

CRAYFISHES OF THE GENUS CAMBARUS IN NEBRASKA AND EASTERN COLORADO

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INTRODUCTION

The morphology of the crayfish has been studied in most elementary courses of zoology since the inception of the type method of study with Huxley's *Anatomy of Invertebrated Animals* in 1877. Previous to this (in 1878) Huxley had published a comprehensive treatise on the classification and distribution of the crayfish. Field observations in the United States began as early as 1852, when Girard investigated the habits of certain species and did some preliminary work on the geographical distribution of the family *Astacidae*. This type of field observation was soon replaced by the taxonomic work of many writers, which resulted in the monographs of Hagen (1870) and Faxon (1885a) and in the numerous State surveys, of which the earliest were those of Forbes (1876) for Illinois, Bundy (1877) for Wisconsin, Herrick (1882) for Minnesota, and Hay (1896) for Indiana. With the exception of the crayfish surveys for Missouri (Steele, 1902) and Kansas (Faxon, 1885b; Harris, 1900), no work has been done up to this time within the States of the Missouri River drainage system.

In addition to the numerous studies on the taxonomy and geographical distribution of crayfishes, much work has been done in physiological experimentation with these animals. Powers (1914), Bell (1906 and 1906a), and others have used various species of crayfishes in experimental work, and others will doubtless use them for ecological investigation. They are very hardy and more easily kept in the labora-

tory than are many fishes, and they are easily obtainable in any locality. The present account gathers the literature relating to the species of crayfishes of these States, and gives a certain amount of information based on the author's studies in the field.

METHODS

The field work in this investigation extended from March 15 to October 30, 1922, and from April 15 to October 6, 1923. During that time several areas of relatively easy accessibility were studied intensively, while only a few hours or a day were devoted to others. It is felt, however, that the records furnish an accurate account of the distribution and habits of the genus *Cambarus* in Nebraska and eastern Colorado.

Occasionally collections were made with a net in open ponds and creeks, though, except in the evenings, this method gave only immature specimens. The most fruitful though often laborious and certainly not aesthetic method is to dig into a burrow that gives evidence of habitation, with the hands or with the aid of a small trowel, and capture the animals. Although this method is slow and difficult it yields a specimen in almost every instance, and permits a study of the nature of the soil in which the burrow is located and of the type of burrow made by each species. In addition to this, it permits the collector to work throughout the day, as the crayfishes are always to be found in their burrows save in the early morning and in the evening, when they are in the water feeding. In the case of the creek and river species (as *Cambarus propinquus*) a minnow trap was used successfully.

ACKNOWLEDGMENTS

An investigation of the crayfishes of Nebraska was first begun at the suggestion of Dr. Robert H. Wolcott, chairman of the department of zoology of the University of Nebraska, and was later extended to the crayfishes of Colorado through the encouragement of Dr. Francis Ramaley, head of the department of biology of the University of Colorado. To both of these gentlemen I am greatly indebted for their helpful suggestions and for laboratory facilities. I desire also to thank Dr. T. D. A. Cockerell, of the University of Colorado, for the loan of literature, which was not otherwise available; Dr. A. W. Meyer, of Stanford University, for reading the manuscript and for suggestions; Dr. E. B. Powers, now head of the department of zoology of the University of Tennessee, for assistance in collecting and for the loan of literature; and Gayle Pickwell, of the department of zoology of Northwestern University, for assistance in collecting.

DESCRIPTION OF SPECIES, WITH KEY TO SUBGENERA AND SPECIES

The first record of a crayfish from Nebraska is by Faxon (1885a)—“one species, *C. virilis*, from Omaha.” Faxon (1898) also reports *C. virilis* and *C. immunis* as being in the collections of Seth E. Meek in the United States National Museum, bearing the locality label of “Blue River, Crete County, Nebr.,” and a specimen of *C. immunis* from South Bend, Case County, Nebr.

Girard (1854) reported a new species, collected at Fort Pierre, which is in the present State of South Dakota and which he named *Cambarus nebrascensis*. Faxon regards this species as the western form of *C. diogenes*.

The previous records of the Colorado species are no more abundant. In the collections of Seth E. Meek, mentioned by Faxon (1885a and 1898), is a specimen of *C. diogenes* bearing the label "Clear Lake, Colorado." This is probably Clear Lake in Lake County, west of Denver, as the other locality by that name is in San Juan County in the more arid Southwest.

Harris (1903) reports a specimen of *C. diogenes* from the St. Vrain River near Boulder, Colo. Ortmann (1906) says "Prof. T. D. A. Cockerell has sent me for examination a young male, collected October 7, 1905, in a small stream near Boulder." This specimen was also *C. diogenes*. During 1912 and 1913 Dr. Max M. Ellis made collections at Boulder and in other parts of Colorado while working on the "Fishes of Colorado," but he did not publish his records. These records were placed at my disposal by Dr. Francis Ramaley.

While the previous records give but one species for Colorado and two valid species for Nebraska, the present investigation has given eight species for the two States, two of these being found only in Nebraska, two only in Colorado, and four being common to both States.

According to Ortmann (1906, p. 407), the genus *Cambarus* is divided into four subgenera. Three of these are represented in Colorado and two in Nebraska.

In the following key and description of species the male of Form I is used; that is, the condition of the adult male before the autumn molt has taken place.

KEY TO THE SPECIES

- a. First pair of abdominal appendages of male short, truncate at tip, outer part ending in one to three horny teeth, inner part terminated by acute spine. Hooks present on third periopod of male.----- Subgenus *Cambarus* (sens. strict.) Ortmann.
 Represented by one species. Outer half of first pleopod of male with two terminal teeth, both alike; shoulder on anterior margin of pleopod. Rostrum without marginal teeth.----- *C. (Cambarus) simulans* Faxon.
- aa. First pair of abdominal appendages of male generally slender, each division of the appendage bearing a more or less elongate spine.----- Subgenus *Faxonius* Ortmann.
- b. Rostrum with median keel.
- c. First abdominal appendages of male reaching to third periopod; rostral keel often indistinct.----- *C. (Faxonius) propinquus* Girard.
- cc. First abdominal appendages of male reaching to the first periopod. Rostrum with distinct keel; margins of rostrum subparallel.----- *C. (Faxonius) neglectus* Faxon.
- bb. Rostrum without median keel and without spines. Carapace with lateral spines.
- d. First abdominal appendage of male long and deeply bifid, reaching to base of chela; branches slender, the outer branch long, inner branch with spoon-shaped tip.----- *C. (Faxonius) virilis* Hagen.
- dd. First abdominal appendage short, with sharply recurving tips. Inner face of immovable finger of chela thickly covered with hair. Tufts of hair on second periopod.----- *C. (Faxonius) immunis* Hagen.
- bbb. Rostrum without median keel but with marginal spines. Chela and first abdominal appendage of male as in *C. immunis*.----- *C. (Faxonius) immunis spinirostris* Faxon.
- aaa. First abdominal appendage of male short and thick, inner and outer parts each terminating in only one short and thick, strongly recurved spine, which is set at right angles to long axis of appendage.----- Subgenus (*Bartonius*) Ortmann.
- e. Inner finger of chela without excision at base; outer finger not bearded. Areola obliterated in middle.----- *C. (Bartonius) diogenes* Girard.
- ee. Inner finger of chela with deep excision at base; outer finger bearded. Extremity of inner tooth of first abdominal appendage of male long and slender. Areola obliterated in middle.----- *C. (Bartonius) argillicola* Faxon.

CAMBARUS (CAMBARUS) SIMULANS FAXON

Cambarus simulans, Faxon, 1885, p. 112; Faxon, 1885a, p. 48.

Cambarus (Cambarus) simulans, Ortmann, 1905a, p. 105.

Male, Form I.

"Rostrum broad, deeply excavated; margins raised into sharp crests which overhang the base of the sides of the rostrum, converging, sinuated before the tip to form the short acumen; no lateral spines; the acumen is barely margined. Post-orbital ridges subacute in front, divergent and ending in slight callosities behind. Carapace ovate, narrowing in front, gastric area smooth, cardiac area lightly punctate, sides granulate; anterior border notched behind the antennæ; cervical groove sinuate, split on the sides, with a minute terminal branchiostegian spine; no lateral spine; areola more than one-half as long as the distance from the point of the rostrum to cervical groove, narrow, carinate, expanding into an anterior and a posterior triangular field; * * *. Chela long, slender, squamoso-tuberculate, internal margin long, straight, strongly dentate; fingers long, punctate, external border of movable finger tuberculate, inner border of both fingers toothed, a prominent tubercle near the base of external finger opposite a more or less clearly marked incision in the base of the thumb. * * *. Third pair of legs hooked. First pair of abdominal appendages strong, straight; internal part with a very small, straight apical spine, which does not reach the end of the external part; external part with two horny terminal teeth, one of which is flat and disk-shaped, the other slender and somewhat curved." (Faxon, 1885, p. 112.)

Colorado locality.—One collection from the north fork of the Smoky Hill River, near Oriska, Kit Carson County. I have been unable to obtain this specimen. Place records are from the records of the Museum of the University of Colorado, noting a single collection of *C. simulans*, determined by Faxon, but the specimens have been lost.

CAMBARUS (FAXONIUS) PROPINQUUS GIRARD

Cambarus propinquus, Girard, 1854, p. 88; Hagen, 1870, p. 67, Pl. I, ff. 34-38, Pl. III, f. 153; Smith, 1874, p. 638; Forbes, 1876, pp. 4 and 19; Bundy, 1877, p. 171; Bundy, 1882, p. 181; Bundy, 1882a, p. 402; Faxon, 1885, p. 147; Faxon, 1885a, p. 91; Faxon, 1885b, p. 360; Faxon, 1890, p. 628; Hay, 1896, p. 497; Faxon, 1898, p. 651; Hay, 1899, pp. 960 and 962; Ortmann, 1905, p. 400; Pears, 1910, p. 16.

Cambarus (Faxonius) propinquus, Ortmann, 1905a, pp. 112 and 132.

Male, Form I.

Body small, not pubescent, few hairs on chelæ; rostrum long, narrow, margins thin, spines on anterior end of rostrum, posterior to acumen; acumen long and triangular; rostrum carinated; post-orbital ridges short, grooved on outer surface, spines short and acute; carapace subovate, depressed or flattened dorsally; cervical groove deep, slightly sinuate, broken on sides; areola broad and smooth; chelæ short, rounded, slightly pitted on surface; third periopods hooked; first pair of abdominal appendages short and spiral shaped; the free tips long and slender, not recurved; general color dark olive green; chelæ olive yellow, mottled with olive green; finger tips orange, followed proximally by band of citron yellow. This color character is quite constant.

Nebraska locality.—Coon Creek, Milford, Seward County, several colonies.

CAMBARUS (FAXONIUS) VIRILIS HAGEN

Cambarus virilis, Hagen, 1870, p. 63; Forbes, 1876, pp. 4 and 19; Bundy, 1877, p. 171; Herrick, 1882, p. 253; Faxon, 1885, p. 147; Faxon 1885a, p. 96; Hay, 1896, p. 499; Pearse, 1910, p. 17.

Cambarus (Faxonius) virilis, Ortmann, 1905a, pp. 112-113.

Male, Form I.

Body long, not very robust; rostrum broad, long, well excavated, with raised margins, lateral teeth prominent and acute; acumen long, slender, terminal spine sharp; post-orbital ridges grooved on outer edge, slightly swollen posteriorly, having an acute spine anteriorly; carapace cylindrical, pitted dorsally, granulate laterally; lateral spine on cervical groove; cervical groove deep, broken; areola of moderate width, posterior triangle much longer than anterior; chela strong, thickly punctuate, tips of fingers equal, decurved, horny, with small tubercles on cutting edges of both fingers, immovable finger pubescent; third pair of periopods hooked; first pair of abdominal appendages very long, reaching nearly to the base of second periopods, bifid, falciform, the external branch longer, with recurved chitinous tip, inner branch recurved, flattened and spatulate at tip.

Colorado localities.—South Platte River, near Julesberg, Sedgwick County; Republican River, Wray, Yuma County; St. Charles River, tributary of the Arkansas River near Pueblo, Pueblo County.

Nebraska localities.—Blue River, Milford, Seward County; creek 6 miles south of Grand Island, Hall County; Louisville (collected by Theodore Stander).

CAMBARUS (FAXONIUS) IMMUNIS HAGEN

Cambarus immuns, Hagen, 1870, p. 71; Forbes, 1876, pp. 4 and 19; Bundy, 1877, p. 171; Pearse, 1910, p. 81.

Cambarus signifer, Herrick, 1882, p. 253.

Cambarus (Faxonius) immuns, Ortmann, 1905a, p. 113.

Form I.

Body slender; rostrum broad at base, well excavated, very slightly decurved, margins raised, converging; no marginal spines; acumen blunt, with concave sides; post-orbital ridges grooved on lateral face, without spines; carapace smooth, flattened dorsally, granulate laterally; lateral spine small, cervical groove deep, broken; areola narrow in middle, anterior triangle small and indistinct, posterior triangle larger, not distinct; chela long and tapering, internal finger deeply excised at base, immovable finger heavily bearded; second periopods with dense tufts of hair on inner side of distal segments; third periopods hooked; first pair abdominal appendages reaching nearly to the base of second periopods, falciform, bifid, external branch longer, with strongly recurved chitinous tip, inner branch recurved, flattened, and spatulate.

Colorado localities.—Denver, Denver County; Dry Creek, near Boulder, Boulder County; St. Vrain, Weld County; Greeley, Weld County; Empire Reservoir, near Deerfield, Weld County; Fort Collins, Larimer County; Louisville Junction, Boulder County; Allens Lake, Boulder County; Castle Rock, Douglas County.

Nebraska localities.—Lincoln, Lancaster County, many vicinities; Grand Island, Hall County; State fisheries, Sarpy County; Seward, Seward County; Hanlon, Lancaster County; Humboldt, Richardson County, sent by Irving Moore; Cass County; Richardson County, sent by Theodore Stander; Atkinson, Holt County; Pleasantdale, Seward County; Havelock, Lancaster County; Roca, Lancaster County.

CAMBARUS (FAXONIUS) IMMUNIS SPINIROSTRIS FAXON

Cambarus immunis var. *spinirostris*, Faxon, 1885, p. 146; Faxon, 1885a, p. 99; Hay, 1896, p. 502; Pearse, 1910, p. 20.

Male, Form I.

Generally smaller than *C. immunis*; rostrum with small but acute lateral teeth; post-orbital spines well developed; lateral spines strong and acute; areola wider and slightly shorter than *C. immunis*; first abdominal appendages as in *C. immunis*.

Colorado localities.—Empire Reservoir near Deerfield, Weld County. Other specimens, labeled as *C. immunis*, in the University of Colorado collections are without definite locality records.

Nebraska localities.—Big Horseshoe pond, State fair grounds, Lincoln, Lancaster County; Stevens Creek, Havelock, Lancaster County; Louisville, Richardson County, collected by Theodore Stander.

CAMBARUS (FAXONIUS) NEGLECTUS FAXON

Cambarus neglectus, Faxon, 1914, p. 375.

Cambarus (Faxonius) neglectus, Ortmann, 1905a, p. 112.

Male, Form I.

Body small, not very robust; rostrum long, deeply excavated, margins raised, subparallel; marginal teeth small; acumen long, with horny tip, carinated; post-orbital ridges not prominent; spine blunt; cervical groove not deep, broken; areola broad, posterior triangle slightly larger than anterior; carapace subovate, depressed, punctuate; lateral spine very small; chela heavy and short, punctuate, slightly pubescent, inner finger longer, no excision at base of fingers; cutting edge of fingers with single row of small tubercles; carpus furrowed above, one large and one small spine on inner side; hooks on third pereopods; first pair of abdominal appendages reaching to base of second pereopods, long, slender, horny, bispinose, outer half longer, with slightly curving tip, inner half more slender, with slightly curving spatulate tip.

Colorado localities.—Republican River at Wray, Yuma County; Black Wolf Creek, tributary of Arikarre River, Yuma County; Arikarre River, Beecher's Island, Yuma County; South Platte River, Julesburg, Sedgwick County.

This species should be found in both the South Platte River drainage and in the Republican River drainage of Nebraska.

CAMBARUS (BARTONIUS) DIOGENES GIRARD

Cambarus diogenes, Girard, 1854, p. 88; Faxon, 1885, p. 144; Faxon, 1885a, p. 71; Faxon, 1885b, p. 359; Faxon, 1885a, p. 140; Faxon, 1890, p. 624; Hay, 1896, p. 489; Faxon, 1898, p. 650; Osburn and Williamson, 1898, p. 21; Williamson, 1899, pp. 20 and 48; Hay, 1899, pp. 959 and 961; Harris, 1900, p. 267; Ortmann, 1905, p. 398; Pearse, 1910, p. 20.

Cambarus obesus, Hagen, 1870, p. 81; Smith, 1874, p. 639; Forbes, 1876, pp. 5 and 19; Bundy, 1877, p. 171; Bundy, 1882, p. 183.

Cambarus dubius, Osburn and Williamson, 1898, p. 21.

Cambarus (Bartoniuss) diogenes, Ortmann, 1905a, pp. 120 and 135.

Male, Form I.

Body robust, smooth except for short hairs on chela and pereopods; rostrum short, broad, deeply excavated, down-curved, without lateral spines; post-orbital ridges low, grooved externally and swollen posteriorly, without spines; carapace lightly granulated, with projecting angle just below the eye; no lateral spines; cervical groove deep and sinuate; areola very narrow, usually obliterated, posterior

angle larger than anterior but less well defined; abdomen shorter than cephalothorax; chela large and strong; swollen and heavily punctate, flattened dorso-ventrally; inner finger slightly longer than outer; carpus short and thick, deeply furrowed above, with small blunt spine on inner surface and two smaller spines beneath; third periopods hooked; first pair of abdominal appendages of male thick and short, ending in two recurved falciform teeth, upper ones large, strong, corneous, inner ones smaller, terminating in mammary-like spine.

Nebraska localities.—Hall County, 6 miles south of Grand Island; Coon Creek, Seward County; Minichaduza Creek, Valentine, Cherry County.

Colorado localities.—Boulder, Boulder County; Fort Collins, Larimer County; Greeley, Weld County; Denver, Denver County; Louisville Junction, Boulder County; St. Vrains, Weld County; Empire Reservoir near Deerfield, Weld County; Lakeside, Boulder County.

CAMBARUS (BARTONIUS) ARGILLICOLA FAXON

Cambarus argillicola, Faxon, 1885, p. 115; Faxon, 1885a, p. 76; Pearse, 1910, p. 19; Hay, 1896, p. 492.
Cambarus (Bartoniuss) argillicola, Ortmann, 1906, p. 120.

Male, Form I.

Body robust; rostrum short, broad, strongly decurved, and well excavated; margins raised, slightly convergent; lateral teeth absent, acumen triangular, not sharp; post-orbital ridges prominent, without spine; carapace depressed, smooth dorsally, granulate laterally, without lateral spines; cervical groove deep, sinuate, broken; areola obliterated in middle, anterior triangular space very small, posterior larger but less distinct; chela strong and large, hand nearly smooth, inner border serrate or tuberculate, fingers thickly punctate, movable finger deeply excised at base, outer finger shorter than inner finger; third periopods hooked; first pair of abdominal appendages consisting of two falciform teeth, placed one anteriorly to the other, posterior tooth thick and strong, anterior tooth thin, spatulate, and horny, inner tooth slightly longer than outer.

Nebraska locality.—Ponds near State fair grounds, Lincoln, Lancaster County.

GEOGRAPHICAL DISTRIBUTION

IN NEBRASKA

The entire drainage of the State of Nebraska leads to the Missouri River, and is everywhere toward the east and southeast except an area north of Chadron, where the drainage is to the north. The following tabulation covers the main drainage systems within the State.

In three cases a river flowing through Nebraska has its source within another State. In each of these cases crayfishes have been reported in these streams outside of the boundaries of the State. It is reasonable to expect that the same species will continue into Nebraska, though there are yet no records of them.

Missouri River.—The banks of the Missouri River at Yankton, S. Dak., on both the Nebraska and South Dakota sides, were studied throughout the month of September, but failed to give any specimens. Investigation in midsummer on the Nebraska side of the Missouri River at Plattsmouth and for several miles north of Nebraska City failed to give the slightest indication of crayfish habitation. A

pond in Cass County, the overflow of which drained into the Missouri River, and several ponds in Richardson County that drained into the Missouri River all contributed collections of *Cambarus immunis*.

Niobrara River.—Several collections of *Cambarus diogenes* were made from Minichaduza Creek, a tributary.

Platte River.—Sarpy County, at the State fisheries, provided a collection of *C. immunis*. At Louisville, a collection of *C. immunis*, *C. immunis spinirostris*, and *C. virilis* was taken from small tributaries, and from Salt Creek and Stevens Creek collections of *C. immunis spinirostris*. From ponds within the drainage of these creeks collections of both *C. immunis* and *C. immunis spinirostris* were taken. In several small creeks in Hall County, tributary to the Platte River, collections of *C. virilis*, *C. immunis*, and *C. diogenes* were taken.

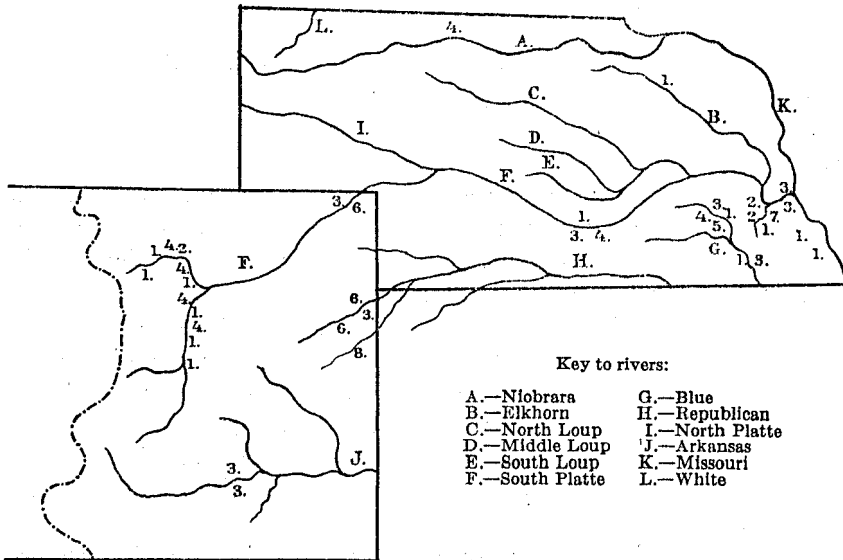


FIG. 1.—Map of rivers of Nebraska and eastern Colorado, showing distribution of crayfishes by river systems

North Platte River.—From the Elkhorn River, in Holt County, a collection of *C. immunis* was taken, and from the Laramie River, Laramie, Wyo., collections of *C. virilis* and *C. immunis* were reported by Harris (1903, pp. 134 and 192).

South Platte River.—Julesburg, Colo., *C. neglectus* and *C. virilis*. From a tributary to the South Platte, in Wyoming, Harris (1903, p. 85) reported *C. diogenes*.

Republican River.—Harris (1903, p. 148) reports *C. neglectus* from near Guy, Cheyenne County, Kans., and *C. virilis* from Fort Riley, Kans.

Big Blue River.—Five species were taken from the ponds, creeks, and rivers in Seward County—viz, *C. immunis* from adjacent ponds, *C. immunis spinirostris* and *C. diogenes* from several creeks, *C. propinquus* from Coon Creek, and *C. virilis* from the Big Blue River. Faxon (1898) reports *C. immunis* and *C. virilis* from "Blue River, Crete, Nebr."

IN COLORADO

The State of Colorado is drained by three major river systems—the Rio Grande, the Colorado, and the Mississippi. The area covered by this study is that which lies east of the Continental Divide and is in the drainage system of the Mississippi River.

Arkansas River.—A collection of *C. virilis* from St. Charles River, a tributary, near Pueblo.

Smoky Hill River.—A collection of *C. simulans* near Oriska, Kit Carson County.

Arikaree River.—A collection of *C. neglectus* from Yuma County and another collection of *C. neglectus* from Black Wolf Creek, a tributary of the Arikaree River.

South Platte River.—At Julesburg, several collections of *C. neglectus* and *C. virilis*. At the Empire Reservoir, Weld County, draining from the Platte River, collections of *C. immunis*, *C. immunis spinirostris*, and *C. diogenes*. From the Poudre River, Larimer County, *C. diogenes* and *C. immunis*. From Middle Boulder Creek and South Boulder Creek, *C. diogenes* and *C. virilis*, and from adjacent ponds *C. immunis*. From creeks and ponds in Douglas County and in Denver County, *C. immunis* and *C. virilis*.

ECOLOGY AND LIFE HISTORIES

The ecology of crayfishes has been studied by Harris (1900, 1901, and 1903), who summarizes the work done by previous workers. Ortmann (1906) has studied the ecology of eastern species, but aside from the work of Harris no one has considered the special habitats of crayfishes in the Missouri River drainage. Some attention was therefore given to the ecological factors of crayfish distribution in Nebraska.

Six species of the genus *Cambarus* are found in Nebraska, three of which have a wide distribution; the remaining three have been found only in restricted areas.

Cambarus immunis has the widest distribution within the State, and the writer has given considerable attention to its habitats. This species was previously studied by Harris (1901) in Kansas. This is the mud crayfish. In Nebraska it is the only form that persistently inhabits the small ponds, many of which contain water only during the spring and early summer. The life of this species in periods of drought and their migration to other ponds is not known. I have found specimens in a dry pond near Lincoln in May, living in a small amount of water at a depth of 32 inches. The pond received only small amounts of water from local rains through the summer.

This species usually digs a straight burrow with a small, shapeless chimney in heavy black soil, rich in decaying vegetable material (fig. 2). Many individuals are found in temporary ponds early in the summer in small burrows several inches in depth, under small stones (fig. 3), empty cans, or decaying logs. According to W. P. Hay (see Evermann and Clark, 1920, pp. 83–86) this is a characteristic also of *C. propinquus* from Indiana.

This is the only species I have observed in the act of chimney building. The process is carried out on cloudy days or, as in the cases observed in this study, in

the evening after sunset. At Hanlon, Nebr., on June 17, I found a small pasture pond that was rapidly drying up. After 6.30 in the evening signs of activity were noticed, and many individuals were seen bringing pellets of earth in the manner

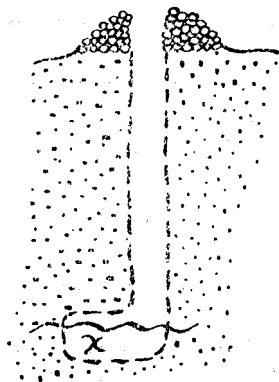


FIG. 2.—Diagram of burrow of *Cambarus immunis* in bank of permanent pond. Length of burrow, 40 centimeters. Wavy line indicates water level. X marks place where specimen was taken

described by Ortmann (1906), and depositing them on the rim of the chimney. This unusual midseason activity in burrows already over 20 inches in depth was probably due to the influence of the drying up of the pond and the necessity for the crayfish to find water at a lower level. The animals were found in burrows during the day, but in the evenings large numbers were present in the open water. I saw many specimens, also, in the streams near the pond colonies, although I did not find them in burrows on the banks of these streams. I have found several colonies of this species in Colorado living in a clay soil on a series of



FIG. 3.—Diagram of burrow of *Cambarus immunis* beneath a stone in a temporary pond. Length of burrow, 14 centimeters. Wavy line indicates water level. X marks place where specimen was taken

alkali flats. Although several similar soils are known in eastern Nebraska, not any of them were inhabited by any species of crayfish.

Cambarus diogenes is perhaps the most interesting form of Nebraska crayfish. Although reported by writers to be an inhabitant of the ponds with *C. immunis*, several hundred collections have failed to give a single *diogenes* from any area save

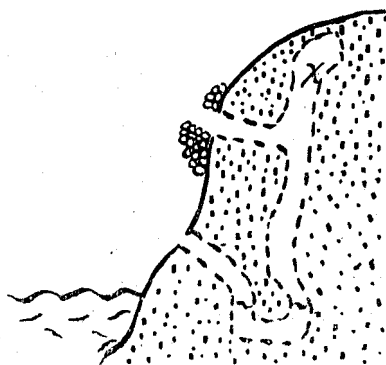


FIG. 4.—Diagram of burrow of *Cambarus diogenes* in the bank of an irrigation ditch. Total length of tunnel, 125 centimeters. Wavy line indicates water level. X marks place where specimen was taken

the clear creeks and smaller rivers. A few were taken from the Empire reservoir, a large artificial lake near Greeley, Colo. I have taken a few specimens from the creek bed in the evening, but most of my species have been obtained from the long and complex burrows which they make (fig. 4). An unusual instance of this well-digging habit is shown in Figure 5. The burrow is not deep, but had been

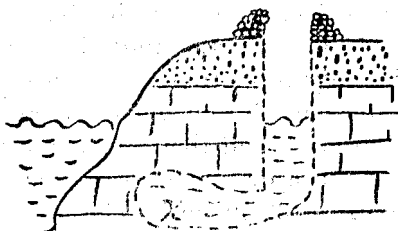


FIG. 5.—Diagram of burrow of *Cambarus diogenes* in disintegrated limestone on the bank of a creek. Depth of well, 30 centimeters. Wavy line indicates water level. X marks spot where specimen was taken

dug through several inches of disintegrated limestone, ending on a harder terrace of the same material. The chimney was asymmetrical, with particles of stone cemented by the mud from the same excavation. In western Nebraska, at Valentine, I found large numbers of this species that had made burrows in the side of a steep bank of sandy loam, which formed the bank of Minichaduza Creek. No chimneys were present, although usually so distinctive a part of the *diogenes* well. This again is

evidence, added to that of Ortmann, Harris, and others, that the chimney is no part of the economy of the crayfish burrow but is the easiest method of disposing of the material excavated. In this case the material was brought to the surface of the tunnel and thrown over the edge, to be swept away by the current. The openings of the burrows were difficult to find, as they were beneath the outthrust roots of shrubs and trees and were often 3 feet above the water level. Young of this species were found in the water throughout the period of 10 days spent in that vicinity in late August, and none in the burrows, each of which was occupied by a single adult. This species has been found in many types of soil, such as clay, sandy loam, black loam, gravel, and shaly limestone, but always on the banks of clear streams and never in ponds.

A variety of *Cambarus immunis* (*C. immunis spinirostris*) is found throughout eastern Nebraska. It is primarily an inhabitant of small, sluggish streams, making a characteristic well in the banks of the stream. In one pond, however, near such a stream, I repeatedly found mature crayfishes of this variety in the open water, and none were taken from burrows on the banks of this pond.

Cambarus virilis occurs in the swift, sandy-bottomed streams, the most constant locality known to the writer being the Blue River at Milford, Nebr. I have not failed to find a few on each trip in the swift, well-oxygenated water just below the milldam. *C. immunis* is found in great numbers in adjoining mud flats, but the two species have not been found to overlap. *C. virilis* and *C. diogenes* were both found in the same area in a creek near Grand Island, Nebr.—*C. diogenes* in one of its characteristic wells and *C. virilis* in the creek bed. *C. virilis* does not dig a well.

Cambarus propinquus is an inhabitant of the more quiet places in small creeks, sometimes making a shallow excavation, more often hiding through the day in old cans or beneath rocks in the stream bed. It has been found in the same stream with *C. diogenes*, but in the more quiet, deeper sections, and it is not a chimney builder.

Cambarus argillicola has been found in Nebraska, but the data are not extensive enough to determine any specific physical character of its environment. The specimens were found at different times in a single meadow pond, within shallow excavations or beneath stones.

It would appear that in this group of crayfishes studied the reaction of the physical environment is well defined, and that the animals differ in physiological as well as taxonomic characters.

The breeding habits of the group are well summarized by Andrews (1904 and 1906), who made a careful study of the copulation, egg laying, and development of *Cambarus affinis*. The difference in times of ovulation and freedom of the young from the egg capsules is very interesting. My own observations are limited to a study of *C. immunis* and *C. diogenes*, and represent a careful investigation of their life history through two consecutive seasons.

Two "berried" females of *Cambarus immunis*, 70 and 110 millimeters long, were found in burrows in a pond near Lincoln on April 25. These were taken to the laboratory, where the young of each hatched within 10 days. Both of the adults

died and the young were not raised. It was observed that the "berried" females rarely survived laboratory conditions, whereas smaller specimens of both males and nongravid females were kept for 10 weeks.

Further records of gravid females of this species within the vicinity of Lincoln were taken on April 29 and May 13. Perhaps the most interesting record was one of two *C. immunis* 40 millimeters in length, taken at Atkinson, Nebr., on October 30. One female carried a large cluster of eggs, which were hatching, but both specimens died three days later.

Harris records March 21 as the earliest date for berried females of this species in Kansas. This is more than a month earlier than my records for the same species in an adjoining State, although I have taken specimens as early as April 1, but found no gravid females.

Herrick (1896) reports a number of females of *C. immunis* already in berry taken at Ann Arbor, Mich., on November 16, when the ice was beginning to form.

The earliest records for *C. diogenes* are May 13, taken at Seward, Nebr., and May 30, taken at Boulder, Colo. Harris (1902) reports a female with eggs taken on May 3. Pearse (1910) reports a pair copulating in White Pigeon River, Mich., on April 13. Hay reports *C. argillicola* with young on April 2. Ortmann (1906) gives April 6 as the earliest records for females of *C. diogenes* with eggs, and May 21 as the earliest date for females with young taken in Pennsylvania.

Copulation has not been observed in either Nebraska or Colorado species, though on June 17, at Hanlon, Nebr., I examined 15 burrows, in 7 of which both the male and the female of *Cambarus immunis* were found in the same burrow but not in copulatory position. This is, however, a rare condition, and according to Ortmann (1906, p. 482) it is "an absolute rule that under ordinary circumstances only one specimen occupies a hole," and that this association is found only during the mating period. That this pond was drying up, owing to an especially dry summer, may have had some influence on the time of copulation.

Ortmann states that the copulating season for *C. diogenes* falls in the autumn, having observed it on October 24 and November 5. At variance with this is the record of Hay (1896, p. 491) that *C. diogenes* was taken in Indiana on April 2 with pairs in copulation.

It is apparent that careful attention should be given to the geographical differences in the life history of a single species, studied over a series of years in localities of distinct climatic and seasonal differences.

Young of all these species leave the burrow of the mother and may be taken in schools in the open water when from 8 to 20 millimeters in length. At from 18 to 25 millimeters they begin to dig burrows for themselves, and may no longer be taken throughout the day in the open water.

PARASITES

In most of the collections of crayfishes in both Colorado and Nebraska a few specimens were found that bore the interesting annelids belonging to the Discodrilidæ. On some specimens of *C. immunis* found near Lincoln the entire carapace was covered with the cocoons of this worm, while on the ventral portion, especially around the mouth, were many of the mature animals. These annelids are rather

small, ranging from 2 to 4.5 millimeters in length. Pierantoni (1912), quoted by Hall (1915), states that this family ranges in length from 1 to 12 millimeters, with a maximum width, when in a moderate distension, not to exceed one-tenth of the body length.

The cocoons are quite conspicuous, being about 3 millimeters in length and fastened to the body of the host by a narrow stalk. It was formerly thought that these might be the eggs of *Corixia*, the giant water beetle, but their relationship to the parasitic worms is now known. Likewise, it was not known for a time whether they were to be considered parasites on the crayfish or messmates with it. Hall (1915) regards them as parasitic in the adult stage. "They are not parasitic when young, a study of the intestinal tract at this period showing vegetable detritus and small animals. In the adult stage the teeth are used to break the skin of the host animal in order to suck the blood. I have found several pieces of striated, voluntary muscle fiber in the intestine of the adult discodrilid described in this paper."

Ellis (1920), in a revision of the Branchiobdellidæ in the United States National Museum, records the species found on the Colorado and Nebraska crayfishes. The Nebraska species collected during this investigation have not yet been identified. *Cambarus diogenes* was found to be host to *Cambarincola macrodonta* Ellis and *C. philadelphia* Leidy, the former species only being found on *C. diogenes* from four localities in Colorado, and *C. philadelphia* being found by Ellis at Rhineland, Wis. *Cambarus immunis* and *C. virilis* from Colorado, and *C. propinquus* from Douglas Lake, Mich., were host to *Cambarincola vitrea* Ellis. *C. propinquus* from Irondale, Ind., is host to *Xitonodrilus formosus* Ellis, and the same species from Bloomington, Ind., is host to *C. philadelphia* Leidy. *Cambarus virilis*, from Rolla, Mo., is host to *C. chirocephala* Ellis and also to *Cambarincola vitrea* Ellis and the same species from Douglas Lake, Mich., is host to *C. philadelphia* Leidy.

It is thus seen that the parasites have not developed into specific form along with the differentiation of the host species and seem to show no selection of hosts. There is no record of one specimen being host to two species of parasites, though the same species of crayfish in different localities may harbor at least three different parasites.

ECONOMIC IMPORTANCE

Although very abundant in these two States, especially in Nebraska, the crayfishes have received very little attention as regards economic importance. Personal inquiry at the office of the game and fish department of Nebraska, at Lincoln, brought the information that crayfishes were worth nothing and could not be considered among the resources of the State.

Careful investigation shows them to be of no inconsiderable value in the life balance of our streams and meadows. Shelford (1913) has shown that they play a definite part in the equilibrium of the fresh-water community, feeding upon the decaying vegetable matter, the larger aquatic insects (probably those that have died), and possibly the young of frogs and fishes. They, in turn, serve as food for the bullheads, the young and the adult black bass, and possibly also for other forms.

Pearse (1910) states that they furnish food for many turtles and snakes as well as other animals. I have examined the stomachs of a number of snakes that are frequenters of streams (*Tropidonatus sipedon fasciatus*, *Thamnopsis radix*, and *T. elegans*) and have found no trace of crayfish remains. Ortmann (1906, p. 495) has seen *Natrix leberis* disgorge *C. obscurus* when captured. He also quotes Prof. H. A. Surface as the authority for the statement that *Cryptobranchus alleghensis* and *Necturus* feed upon crayfish. I have found the carapaces of freshly killed crayfishes (*C. immunitis*) on the banks of a small stream west of Lincoln in the early morning, and many tracks of a raccoon (probably *Procyon lotor*). It is evident that this night-feeding animal feeds on the crayfishes as well as upon the mussels that are found in the same community. I have not examined the stomachs of wading birds, but undoubtedly they catch many of the young crayfishes as they swim in schools in the shallow water during the evening and morning hours.

Owing to their great numbers and the large size reached by *Cambarus immunitis*, *C. diogenes*, and *C. virilis*, there is a great deal of potential food in the ponds and streams which is not utilized. I have heard of no one who has eaten them in these two States, but there is no good reason for not doing so, since they are so highly esteemed in other localities, especially in the southern United States.

The crayfishes of Wisconsin have been of some slight importance, according to R. S. Scheibel, assistant commissioner of conservation, who says:¹ "They are gathered mostly around the waters adjacent to Green Bay, and in Wisconsin were used almost entirely for free lunches in saloons. Since prohibition has been in effect the crayfish business has dropped off considerably, the last report showing that only approximately 400,000 pounds were caught and sold."

Speaking of another genus of this family—the genus *Astacus*—Carl D. Shoemaker, master fish warden of the State of Oregon, says:² "We issue in the neighborhood of three dozen crayfish licenses a year. * * * I know that in the neighborhood of 100,000 dozen are taken annually in our waters. These are sold to restaurants and hotels, and are kept in live boxes, where they are held and fed until served. The industry is not a very profitable one, as the price paid per dozen is small. Those who engage in the taking of these crayfish make a poor living and have to augment their income from other sources."

The abdomen of the crayfish is also used extensively for bait by fishermen, but the animals are usually caught alive for each trip and are of no great importance commercially.

Fisher (1912) suggests that if boiled with meal and allowed to dry, crayfish make an extremely valuable egg-producing food for poultry.

As an item of negative economic importance the crayfish has received slight attention. In some of the lower areas of the eastern part of the State the meadows along the streams and surrounding the ponds may be infested with the burrowing forms *C. diogenes* and *C. immunitis*, especially the latter. A certain though negligible amount of grass may be destroyed, and the mounds may interfere with the mowing operations, but farmers who were questioned did not seem to regard them as a nuisance. In the Southern States crayfishes were at one time a very great pest,

¹ From personal letter, Aug. 20, 1923.

² From personal letter, Aug. 29, 1923.

and "in badly infested areas, near Muldoon, Miss., there are from 8,000 to 12,000 holes to the acre." (Fisher, 1912, p. 322.) The name of the species was not recorded, but it destroyed a great deal of the young cotton and corn crop, tearing the cotyledons and young leaves and carrying them to their burrows.

In the irrigated districts of Colorado crayfishes are very plentiful, the burrows of *C. diogenes* being seen along the banks of the ditches where they run their complex underground tunnels, often causing breaks in the bank of the ditch. A single alfalfa field inspected near Boulder has a great number of burrows of this species extending from 1 to 3 meters from the bank of the ditch, the young crop in this strip being quite destroyed.

Cambarus diogenes has become a very great nuisance on the campus of the University of Colorado at Boulder. The young entered an artificial pond by way of a small inlet stream, and the following autumn dug many burrows in the embankment on the north side of the pond. A cement wall, which was placed along this bank, extending to a depth of 2 feet below the usual water level, has eliminated the attacks of the crayfishes at this point.

The crayfish may be exterminated in a given locality, according to Fisher (1912), by using carbon bisulphide, chloride of lime, or calcium carbide. I believe that this would suffice for a single season only, and that with the migration of the following spring the population would be renewed.

SUMMARY

This study of the genus *Cambarus* of Nebraska and eastern Colorado summarizes the literature dealing with crayfishes of the area, paying special attention to the previous records and giving a redescription of the eight species. The geographical distribution is considered and the ecology of the species studied with evidence gathered in a field investigation for two consecutive seasons. Life history data are gathered, which demonstrate the existence of geographical differences in time of copulation and spawning, and suggestions are offered for more detailed observations regarding these differences. The literature on discodrilid parasites of the crayfish has been reviewed and the suggestion made that the generic and specific differentiation of these parasites has been independent of the evolution of the host species. Information regarding the economic value and the food relationships is presented.

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