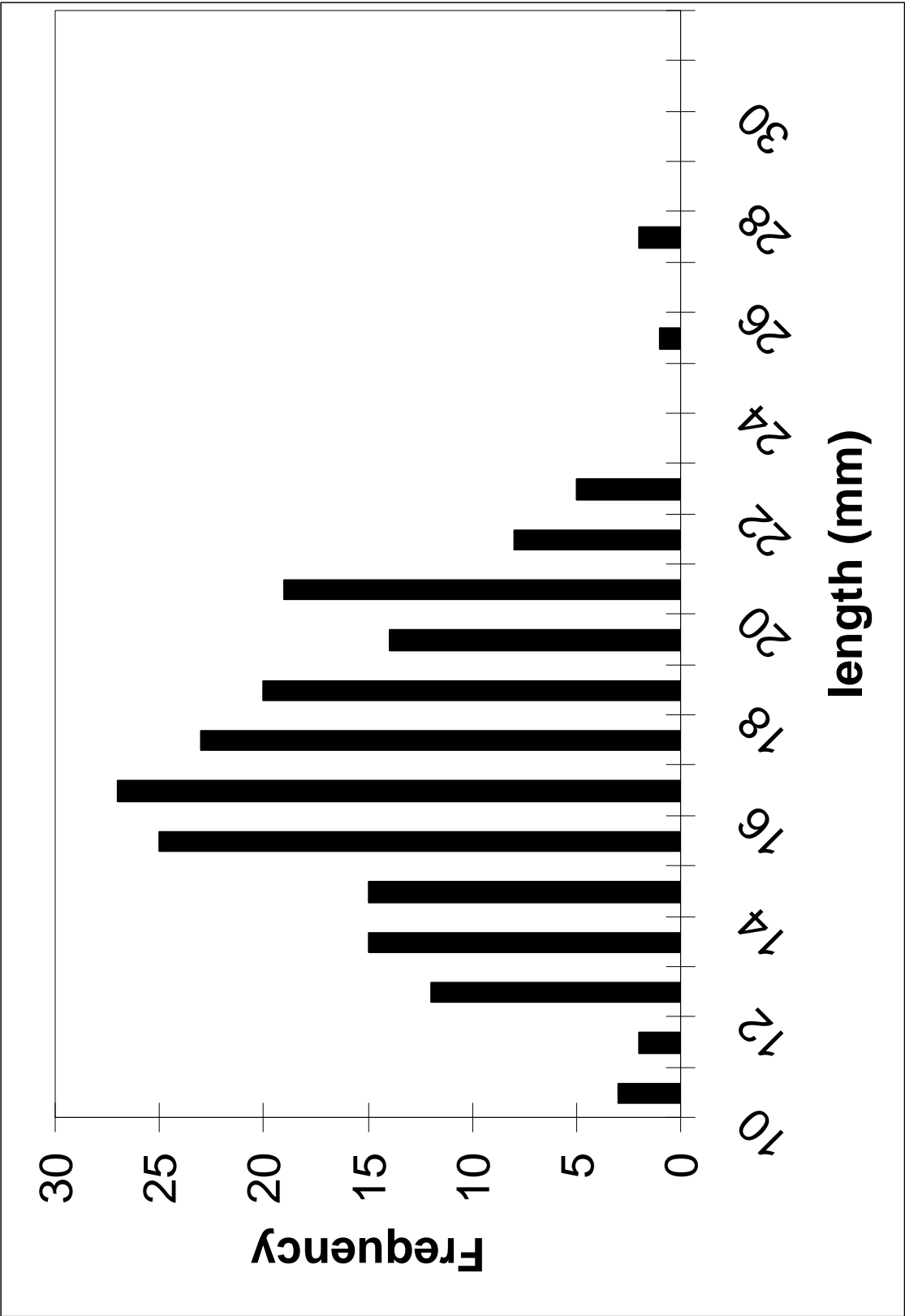


Figure 3: *Orconectes meeki meeki* length frequency.

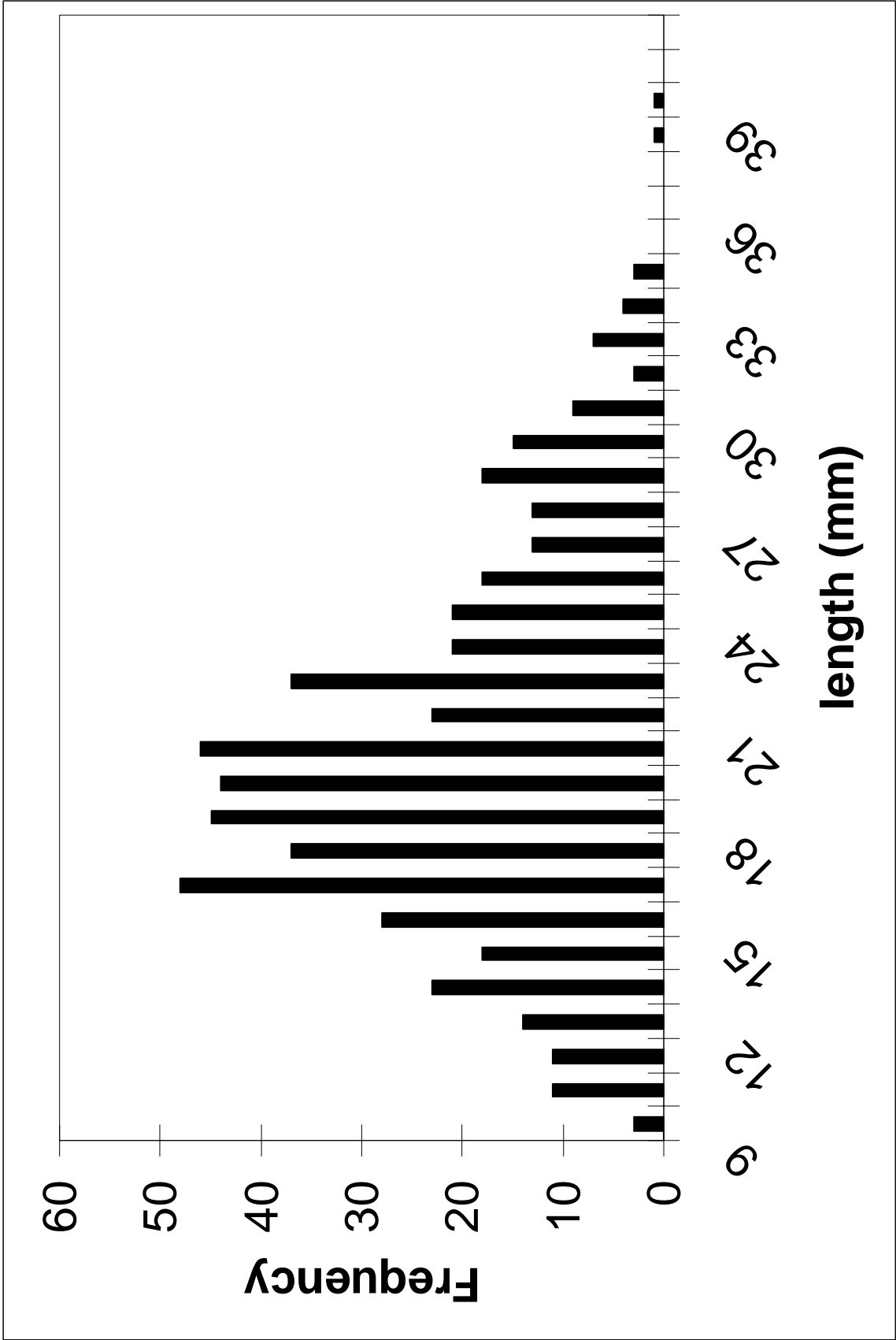


Figure 4: *Orconectes neglectus neglectus* length frequency.

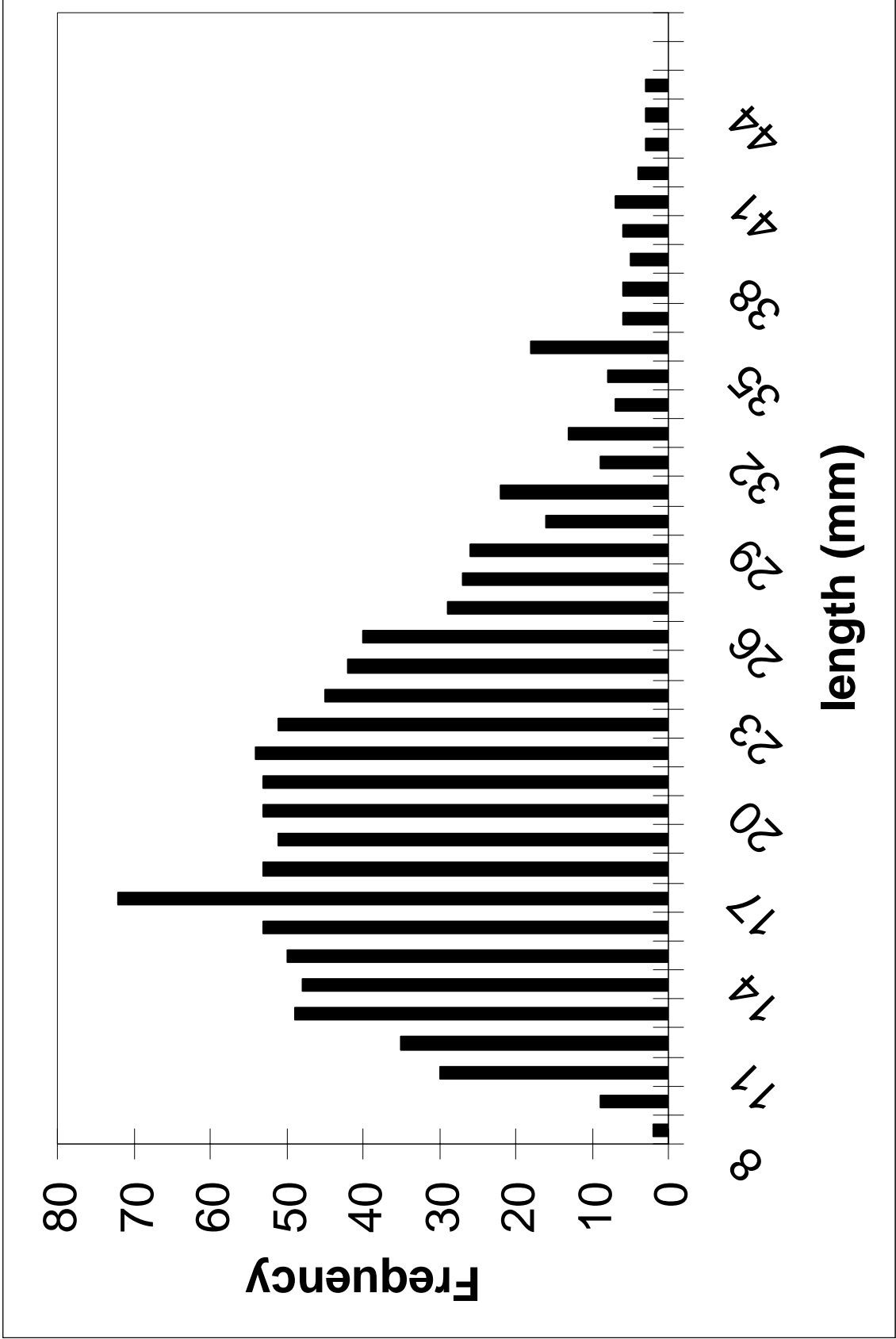


Figure 5: *Orconectes ozarkae* length frequency.

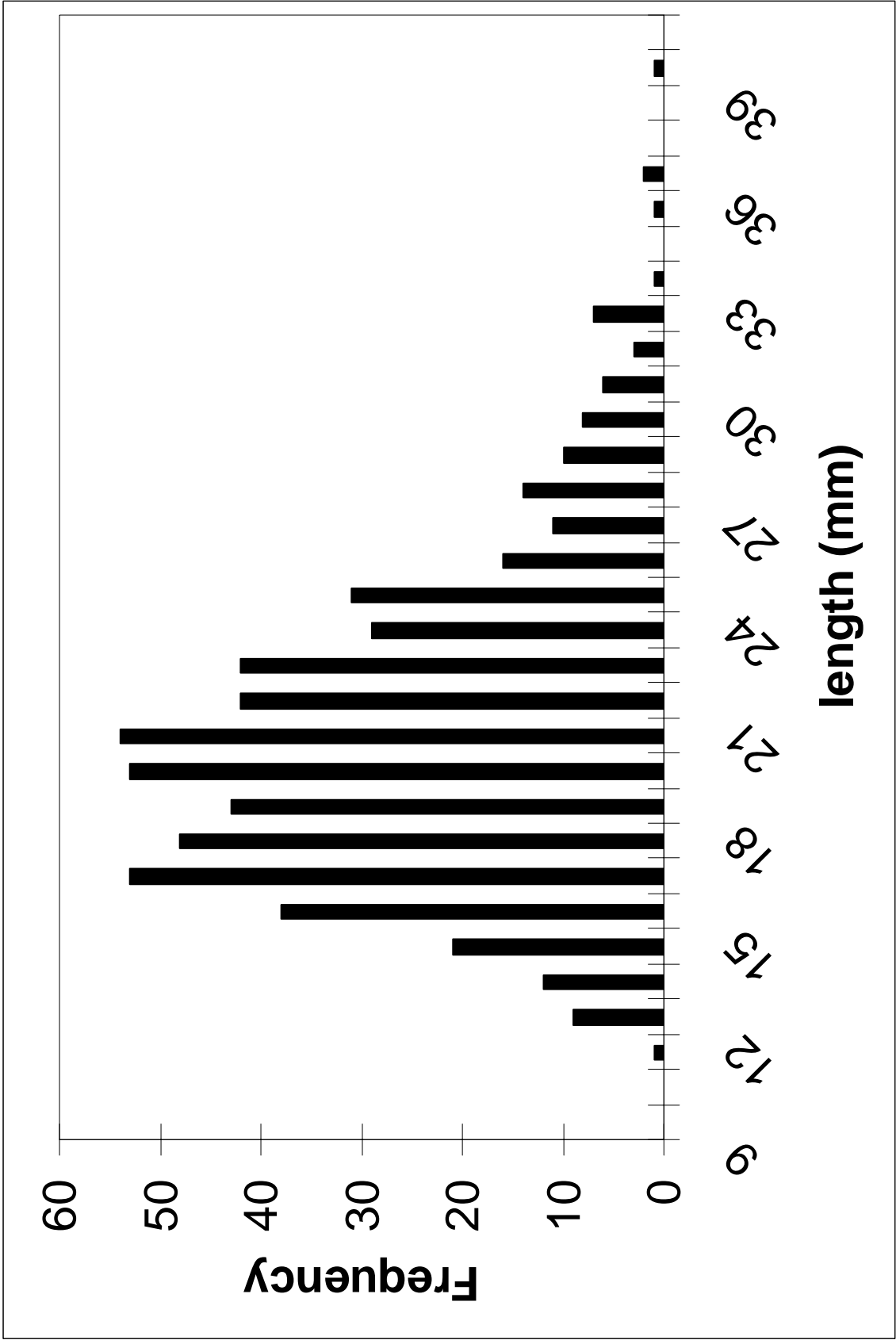


Table 1: Site locations and crayfish species and numbers collected by site. Collections highlighted in gray included *Orconectes williamsi*. Supplemental records outside study area are denoted by “*”.

Collection #	Stream	Collection Date	Longitude	Latitude	<i>Cambarus hubbsi</i>	<i>Orconectes longidigitis</i>	<i>Orconectes nama</i>	<i>Orconectes meeki meeki</i>	<i>Orconectes neglectus neglectus</i>	<i>Orconectes ozarkae</i>	<i>Orconectes palmeri longimanus</i>	<i>Orconectes virilis</i>	<i>Orconectes williamsi</i>	<i>Procambarus acutus</i>	Unid. <i>Procambarus</i>
BKW2004-028	unnamed trib of White River	10/4/2004	-93.63557	35.82273				12					3		
BKW2004-029	Kilgore Branch	10/4/2004	-93.70647	35.78671				5					17		
BKW2004-030	Fleming Creek	10/4/2004	-93.78645	35.79686				9							
BKW2004-031	Osage Creek	10/5/2004	-93.30286	36.11073				93							
BKW2004-032	Boatright Creek	10/5/2004	-93.54436	36.10094					27						
BKW2004-033	Felkins Creek	10/5/2004	-93.51535	35.96103				124	2						
BKW2004-034	tributary of Mill Creek	10/6/2004	-93.86790	35.73721				30					6		
BKW2004-035	Kings River	10/6/2004	-93.58251	35.89365				44					3		
BKW2004-036	Whorton Creek	10/6/2004	-93.66170	36.03901	6			15	9						
BKW2004-037	Huzzah Creek	10/13/2004	-93.03061	36.21012				230	63						
BKW2004-038	East Fork Crooked Creek	10/13/2004	-93.11015	36.16759				12	16						
BKW2004-039	West Fork Crooked Creek	10/13/2004	-93.12332	36.18422				13	26						
BKW2004-040	West Fork Clear Creek	10/14/2004	-92.91327	36.10796				25	28						
BKW2004-041	Hog Creek	10/14/2004	-92.96464	36.15104				11	13						
BKW2004-042	Clear Creek	10/15/2004	-92.82650	36.22405				8	68						
BKW2004-043	Hampton Creek	10/15/2004	-92.82175	36.21714				21	12						
BKW2004-044	Crooked Creek	10/20/2004	-92.92242	36.23405				18	20						
BKW2004-045	Mill Branch	10/20/2004	-92.90609	36.30292				6	15						
BKW2004-046	East Sugarloaf Creek	10/20/2004	-92.80988	36.34929				56							
BKW2004-052	Long Creek	11/8/2004	-93.29630	36.26486				24	26						
BKW2004-053	Dry Creek	11/8/2004	-93.35445	36.33036				11	76						
BKW2004-054	Deshield Fork	11/9/2004	-92.89559	36.40635	1			1	1						
BKW2004-055	Sugarloaf Creek	11/9/2004	-92.89559	36.40982				35	32			1			
BKW2004-056	Brushy Fork Creek	11/10/2004	-92.67531	36.33711				43	32						
BKW2004-057	Shakerag Creek	11/10/2004	-92.66260	36.18032				4	3						
BKW2004-058	Mill Creek	11/10/2004	-92.67857	36.19315				21	9						
BKW2004-059	Prairie Creek	11/15/2004	-94.10339	36.33278			19	1	32						

Collection #	Stream	Collection Date	Longitude	Latitude	<i>Cambarus hubbsi</i>	<i>Orconectes longidigitis</i>	<i>Orconectes nana</i>	<i>Orconectes meeki meeki</i>	<i>Orconectes neglectus neglectus</i>	<i>Orconectes ozarkae</i>	<i>Orconectes palmeri longimanus</i>	<i>Orconectes virilis</i>	<i>Orconectes williamsi</i>	<i>Procambarus acutus</i>	Unid. <i>Procambarus</i>
BKW2004-060	Brush Creek	11/15/2004	-93.94791	36.13147		1		2							
BKW2004-061	Unnamed tributary	11/16/2004	-94.03355	36.03067							1			2	47
BKW2004-062	Stout Spring Branch	11/16/2004	-94.16228	36.04855				6	6						
BKW2004-063	West Fork White River	11/16/2004	-94.17332	35.97896				9	3						
BKW2004-064	Trib. of W Fork White River	11/22/2004	-94.19118	35.94394				7	3				9		
BKW2004-065	Unnamed spring branch	11/23/2004	-93.89050	36.18173				15							
BKW2004-066	War Eagle Creek	11/23/2004	-93.85680	36.20218					11						
BKW2004-067	Pine Creek	11/23/2004	-93.69450	36.20042				9	32						
BKW2004-068	Brush Creek	11/23/2004	-93.88148	36.09062				18							
BKW2004-069	Cherry Creek	11/23/2004	-93.89997	36.04985				15							
BKW2004-070	Cricket Creek	12/2/2004	-93.21907	36.46222					1						
BKW2004-071	Blevins Hollow	12/2/2004	-93.29372	36.41960					8						
BKW2004-072	Yocum Creek	12/2/2004	-93.35641	36.45444					23	43					
BKW2004-073	Callens Branch	12/2/2004	-93.35203	36.36753					8	1					
BKW2004-074	Barren Fork	12/3/2004	-93.09570	36.41999					8	43			1		
BKW2004-075	Mill Hollow	12/3/2004	-93.11344	36.33128					1				20		
BKW2004-076	Wolf Creek	12/3/2004	-93.13675	36.30125					24						
BKW2004-077	White Oak Creek	12/3/2004	-92.99525	36.27831					10						
BKW2004-078	Hutchins Creek	12/6/2004	-94.07706	35.84777				16					1		
BKW2004-079	Riley Creek	12/6/2004	-94.14201	35.83952				5					11		
BKW2004-080	Trib. of W Fork White River	12/6/2004	-94.12405	35.87219				6					5		
BKW2004-081	Peach Branch	12/7/2004	-93.98595	35.87267				1					30		
BKW2004-082	Trib. of Fritts Creek	12/7/2004	-93.93079	35.94046				6					12		
BKW2004-083	Trib. of War Eagle Creek	12/7/2004	-93.73191	36.02557									6		
BKW2004-084	Jackson Creek	12/7/2004	-93.74547	35.95602				15					14		
BKW2004-085	Trib. of Drakes Creek	12/7/2004	-93.83117	35.98109				7					15		
BKW2004-086	Middle Fork White River	12/9/2004	-93.99018	35.86267				14					6		

Collection #	Stream	Collection Date	Longitude	Latitude	<i>Cambarus hubbsi</i>	<i>Orconectes longidigitis</i>	<i>Orconectes nana</i>	<i>Orconectes meeki meeki</i>	<i>Orconectes neglectus neglectus</i>	<i>Orconectes ozarkae</i>	<i>Orconectes palmeri longimanus</i>	<i>Orconectes virilis</i>	<i>Orconectes williamsi</i>	<i>Procambarus acutus</i>	Unid. <i>Procambarus</i>
BKW2004-087	Leatherwood Creek	12/15/2004	-93.73296	36.41032				4					7		
BKW2004-088	Keels Creek	12/15/2004	-93.69500	36.36353				3					12		
BKW2004-089	Pine Creek	12/15/2004	-93.65939	36.41402				5					4		
BKW2004-090	Warden Creek	12/15/2004	-93.54617	36.34565				1	31				4		
BKW2004-091	Clabber Creek	12/15/2005	-93.57020	36.40859				7							
BKW2004-092	Lundy Cove	12/16/2004	-93.53770	36.31207				4	20						
BKW2004-093	Cedar Creek	12/16/2004	-93.54392	36.22679				3	9				6		
BKW2004-094	Dry Fork Creek	12/16/2004	-93.53813	36.16791				1	61						
BKW2004-095	Dog Branch	12/16/2004	-93.38892	36.18707				6					4		
BKW2004-096	Osage Creek	12/16/2004	-93.49690	36.29973					21	2					
BKW2004-097	Little Indian Creek	12/17/2004	-93.43978	36.48871				4	15				1		
BKW2004-098	Yocum Creek	12/17/2004	-93.44534	36.37862					61	25					
BKW2004-099	Long Creek	12/17/2004	-93.28893	36.33719	7	7		1	6						
BKW2004-100	Bear Creek Springs	12/17/2004	-93.17879	36.29786					33	2					
bkw2005-027*	Washita Creek	5/24/2005	-93.59897	35.68332				13					1		
bkw2005-069*	spring trib to Spanker Branch	10/26/2005	-94.15937	36.44589					28				10		
bkw2005-084*	Spring run trib of Big Sugar Creek	11/17/2005	-94.08805	36.49162					17				1		

Table 2: Fish species collected by site. Collections highlighted in gray included *Orconectes williamsi*.

Collection #	Total Number of Species Collected	<i>Campostoma anomalum</i>	<i>Campostoma oligolepis</i>	<i>Cyprinella galactura</i>	<i>Cyprinella whipplei</i>	<i>Hybopsis amblops</i>	<i>Luxilus chrysocephalus</i>	<i>Luxilus pilsbryi</i>	<i>Nocomis biguttatus</i>	<i>Notemigonus crysoleucas</i>	<i>Notropis boops</i>	<i>Notropis nubilus</i>	<i>Notropis percobromus</i>	<i>Notropis telescopus</i>	<i>Phoxinus erythrogaster</i>	<i>Pimephales notatus</i>	<i>Pimephales promelas</i>	<i>Semotilus atromaculatus</i>	<i>Catostomus commersoni</i>	<i>Erimyzon oblongus</i>	<i>Hypentelium nigricans</i>	<i>Moxostoma duquesnei</i>	<i>Moxostoma erythrum</i>
BKW2004-028	7	X						X										X					
BKW2004-029	1																	X					
BKW2004-030	10	X						X				X						X					
BKW2004-031	2	X																					
BKW2004-032	8	X						X				X			X			X					
BKW2004-033	4							X				X											
BKW2004-034	4	X																X		X			
BKW2004-035	5	X																X					
BKW2004-036	9	X			X			X				X				X							
BKW2004-037	6	X							X						X								
BKW2004-038	2							X															
BKW2004-039	13	X	X				X	X				X			X	X							
BKW2004-040	6	X													X			X					
BKW2004-041	9	X						X				X			X			X					
BKW2004-042	22	X		X			X	X	X		X	X				X						X	
BKW2004-043	17	X	X	X			X	X	X			X				X						X	
BKW2004-044	7	X						X															
BKW2004-045	6		X						X						X								
BKW2004-046	5		X					X							X								
BKW2004-052	13	X	X								X	X				X							X
BKW2004-053	11	X					X	X				X			X			X	X				
BKW2004-054	12	X						X															
BKW2004-055	15	X	X			X		X	X			X											
BKW2004-056	8		X			X		X	X														
BKW2004-057	5	X													X			X					
BKW2004-058	9	X						X	X			X			X			X					
BKW2004-059 ¹	9	X								X					X								

Collection #	<i>Ameiurus melas</i>	<i>Noturus albater</i>	<i>Noturus exilis</i>	<i>Labidesthes sicculus</i>	<i>Fundulus catenatus</i>	<i>Fundulus olivaceus</i>	<i>Gambusia affinis</i>	<i>Cottus caroliniae</i>	<i>Cottus hypselurus</i>	<i>Ambloplites constellatus</i>	<i>Lepomis cyanellus</i>	<i>Lepomis gulosus</i>	<i>Lepomis macrochirus</i>	<i>Lepomis megalotis</i>	<i>Lepomis microlophus</i>	<i>Micropterus dolomieu</i>	<i>Micropterus salmoides</i>	<i>Etheostoma blennioides</i>	<i>Etheostoma caeruleum</i>	<i>Etheostoma flabellare</i>	<i>Etheostoma juliae</i>	<i>Etheostoma punctulatum</i>	<i>Etheostoma spectabile</i>	<i>Etheostoma zonale</i>	
BKW2004-028											X								X			X	X		
BKW2004-029																									
BKW2004-030			X		X						X							X					X	X	
BKW2004-031																								X	
BKW2004-032					X			X											X						
BKW2004-033					X	X																			
BKW2004-034																								X	
BKW2004-035													X	X											X
BKW2004-036					X		X							X											X
BKW2004-037					X			X																	X
BKW2004-038																									X
BKW2004-039					X	X		X										X	X						X
BKW2004-040									X		X														X
BKW2004-041					X						X		X												X
BKW2004-042		X	X		X	X	X							X	X	X	X	X	X			X			X
BKW2004-043			X		X	X								X	X	X			X						X
BKW2004-044					X	X	X												X						X
BKW2004-045								X													X				X
BKW2004-046								X																	X
BKW2004-052			X	X	X	X								X					X						X
BKW2004-053					X	X					X														X
BKW2004-054				X	X	X					X		X	X			X		X				X	X	
BKW2004-055					X	X				X	X		X				X		X				X	X	
BKW2004-056					X	X										X			X						
BKW2004-057						X																			X
BKW2004-058																			X						X
BKW2004-059 ¹						X	X		X		X		X												X

Collection #	Total Number of Species Collected	<i>Campostoma anomalum</i>	<i>Campostoma oligolepis</i>	<i>Cyprinella galactura</i>	<i>Cyprinella whipplei</i>	<i>Hybopsis amblops</i>	<i>Luxilus chrysocephalus</i>	<i>Luxilus pilsbryi</i>	<i>Nocomis biguttatus</i>	<i>Notemigonus crysoleucas</i>	<i>Notropis boops</i>	<i>Notropis nubilus</i>	<i>Notropis percobromus</i>	<i>Notropis telescopus</i>	<i>Phoxinus erythrogaster</i>	<i>Pimephales notatus</i>	<i>Pimephales promelas</i>	<i>Semotilus atromaculatus</i>	<i>Catostomus commersoni</i>	<i>Erimyzon oblongus</i>	<i>Hypentelium nigricans</i>	<i>Moxostoma duquesnei</i>	<i>Moxostoma erythrum</i>
BKW2004-060	8						X	X				X											
BKW2004-061	4	X																					
BKW2004-062	4	X			X													X					
BKW2004-063	22	X			X		X	X			X	X	X			X					X	X	X
BKW2004-064	17	X						X			X	X				X						X	X
BKW2004-065	2	X													X								
BKW2004-066 ²	0																						
BKW2004-067	6	X						X							X			X					
BKW2004-068	3	X																X					
BKW2004-069	3	X																					
BKW2004-070	7	X					X	X							X		X						
BKW2004-071	6	X						X															
BKW2004-072	6							X	X														
BKW2004-073	6	X						X	X						X								
BKW2004-074	7	X						X															
BKW2004-075 ³	0																						
BKW2004-076	4	X													X			X					
BKW2004-077	2	X																					
BKW2004-078	3	X																X					
BKW2004-079	2																	X					
BKW2004-080	9	X						X				X						X				X	
BKW2004-081	2	X																X					
BKW2004-082	3							X										X					
BKW2004-083	2	X																					
BKW2004-084	3	X																X					
BKW2004-085	2	X																					
BKW2004-086	4	X																X					

Collection #	<i>Ameiurus melas</i>	<i>Noturus albatel</i>	<i>Noturus exilis</i>	<i>Labidesthes sicculus</i>	<i>Fundulus catenatus</i>	<i>Fundulus olivaceus</i>	<i>Gambusia affinis</i>	<i>Cottus carolinae</i>	<i>Cottus hypselurus</i>	<i>Ambloplites constellatus</i>	<i>Lepomis cyanellus</i>	<i>Lepomis gulosus</i>	<i>Lepomis macrochirus</i>	<i>Lepomis megalotis</i>	<i>Lepomis microlophus</i>	<i>Micropterus dolomieu</i>	<i>Micropterus salmoides</i>	<i>Etheostoma blennioides</i>	<i>Etheostoma caeruleum</i>	<i>Etheostoma flabellare</i>	<i>Etheostoma juliae</i>	<i>Etheostoma punctulatum</i>	<i>Etheostoma spectabile</i>	<i>Etheostoma zonale</i>	
BKW2004-060					X		X				X	X						X							
BKW2004-061							X				X											X			
BKW2004-062																							X		
BKW2004-063			X	X		X	X							X			X	X	X				X	X	X
BKW2004-064			X		X	X					X		X	X	X		X						X	X	
BKW2004-065																									
BKW2004-066 ²																									
BKW2004-067								X															X		
BKW2004-068																							X		
BKW2004-069	X																						X		
BKW2004-070																						X	X		
BKW2004-071								X			X								X				X		
BKW2004-072			X					X											X				X		
BKW2004-073											X											X			
BKW2004-074			X		X														X	X			X		
BKW2004-075 ³																									
BKW2004-076									X																
BKW2004-077								X																	
BKW2004-078																							X		
BKW2004-079																							X		
BKW2004-080			X								X			X									X		
BKW2004-081																									
BKW2004-082																							X		
BKW2004-083																						X			
BKW2004-084																							X		
BKW2004-085																							X		
BKW2004-086			X																				X		

Collection #	Total Number of Species Collected	<i>Campostoma anomalum</i>	<i>Campostoma oligolepis</i>	<i>Cyprinella galactura</i>	<i>Cyprinella whipplei</i>	<i>Hybopsis amblops</i>	<i>Luxilus chrysocephalus</i>	<i>Luxilus pilsbryi</i>	<i>Nocomis biguttatus</i>	<i>Notemigonus crysoleucas</i>	<i>Notropis boops</i>	<i>Notropis nubilus</i>	<i>Notropis percobromus</i>	<i>Notropis telescopus</i>	<i>Phoxinus erythrogaster</i>	<i>Pimephales notatus</i>	<i>Pimephales promelas</i>	<i>Semotilus atromaculatus</i>	<i>Catostomus commersoni</i>	<i>Erimyzon oblongus</i>	<i>Hypentelium nigricans</i>	<i>Moxostoma duquesnei</i>	<i>Moxostoma erythrum</i>
BKW2004-087	4																						
BKW2004-088 ³	0																						
BKW2004-089 ³	0																						
BKW2004-090	11	X	X	X			X	X				X		X	X								
BKW2004-091	5	X					X	X															
BKW2004-092	7		X					X															
BKW2004-093	8	X					X	X		X					X			X					
BKW2004-094	5							X															
BKW2004-095	7	X						X				X		X									
BKW2004-096	6		X									X											
BKW2004-097	4	X													X								
BKW2004-098	5							X							X								
BKW2004-099	6	X	X					X															
BKW2004-100	3																						
bkw2005-027 ³	0																						
bkw2005-069	3	X													X								
bkw2005-084	3														X								

Collection #	<i>Ameiurus melas</i>	<i>Noturus albatro</i>	<i>Noturus exilis</i>	<i>Labidesthes sicculus</i>	<i>Fundulus catenatus</i>	<i>Fundulus olivaceus</i>	<i>Gambusia affinis</i>	<i>Cottus carolinae</i>	<i>Cottus hypselurus</i>	<i>Ambloplites constellatus</i>	<i>Lepomis cyanellus</i>	<i>Lepomis gulosus</i>	<i>Lepomis macrochirus</i>	<i>Lepomis megalotis</i>	<i>Lepomis microlophus</i>	<i>Micropterus dolomieu</i>	<i>Micropterus salmoides</i>	<i>Etheostoma blennioides</i>	<i>Etheostoma caeruleum</i>	<i>Etheostoma flabellare</i>	<i>Etheostoma juliae</i>	<i>Etheostoma punctulatum</i>	<i>Etheostoma spectabile</i>	<i>Etheostoma zonale</i>
BKW2004-087								X											X			X	X	
BKW2004-088 ³																								
BKW2004-089 ³																								
BKW2004-090					X														X				X	
BKW2004-091																						X	X	
BKW2004-092								X					X						X			X	X	
BKW2004-093																			X				X	
BKW2004-094								X											X	X			X	
BKW2004-095								X														X	X	
BKW2004-096		X	X																X		X			
BKW2004-097									X														X	
BKW2004-098								X											X				X	
BKW2004-099								X											X					X
BKW2004-100									X										X				X	
bkw2005-027 ³																								
bkw2005-069																					X			
bkw2005-084								X												X				

Footnotes:

- 1- Fish species list compiled from 2003 sample at same site.
- 2- No fish collected during this sample due to high flow.
- 3- No fish collected during this sample.

Table 3: Numbers of crayfish collected in study by species, % of total, number of sites occupied, and % of sites occupied.

	<i>Cambarus hubbsi</i>	<i>Orconectes longidigitis</i>	<i>Orconectes nana</i>	<i>Orconectes meeki meeki</i>	<i>Orconectes neglectus neglectus</i>	<i>Orconectes ozarkae</i>	<i>Orconectes palmeri longimanus</i>	<i>Orconectes virilis</i>	<i>Orconectes williamsi</i>	<i>Procambarus acutus</i>	<i>Unid. Procambarus</i>
Total # of individuals	7	15	19	523	1004	556	1	1	197	2	47
% of individuals	0.30	0.63	0.80	22.05	42.33	23.44	0.04	0.04	8.31	0.08	1.98
# of sites	1	4	1	36	43	22	1	1	23	1	1
% of sites	1.47	5.88	1.47	52.94	63.24	32.35	1.47	1.47	33.82	1.47	1.47
Dominance (%)	-	-	-	38.49	13.89	8.53	-	-	39.09	-	-

Table 4: Crayfish mean length and gender by species.

<u>Species (N assigned to a gender)</u>	<u>Mean Carapace Length (CL)</u>	<u>Standard Deviation CL</u>	<u>Males</u>	<u>Females</u>
<i>C. hubbsi</i> (7)	28.7 mm	4.5	5 (71%)	2 (29%)
<i>O. longidigitis</i> (14)	40.7 mm	10.9	6 (43%)	8 (57%)
<i>O. m. meeki</i> (519)	19.8 mm	5.5	251 (48%)	268 (52%)
<i>O. nana</i> (19)	19.9 mm	1.9	2 (11%)	17 (89%)
<i>O. n. neglectus</i> (1008)	20.5 mm	7.3	528 (52%)	480 (48%)
<i>O. ozarkae</i> (555)	20.0 mm	4.5	207 (37%)	348 (63%)
<i>O. palmeri longimanus</i> (1)	24 mm	-	0 (-)	1 (-)
<i>O. virilis</i> (1)	22 mm	-	1 (-)	0 (-)
<i>O. williamsi</i> (192)	16.5 mm	3.1	110 (57%)	82 (43%)
<i>Procambarus</i> sp. (19)	10.6 mm	2.7	4 (21%)	15 (79%)

Table 5: Species associations for most commonly encountered species.

	<i>Orconectes meeki meeki</i>	<i>Orconectes neglectus neglectus</i>	<i>Orconectes ozarkae</i>	<i>Orconectes williamsi</i>
total # sites occupied	36	43	22	23
% of sites co-occurring with:				
<i>Orconectes meeki meeki</i>	100	30	0	87
<i>Orconectes neglectus neglectus</i>	36	100	100	26
<i>Orconectes ozarkae</i>	0	51	100	4
<i>Orconectes williamsi</i>	56	14	5	100

Table 6: Further analysis of *Orconectes williamsi* species associations, including dominance, constancy, and fidelity, after Pflieger (1978). Dominance = the proportion of all crayfish collected at sites with *O. williamsi* that are the given species. Constancy = the proportion of *O. williamsi* sites also having the given species. Fidelity = the proportion of sites having the given species that also have *O. williamsi*.

	<i>Orconectes meeki</i>	<i>Orconectes neglectus neglectus</i>	<i>Orconectes ozarkae</i>	<i>Orconectes williamsi</i>
Dominance (%) at <i>O. williamsi</i> sites	38.5	13.9	8.5	39.1
Constancy (%) at <i>O. williamsi</i> sites	87.0	26.1	4.3	-
Fidelity (%) at <i>O. williamsi</i> sites	55.6	14.0	4.5	-

Table 7: Comparison of selected habitat characteristics at sites with *O. williamsi* and all sites sampled.

<u>Habitat Characteristic</u>	<u>At All Sites Sampled</u>	<u>At Sites with <i>O. williamsi</i></u>
Described as “clear” (very low turbidity)	84%	70%
No aquatic vegetation present	69%	91%
Cobble/boulder as dominant substrate	15%	39%
Stream width < 10 m	68%	87%

Table 8: Crayfish occurrence in pool habitats, by species.

Species (N, sites)	% found in pools*
<i>Cambarus hubbsi</i> (7, 1)	100%
<i>Orconectes longidigitis</i> (14, 4)	100%
<i>Orconectes meeki meeki</i> (536, 37)	76%
<i>Orconectes nana</i> (19, 1)	11%
<i>Orconectes neglectus neglectus</i> (1009, 39)	36%
<i>Orconectes ozarkae</i> (556, 22)	40%
<i>Orconectes palmeri longimanus</i> (1, 1)	100%
<i>Orconectes virilis</i> (1, 1)	100%
<i>Orconectes williamsi</i> (192, 23)	21%
<i>Procambarus</i> sp. (59, 1)	100%

*Includes collections assigned to pool or riffle habitats only.