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LIFE-HISTORY NOTES AND DISTRIBUTIONS OF CRAYFISHES (DECAPODA:CAMBARIDAE) FROM THE CHAGRIN RIVER BASIN, NORTHEASTERN OHIO[1]

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ABSTRACT. Stream crayfishes were collected from the Chagrin River watershed during 1963-65 to determine their distributional patterns and to gather life-history information. *Orconectes rusticus* (Girard 1852), probably introduced into the basin in the early 1930s, was the dominant pool-dwelling species in the Chagrin River and Aurora Branch. *Orconectes propinquus* (Girard 1852), was restricted to the head-water portions of the main stream, the East, the Aurora Branches, and their tributaries; amplexus of this species was observed in September and March. *Orconectes sanbornii sanbornii* (Faxon 1884), was caught at one locality; this is the first record of its presence in the watershed. *Orconectes virilis* (Hagen 1870), inhabited pools of the middle and upper portions of the East Branch and its tributaries; its presence in the basin may be a remnant of a more expansive distribution. *Orconectes immunis* (Hagen 1870), probably a prairie relict, was captured at 2 disjunct localities in the watershed and at 3 other sites in northeastern Ohio. These are the first records of this species in these areas. *Cambarus* (*Puncticambarus*) *robustus* (Girard 1852), was widely distributed and abundant in the pools and riffles of the smaller tributaries and in riffles of the larger streams. An undescribed species, related to Cambarus (*Cambarus*) *bartonii* (Fabricius 1798), was captured at 8 localities. Equal sex ratios occurred in populations of *O. virilis* and *C.* (*P.*) *robustus*, but *O. rusticus* and *O. propinquus* had unequal ratios of 1.30:1 and 1.49:1 (male:female), respectively.

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INTRODUCTION

Ortmann (1924) captured *Orconectes propinquus* (Girard 1852) and *Cambarus* (*Puncticambarus*) *robustus* (Girard 1852) from the Chagrin River in 1920. Turner (1926) cited Ortmann's records, but apparently did not investigate the river system himself. When Rhoades (1944b) published a supplement to Turner's paper, he mentioned the presence of *Orconectes rusticus* (Girard 1852) in Geauga County.

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Before 1963, 3 species of crayfish had been recorded from the river system.

During 1963 and 1964, I collected 2 additional species from the drainage: *Orconectes virilis* (Hagen 1870) and *Orconectes immunis* (Hagen 1870). It became apparent that the Chagrin River system had one of the highest diversity indices of crayfishes of any Ohio stream. This investigation was initiated to determine (1) if additional species might be present, (2) the current spatial distribution of crayfishes in the basin, (3) what physical and/or biotic factors might affect their distributional patterns, and (4) to collect information on habitats, sex ratios, breeding, and crayfish associates for each species.

STUDY SITE

The Chagrin River watershed is located in northeastern Ohio, approximately 24 km east of Cleveland. It drains 692 ha of land (Frost et al. 1959) in parts of Cuyahoga, Geauga, Lake, and Portage counties. The main stream is approximately 77 km long (Frost et al. 1959) and has an average gradient of 7.9 m/km. The lowest 8.9 km of the river transverses the Lake Plain, part of the Central Lowland physiographic province, whereas the remainder flows upon the Glaciated Allegheny Plateau (Fenneman 1938). Additional information on the bedrock geology (Pedry 1961), Pleistocene geology (Baker 1957), forest communities (Ohio Division of Water 1959, Gordon 1969), and physical and chemical properties of the surface waters (Ohio Division of Water 1953) is available for this watershed.

METHODS AND MATERIALS

Incidental collections of crayfishes were made during 1963 (6 sites) and 1964 (5 sites). A systematic investigation of 118 additional localities was made between 29 August and 20 September 1965. This time was chosen because most males would be first form, or breeding, individuals. Such individuals are essential for unambiguous species identification.

A total of 129 localities were investigated (fig. 1). Habitat data and specimens were collected at 121 localities and habitat data only at 8 localities because specimens could not be found. Each locality was sampled for at least one hour. Immediately thereafter, the locality was marked on a 7.5 min topographic map of the United States Geological Survey (1961 series) and habitat data were recorded on a field sheet similar to Trautman's (1957).

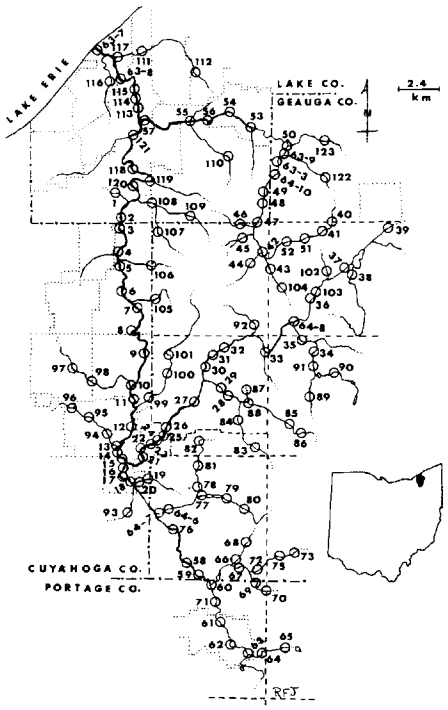

FIGURE 1. Localities investigated in the Chagrin River basin, northeastern Ohio. 1965 field collection numbers are given unless preceded by a prefix indicating 1963 (63–) or 1964 (64–). Political boundaries: dot-dashes, a county line; dashes, a township line; dots, a city limit.

A total of 4,260 crayfishes was collected and identified, using both the taxonomic keys of Turner (1926) and the reference collection at the Ohio State University Museum of Zoology. The nomenclature of Hobbs (1974) was followed. All specimens were catalogued and deposited in the crayfish collections of The Ohio State University Museum of Zoology (OSUMZ), and all field notes and maps associated with the study were deposited in the museum's archives. The method of Freund et al. (1960) was used to determine if differences in sex ratios were statistically significant at the 0.05 level ($Z_{0.05} = 1.96$). The given ratios are the proportion of males to females. Sample sizes of less than 50 individuals could not be validly analyzed because a maximum permissible error of 0.10 was arbitrarily chosen to determine the statistical significance of the proportion.

Orconectes rusticus
(Girard 1852)

HABITAT. The 16 collections containing more than 50 individuals each came from permanently flowing streams that were between 4.6 m and 18.3 m wide, had pools 0.5 m–1.2 m deep, and had moderate to low gradients (see Trautman 1957 for a discussion of stream gradient). The pools ranged from well defined to poorly defined, all with current. They contained substrates primarily of silt, sand, and some gravel and cobbles. Algae (primarily *Spirogyra* and *Cladophora*) was usually abundant and pollution, determined by smell and the appearance of the water, was generally absent.

The microhabitat of *O. rusticus* was pools containing substrates of silt, sand, gravels, and some cobbles. Specimens with a total carapace length of 2.5 cm or greater were commonly captured in the deepest parts of pools among cobbles, whereas the smallest individuals were most often taken from the shallowest waters of the pools where gravel formed the substrate. Individuals of intermediate size were the most randomly distributed members of the population.

Elsewhere in its range, *O. rusticus* is common in flowing streams with limestone bottoms. Rhoades (1944b) reported that it has a "preference for limestone habitats" and might be successfully introduced into non-limestone streams, such as the Chagrin River, provided that there exist "'islands' of limestone in an area of silicious rock." Pedry (1951) found iron carbonate concretions in the shales outcropping in the Chagrin River basin, but these carbonates are probably quickly neutralized by the acidic shales. The abundance of *O. rusticus* in the Chagrin River system is unexpected if limestone is a necessary part of its habitat. Lime is present in the glacial till overlying most of the watershed and these deposits may provide the calcium carbonate that this species seems to require (J. L. Forsyth, pers. comm.).

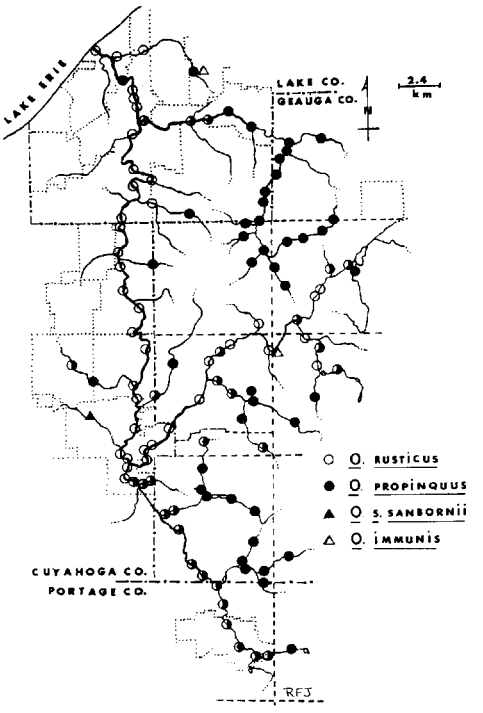

FIGURE 2. Chagrin River distribution of *O. rusticus*, *O. propinquus*, *O.s. sanbornii*, and *O. immunis* during 1963-65. Half-shaded circles indicate that both *O. rusticus* and *O. propinquus* were captured at the site. Political boundaries are the same as in fig. 1.

SEX RATIO. A total of 2,117 specimens of *O. rusticus* was captured and preserved during this study. Except for 17 individuals whose sex could not be determined because of their small size, 1,188 (56.6%) of the specimens were males. The result of a statistical testing indicates that an equal sex ratio should be rejected ($Z = 6.02$). The ratio was 1.30:1. Why males were more often captured than females is unknown.

BREEDING. Of the 1,188 males, 524 (50.0%) were first form individuals. These data suggest that the molt producing first form males begins in the late summer and that *O. rusticus* has a breeding cycle similar to that of *O. obscurus* (Hagen 1970), *O. limosus* (Rafinesque *1817)*, and *O. pro-*

pinquus (Girard 1852), (Ortmann 1906, Crocker 1957, Van Deventer 1937).

CRAYFISH ASSOCIATES. *Orconectes rusticus* was most often captured alone (31 sites), with *O. propinquus* (24 sites), with *O. immunis* (one site) with *C. (P.) robustus* (21 sites), and with *C. (C.) sp. A* (12 sites). The species and *O. propinquus* inhibit similar types of pools and, numerically, *O. rusticus* appears to be replacing *O. propinquus*. When *O. rusticus, Cambarus (C.) sp. A,* and *O. immunis* occurred at the same site, *O. rusticus* was most abundant in the pools, whereas *C. (P.) robustus* inhabited the riffles, *C. (C.) sp. A.* was found in small seeps away from the main stream, and *O. immunis* was in a backwater pool.

DISTRIBUTION. *Orconectes rusticus,* captured at 62 localities, was the most abundant and widely dispersed crayfish in the parent stream, in the Aurora Branch, and in the lower section of the tributaries of these streams (fig. 2). The species was seldom captured in headwater regions, although 2 exceptions were noted: sites 82 and 83. The individual at 82 (OSUMZ 1156) is a possible hybrid between *O. rusticus* x *O. propinquus.*

The first record of *O. rusticus* in the Chagrin River system appears to be specimens captured at the Chagrin Falls Fish Hatchery by E. L. Wickliff during the 1930s (Langlois 1936, Rhoades 1937, 1944b). During these years, quantities of crayfishes were stocked into Ohio streams to provide food for game fishes by personnel of the Ohio Department of Wildlife (Rhoades 1944b). Most of the crayfishes stocked into northeastern Ohio streams came from the Lake St. Mary's Fish Hatchery, Auglaize County, Ohio, where *O. rusticus* was cultured for fish food (M. B. Trautman, pers. comm.). *Orconectes rusticus* was probably introduced one or more times into the Chagrin River system during the stocking programs and, apparently, one or more of these introductions was successful. Rhoades (1944b) pointed out that "successful introductions [of *O. rusticus*] are apparently rather rare."

Orconectes propinquus
(Girard 1852)

HABITAT. At localities from which 30 or more individuals were captured, the stream was 1.8 m–10.7 m wide, usually 15 cm–0.9 m deep, and had moderate to high gradients. The pools were chiefly well defined, with moderate current, and had substrates of sand, gravel, and cobbles. Algae (primarily *Spirogyra*) was abundant and pollutants were non-evident.

The primary microhabitat of the species was pools containing substrates of gravel and cobble. Individuals having carapace lengths >2.5 cm were captured usually in the deepest parts of the pools among cobbles, whereas smaller indivduals were caught consistently in the shallowest water of the pools where gravel was the substrate. The gravel areas of the pools seemed to be nursery areas for the juveniles. When gravel, cobbles, and other types of cover were absent in the pools, the species was captured in the riffles where cover was present.

Elsewhere in its range, *O. propinquus* inhabits rivers and streams having flowing waters free of suspended silt and substrates consisting of gravel and cobble (Van Deventer 1937, Creaser 1931, 1932, Bovbjerg 1952). Individuals are occasionally collected from dense mats of aquatic vegetation (Creaser 1931, 1932). The species also inhabits lakes, "especially the larger lakes with clean shores where there is considerable wave action" (Turner 1926).

SEX RATIO. A total of 1,401 *O. propinquus* was collected and 836 (59.6%) were males. The analysis of sex ratios indicated that an equal ratio should be rejected ($Z = 7.24$). The ratio is 1.48:1. These data are considerably different from those of Creaser (1933a), who found percentages of 36% and 34% males during August and September 1931 and 44% during September 1932, and from Van Deventer (1937) who reported 50% during September 1936. The reason or reasons for

these fluctuating sex ratios have not been explained.

BREEDING. A total of 836 males were collected, of which 533 (63.7%) were first form. First form males were more abundant than second form males at 40 of the 62 localities where this species was captured. These data suggest that the first form molt probably occurs during August and September in the Chagrin River system as it does in Michigan (Creaser 1933b). The exact period of molt cannot be determined, however, because the system was not investigated throughout the year.

Amplexus of the species was noted twice: at 12:30 P. M. on 8 September, and at 3:20 P. M. on 23 March. My field observations were in agreement with the excellent description of amplexus of *C. affinis* (= *O. limosus*) reported by Andrews (1895). The 8 September amplexus data occurred during the late-August-to-early-September mating period reported by Turner (1926) and Van Deventer (1937), but was considerably earlier than the October-to-November period reported by Creaser (1933b) for this species in southern Michigan. The 23 March date apparently belongs to the early spring period during March suggested by Van Deventer (1937). In the Chagrin River watershed, there is a fall mating period probably beginning in mid-August and continuing through September, perhaps into October and November, depending upon weather conditions, and a spring period during March. There are no substantiated records of this species, or any other northern crayfish species, mating during the winter (McManus 1960).

Two crayfishes, one first form male (OSUMZ 1051) and one female (OSUMZ 1156), may be hybrids between *O. propinquus and O. rusticus* (D. H. Stansbery, pers. comm.). Sites 60 and 62 also appear to contain hybrids.

CRAYFISH ASSOCIATES. *Orconectes propinquus* was captured alone at 10 sites, with *C.* (*P.*) *robustus* (38 sites), with *O. rusticus* (24 sites), with *O. virilis* (9 sites), with *C.* (*C.*) *sp. A* (5 sites), and with *O. immunis* (1 site). When *O. propinquus* and *C.* (*P.*) *robustus* occurred together, large individuals of *O. propinquus* were consistently captured in the pools, whereas smaller indivuals of *O. propinquus* and all individuals of *C.* (*P.*) *robustus* were taken from the riffles. Crocker (1957) observed that *C.* (*P.*) *robustus* was the most frequent associate of *O. propinquus* in New York State streams. *Orconectes propinquus* and *O. virilis* have similar habitat preferences (Creaser 1931, 1932) and co-inhabited many pools of the upper and middle sections of the East Branch and its tributaries.

The presence of *O. rusticus* was an important factor influencing the abundance of *O. propinquus* (table 1). Where few *O. rusticus* were present, as in headwaters or smaller tributaries, *O. propinquus* was usually abundant; where *O. rusticus* was abundant, as in the main stream channel, *O. propinquus* was absent, or present only in small numbers. This suggests that *O. rusticus* is probably replacing *O. propinquus*. When *O. propinquus* and *O. rusticus* were caught in the same seine hauls, *O. propinquus* usually remained motionless in the net, while *O. rusticus* was aggressive. If this aggressiveness occurs in their normal environment, *O. rusticus* might be able to exclude *O. propinquus* from hiding places which could result in a greater mortality rate in the *O. propinquus* population due to predation.

DISTRIBUTION. *Orconectes propinquus* was the most frequently captured crayfish, taken at 69 (46.9%) localities, and was the most widely distributed species in the Chagrin River system during the study (fig. 2). The absence or small number of *O. propinquus* in the main stream appears to be a recent event. Ortmann (1924) collected this species in the Chagrin River proper, the Aurora Branch, and the East Branch during 1920 and makes no mention of the presence of *O. rusticus*. It is reasonable to assume that *O. propinquus* was formerly the dominant stream crayfish of the river system. Perhaps only after the

TABLE 1

Localities where O. propinquus *and* O. rusticus *were collected together from the Chagrin River watershed.*

	O. propinquus					*O. rusticus*					
Collection	*I*	*II*	*M*	*F*	*T*	*I*	*II*	*M*	*F*	*T*	Locality
64-6	4	1	5	5	10	9		9	4	13	McFarland Creek
64-7		1	1	1	2		18	18	9	27	McFarland Creek
64-8		1	1		1		11	11		11	Chagrin River
18	1		1		1	5	58	63	52	115	Aurora Branch
19	8	1	9	4	13	3	5	8	8	16	Tributary, Aurora Branch
20	3	1	4	1	5	2	7	9	11	20	Tributary, Aurora Branch
28	1	1	2	5	7	18	17	35	28	63	Silver Creek
29	1		1		1	10	24	34	19	53	Silver Creek
34	1	2	3	10	13	3	22	25	14	39	Tributary, Chagrin River
37	2	11	13	20	33	1	1	2	4	6	Chagrin River
55	17	1	18	4	22	6	2	8	5	13	East Branch
56	32	9	41	29	70		1	1	2	3	East Branch
57	3	2	5	2	7	9	12	21	15	36	East Branch
58	4	1	5	3	8	4	7	11	10	21	Aurora Branch
59	2		2	1	3	4	10	14	12	26	Aurora Branch
60	1		1	3	4	22	26	48	17	65	Aurora Branch
61	15		15	4	19	5	3	8	7	15	Aurora Branch
62	6	2	8	7	15	4	8	12	13	25	Aurora Branch
63		2	2	2	4				1	1	Aurora Branch
64	27	1	28	9	37	1		1		1	Aurora Branch
71	5	3	8	9	17	13	11	24	11	35	Aurora Branch
76	3	2	5	3	8	8	7	15	12	27	Aurora Branch
83	2	1	3	3	6	3	3	6	4	10	Silver Creek
90	1		1	4	5	2	1	3		3	Tributary, Chagrin River
97	47	4	51	48	99	2		2	2	4	Tributary, Chagrin River
99	9		9	4	13				4	4	Griswold Creek
102	2	3	5	5	10		2	2	2	4	Tributary, Chagrin River

I = First form males, II = Second form males, M = Total males, F = Total females, T = Total number of specimens

introduction and increase in abundance of *O. rusticus* has *O. propinquus* become restricted to the smaller streams.

Orconectes sanbornii sanbornii (Faxon 1884)

HABITAT. This species was taken from only site 95 in Willey Creek (fig. 2). At this locality, the stream was approximately 7.6 m wide, had a maximum pool depth of 30 cm, and a high gradient. The riffles had moderately fast currents and a shale bedrock substrate. The pools had some current, a substrate of pea-sized gravel, and some organic pollution, which was detected by the smell of hydrogen sulfide and the presence of a bacterial scum along the banks. No other crayfishes were found associated with the species. Other localities in the watershed appear to contain favorable habitats for this species, but apparently there are unrecognized physical and/or biotic factors acting against its further dispersion. Perhaps it was recently introduced into the system and has not had the opportunity to spread, or it may not be able to compete with the established populations of *O. propinquus* and *O. rusticus*.

BREEDING. Five first form males were captured on 15 September 1965. Their molt did not appear to be recent because their carapaces were darkened (Van Deventer 1937). This suggests that the autumn molting period in the Chagrin River population is similar to the molting period elsewhere in Ohio (St. John 1976, Fielder 1972).

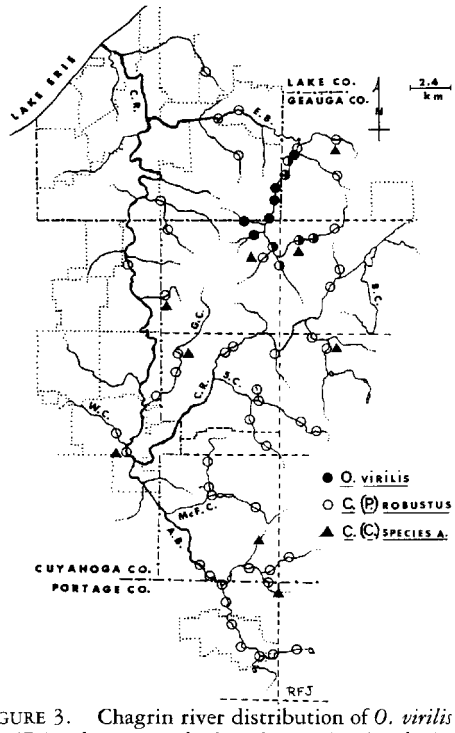

FIGURE 3. Chagrin river distribution of *O. virilis*, *C. (P.) robustus*, and *C. (C.) species A.* during 1963-65. Major streams are indicated: C. R. – Chagrin River; E. B. – East Branch; W. C. – Willey Creek; G. C. – Griswold Creek; S. C. – Silver Creek; B. C. – Beaver Creek; A. B. – Aurora Branch; and McF. C. – McFarland Creek. Political boundaries are the same as in fig. 1.

DISTRIBUTION. *Orconectes s. sanbornii* has not been previously reported from the Chagrin River watershed. A natural occurrence, however, should not be dismissed because it has been recorded from the neighboring Cuyahoga River system (Turner 1926).

Elsewhere in the state, the species is the most common crayfish in streams of the Ohio River drainage from the Ohio Brush Creek in Adams County (Rhoades 1944a) upstream to the southern boundary of the Flushing Escarpment in Monroe County (Turner 1926). It has also entered the Lake Erie drainage in the northcentral region of the state and is found in streams from Sandusky Bay eastward to, and including, the Cuyahoga River (Fitzpatrick 1967), and now the Chagrin River.

Orconectes virilis (Hagen 1870)

HABITAT. This species was captured in only 9 pools of the upper and middle portions of the East Branch and its tributaries (fig. 3). During the investigation, these permanent pools were approximately 0.6 m–9 m wide; had minimum depths of at least 0.6 m; usually contained substrates of cobble, gravel, and sand; had moderate to high gradients; were generally well defined with some current or poorly defined with moderate current; contained cool, clear water with suspended silts and other pollutants being nonevident. The only aquatic vegetation was algae (*Spirogyra*).

The East Branch habitats of *O. virilis* were similar to its habitats in Michigan (Creaser 1931), Wisconsin (Creaser 1932), and Nebraska and Eastern Colorado (Engle 1926). Elsewhere, however, it occupies polluted (Schwartz et al. 1963), and silt-laden streams (Crocker 1957), and lakes (Huntsman 1915). It is apparent that *O. virilis* can adjust to a variety of environmental conditions.

SEX RATIO. Of the 60 specimens captured, 29 (48.3%) were males. The sex ratio is 1:1.08 with no significant deviation from a 1:1 ratio ($Z = 0.25$).

BREEDING. On 2 September 1965, 3 first form males were captured. This suggests an autumn molting period similar to that reported by Momot (1965).

CRAYFISH ASSOCIATES. *Orconectes virilis* was captured with *O. propinquus* (9 sites), *C. (P.) robustus* (4 sites), and *C. (C.) sp. A* (1 site). When *O. virilis* and *O. propinquus* occurred together, they occupied different microhabitats. For example, at site 47, the largest *O. virilis* were captured from the deepest water, whereas the smaller *O. virilis* and numerous large and small *O. propinquus* were caught in the peripheries of the pools where the water was <0.6 m in depth. The smallest individuals of both species were captured in water usually <15 cm in depth, on a substrate con-

sisting of an abundance of cobble and gravel. This microhabitat segregation was observed in every pool containing these 2 species.

A number of factors could cause this segregation. Roberts (1954) stated that, if temperature, oxygen concentration, and pH are fluctuated within normal environmental limits, light intensity is the environmental factor capable of regulating movements in *O. virilis* populations. Sex, size, and the physiological state of the crayfish is also important (Momot 1965), as is the behavior of the species. Bovbjerg (1953) found that a dominance order exists in *O. virilis* populations, large sized individuals were dominant over smaller individuals. He (Bovbjerg 1961) also observed a habitat separation between members of this species and those of *O. i. immunis* in Iowa streams and concluded that interspecific behavioral differences were factors causing this segregation.

In the East Branch, probably the largest *O. virilis* were found in the deepest waters because they respond negatively to light (Roberts 1954), and they dominate smaller individuals of either species. Large *O. propinquus* were confined to the peripheries of the pools because they are "undoubtedly positive to sunlight" (Van Deventer 1937). The smallest individuals of both species utilize the only remaining microhabitats — the shallowest waters of the pools.

DISTRIBUTION. The uniqueness of this species in the Chagrin River watershed has been noted (Jezerinac 1974). A recent introduction of this species into the East Branch might explain its presence, since it has been successfully introduced elsewhere (Hobbs 1974). However, 3 factors suggest that the East Branch populations may be remnants of a more expansive distribution. First, the species has been recorded to the north of the watershed in Ontario (Crocker and Barr 1968), to the east in New York state (Crocker 1957), and to the northwest in Michigan (Creaser 1931). These surrounding populations appear to be natural populations rather than introductions. Second, a more northern environment similar to central Michigan and southern Ontario exists in the East Branch area, as evident by the existence of a hemlock-speckled alder (*Alnus rugosa*)-yellow birch (*Betula lutea*) community (Braun 1961). Third, a relict population of brook trout (*Salivelinus fontinalis*), one of the few natural populations of this species in the state, occurred in the East Branch (Kirtland 1838) and *O. virilis* is an associate of these trout in northern areas (Creaser 1931, Momot 1967). It seems significant that only 2 streams in northeastern Ohio contain brook trout and that one stream also has its natural crayfish associate. The other stream, Conneaut Creek, should be investigated to determine if *O. virilis* is present.

Orconectes immunis (Hagen 1870)

HABITAT. This species was taken at 2 disjunct localities (fig. 2). The first site was a small unnamed tributary in Mentor Township, Geauga County. The stream was approximately 1.8 m wide, had a maximum pool depth of 0.6 m, a moderate to low gradient, and consisted of one sluggish riffle and one pool without current. The substrate consisted primarily of sand and gravel. Organic pollution from a nearby pasture was evident by the odor of the water and the presence of an alga (*Spirogyra*) scum. There was an abundance of aquatic vegetation consisting of *Chara*, cattail (*Typha*), and bur reeds (*Sparganium*).

The second locality was a backwater area off the main stream in Newbury Township, Geauga County. This essentially lentic habitat was approximately 6.1 m in length, 3.0 in width, and had a maximum depth of 0.5 m. The substrate was silt and some sand. Aquatic vegetation, especially *Anacharis* and cattail, was abundant. Nine specimens of *O. immunis* were captured in this area, whereas one *O. propinquus* and 11 *O. rusticus* were taken from the adjacent main stream.

The primary microhabitat of *O. immunis* appeared to be pools of low gradient streams with an abundance of aquatic vegetation and substrates of silt and sand. This microhabitat is similar to those of this species in other parts of Ohio (Turner 1926), and elsewhere in its range (Engle 1926, Creaser 1931, 1932, Rhoades 1944a, Forbes 1876). Its microhabitat in the Reelfoot Lake area in Tennessee, however, is different (Hobbs and Marchand 1943).

Although *O. immunis* was collected at only 2 localities, other stations appeared to contain favorable habitats, especially in Beaver Creek and in most headwater portions of the Aurora Branch. This apparent absence of the species elsewhere in the watershed might be the result of interspecific competition with *O. propinquus* and *O. rusticus*.

BREEDING. No first form males were captured on 21 March 1966, but 4 were collected on 11 June 1964. This early date, compared with the occurrence of first form males of *O. propinquus, O. s. sanbornii, O. rusticus,* and *O. virilis* in August and September, indicates an early summer breeding season for *O. immunis*.

CRAYFISH ASSOCIATES. In the Chagrin River watershed, *O. immunis* was captured with *O. propinquus* at one site and with *O. propinquus, O. rusticus,* and *C. (P.) robustus* at the second site. In streams on the Lake Plain (see below), *O. immunis* either had no associates (Arcola Creek) or was captured with *O. propinquus* (Heisley and Cowles Creek).

DISTRIBUTION. *Orconectes immunis* has not been previously recorded from this watershed. In addition, during March 1966, 31 localities were sampled on the Lake Plain between the eastern Lake County line and the Ohio-Pennsylvania state line, and the species was caught at 3 sites: the East Branch of Arcola Creek, Ashtabula County, Geneva Township (OSUMZ 2021–6 specimens); an eastern tributary of Cowles Creek, Lake County, Mentor-on-the-Lake (OSUMZ 2016–4 specimens), and a tributary of Heisley Creek, Lake County, Mentor (OSUMZ 2018–3 specimens). There appeared to be a decrease in suitable habitat for this species eastward due to a decrease in width of the Lake Plain and a corresponding increase in stream gradients. Ortmann (1906) failed to capture this species in Pennsylvania, but Crocker (1957) collected it from low-gradient streams of the Lake Ontario drainage in New York state.

The present distribution of *O. immunis* is extensive (Hobbs 1974) and is centered in southern Illinois (Crocker and Barr 1968). Forbes (1876) commented on the abundance of this species in prairie ponds in central Illinois, and Tack (1941) stated that it can easily migrate overland from one pond to another. Thus, the ecology and distribution of *O. immunis* appears to be associated with prairie environments. The Chagrin River and other northeastern Ohio populations may be the remnants of prairie communities that existed along the southern shores of Lake Erie (Trautman 1957) during the xeric period dated at 10,000–4,000 years B.P. (Wright 1970), following the Wisconsin glacial stage. If *O. immunis* did enter Ohio during this time, Crocker's (1957) suggestion that the species entered New York State from the east during Lake Lundy or Lake Iroquois time must be rejected as too early because Lake Lundy occurred before 12,500 years B.P. (Forsyth 1973).

Turner (1926) has suggested that *O. immunis* is currently moving eastward in northern Ohio. Such a movement might be prohibited at present because of the lack of suitable habitats along the Lake Plain and Glaciated Allegheny Plateau.

Cambarus (Puncticambarus) robustus Girard 1852

HABITAT. The species was most numerous in the smaller, permanently flowing tributaries and headwaters, especially the Aurora and East Branch, that were <3.0 m in width, <0.3 in depth, and had

moderate to high gradients. Most of these sites had riffles that were well defined with substrates of cobble, or poorly defined with substrates of bedrock and gravel. The pools were either poorly defined with considerable current, well-defined with some current, or plunge pools beneath small waterfalls. The water was usually cold, or cool, and free of suspended silts and pollutants. In these small streams, *C. (P.) robustus* was captured from under rocks in both the riffles and pools.

Numerous individuals were found in small depressions or in small burrows without chimneys underneath stones. These depressions were most frequently observed in the riffles, and consisted of "scooped-out" areas in the sand and gravel substrate. They were only slightly larger than the crayfish inhabiting them. The burrows were found in pools with current, and were approximately 2.5 cm in diameter and at least 5 cm in depth with one enlarged chamber at the bottom. Burrows were consistently seen under rocks lying on sand and gravel whereas they were only occasionally seen under those rocks lying primarily on gravel. Crocker (1957) noted similar burrow construction by this species in streams in New York State.

Besides the small riffles and pools described above, *C. (P.) robustus* was also captured infrequently in other habitats. For example, at 3 localities it was taken in stillwater pools where the stream gradient was low and the riffle environment was either absent or poorly defined. However, pools without current did not typically contain *C. (P.) robustus*.

Single specimens were captured in the riffles of the main stream at 6 localities. These riffles were 9 m – 12 m in width, 0.3 m or less in depth, and were generally short, poorly defined, with gravel substrates.

Ortmann (1906) stated that, in Pennsylvania, *C. (P.) robustus* inhabits the rough, rocky streams of large size and avoids headwaters. However, Creaser (1931), who investigated Michigan streams, found that this species typically inhabits headwaters. It appears that *C. (P.) robustus* occupies different habitats in the eastern and western parts of its range, with the Chagrin River habitats being intermediate between the two.

SEX RATIO. A total of 233 specimens was collected, of which 117 (50.2%) were males. The sex ratio does not significantly differ from an equal ratio ($Z = 0.06$).

BREEDING. Nine first form males (7.25%) were captured between 1 – 20 September. Ortmann (1906) and Crocker (1957) have captured first form males of *C. (P.) robustus* from April through October and have concluded that the species does not have a restricted molting nor breeding season.

CRAYFISH ASSOCIATES. *Cambarus (P.) robustus* was captured with *O. propinquus* (39 sites), *O. rusticus* (21 sites), *O. virilis* (6 sites), *O. immunis* (1 site), *C. (C.) sp. A* (5 sites), and alone at 5 sites. Although *C. (P.) robustus* was usually associated with members of the genus *Orconectes*, the species utilized a different microhabitat and has a dissimilar life cycle.

DISTRIBUTION. *Cambarus (P.) robustus* was captured at 53 of the 147 sites (fig. 3). Although it was widely distributed, fewer than 5 individuals were usually captured at any one locality. It was first recorded from the watershed by Turner (1926) from a small run in Lake County.

The species has been reported from 15 localities in Ohio (Turner 1926). Most records are from the northeastern and central portions of the state with one collection from the Ohio River in Lawrence County. Turner's 7 records of this species from the Scioto River drainage are probably *Cambarus (C.) sciotensis* Rhoades 1944b, a species not recognized as distinct from *Cambarus (C.) bartonii* until 1944. Rhoades (1944b) and Crocker (1957) both suggest that the Lawrence County and other Ohio River drainage records may be *C. (C.) sciotensis*.

Cambarus (Cambarus)
Species A.

HABITAT. Fourteen individuals were captured that are distinct from, but probably related to *C. (C.) bartonii* (Fabricius 1798). These individuals were initially identified and catalogued as *C. b. bartonii* (Fabricius 1798) or *C. b. laevis* (Faxon 1914) during the study. They were captured in small tributaries at 8 different localities (fig. 3). Diverse environmental conditions were encountered at these sites. However, the largest collection (site-70), 6 individuals, was from an intermittent stream in the pool stage in the headwaters of the Aurora Branch. The pool was approximately 1.8 m wide, had a maximum depth of 0.8 m, and had a substrate of silt with some clay and sand. A slight amount of gasoline and organic pollution was evident, and algae (*Spirogya*) was the only aquatic vegetation present. Crayfish burrows without chimneys were present in the clay substrate. No other crayfishes were associated with these individuals.

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