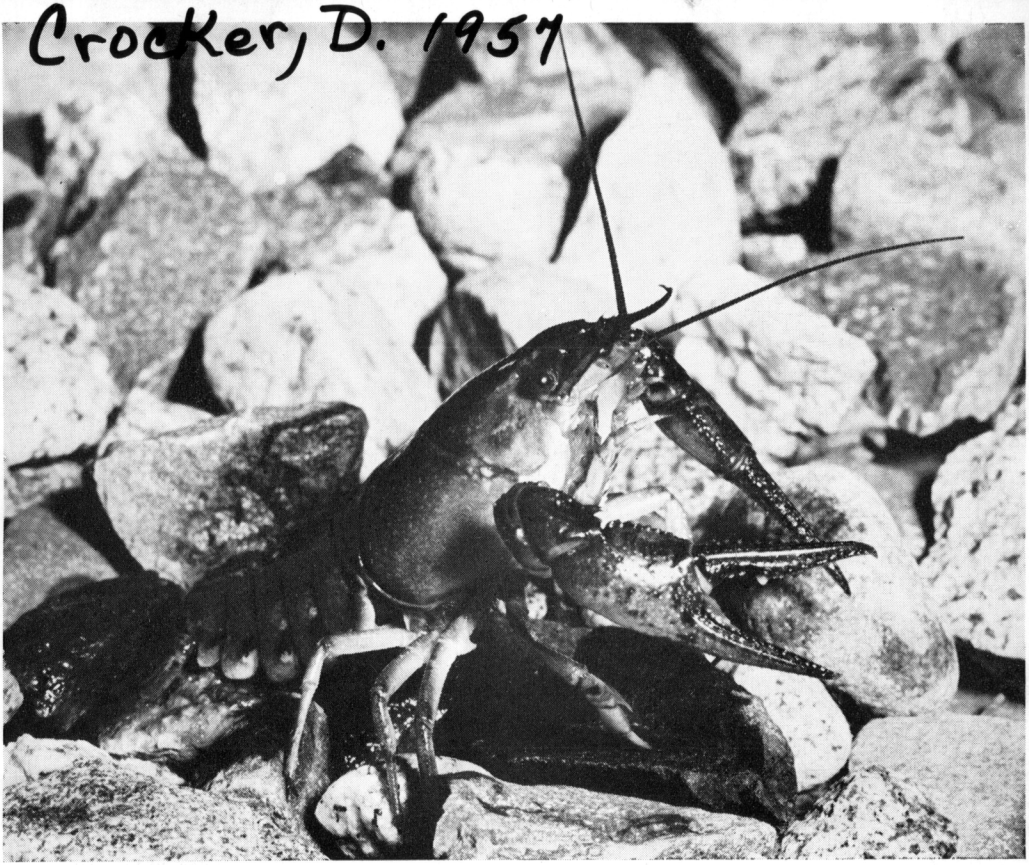

THE CRAYFISHES

of

NEW YORK STATE

(Decapoda, Astacidae)

By

Denton W. Crocker
Temporary Museum Expert

NEW YORK STATE MUSEUM AND SCIENCE SERVICE

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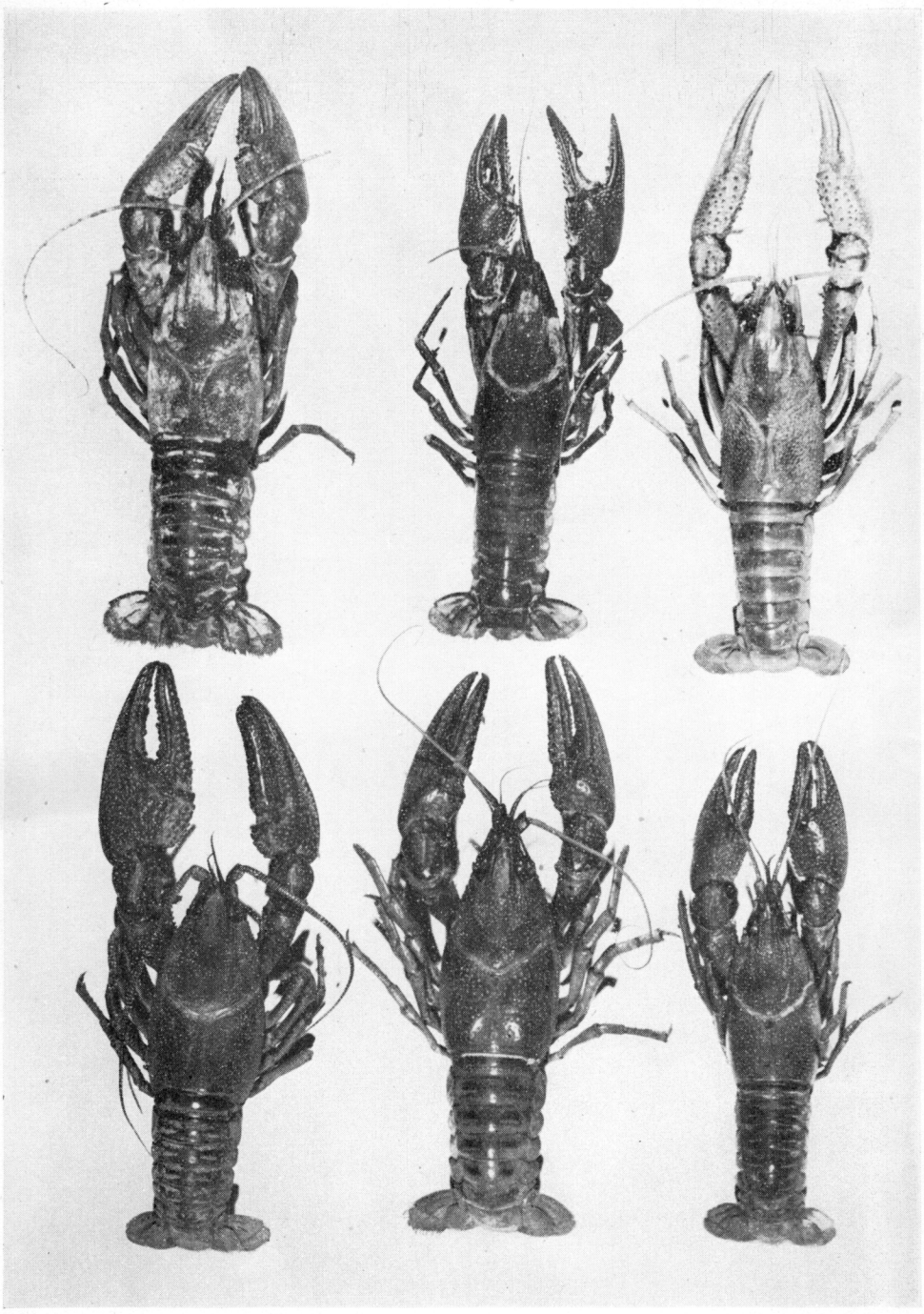


FRONTISPIECE. Dorsal views of form I males of six of the eight known species of New York crayfishes. Upper row from left to right: *Orconectes limosus* (Rafinesque), *Orconectes immunis* (Hagen), and *Procambarus b. blandingi* (Harlan). Lower row: *Cambarus robustus* Girard, *Orconectes virilis* (Hagen), and *Orconectes p. propinquus* (Girard). Collection data for all of these specimens and drawings of their copulatory stylets (except for *O. limosus*) are on plates 2, 3 and 4 and their legends.

INTRODUCTION

Brief Historical Review

The crayfishes (or crawfishes) have long been an object of study by zoologists. Their abundance in many localities and large size (the largest of North American fresh water crustacea) make them excellent animals for zoological study. In fact, Thomas Huxley (1880) wrote a successful textbook of zoology based on this single animal group.

In 1798, Fabricius published the first description of an American crayfish, now known as *Cambarus b. bartoni*. The early published descriptions of our American species by Say (1817), Rafinesque (1817), Girard (1852) and others, were often sketchy and without figures, a characteristic of the times. The first comprehensive systematic work was a *Monograph of the North American Astacidae* (Hagen, 1870). This work was amplified and revised in the several major contributions of Faxon (1885*a*, *b* and *c*, 1890, 1898 and 1914). The taxonomy of crayfishes has undergone many changes culminating, for the present, in the generic revision of Hobbs (1942*a*), who gives a review of taxonomic changes to 1942. Besides these works of larger geographic scope, a number of State surveys have been made.

At present, H. H. Hobbs, Jr. of the University of Virginia is contributing most to crayfish literature and his excellent papers must be included among the basic materials for students of the group.

Studies of life history and ecology are many fewer than those which are primarily taxonomic. Outstanding among the former are the studies of Andrews on breeding behavior (1895, 1904, 1906*a*, and 1910*a*) and on development under laboratory conditions (1907), and the field study by VanDeventer (1937) of the biology of *Cambarus propinquus* (= *Orconectes propinquus*) in Illinois. Ortmann's report of Pennsylvania crayfishes (1906) contains valuable life history information, especially concerning *Orconectes obscurus*. More recent work has been done by Penn (1943), Bovbjerg (1952) and Smith, E. W. (1953).

Although the eight species of crayfishes which occur in New York range beyond the State and have been studied in greater or lesser degree in out-of-State areas, very few studies have been made of these crayfishes within New York State.

Tack (1941) worked out the life history of *Orconectes immunis* at Ithaca. Creaser (1934) reported on the higher Crustacea of the Raquette River system, and Nevin and Townes (1935) include crayfishes in their survey of fish food organisms of the Mohawk-Hudson.

Paulmier (1905) surveyed the higher Crustacea (including marine forms) of New York City and Dekay (1843) gives an account of historical interest of the Crustacea of the State. All other reports of the crayfishes of the State are locality records included in works of larger taxonomic or geographic scope.

Aims of Study

The zoological value of a study of the crayfishes of the State is obvious when the former lack of knowledge is realized. Several adjacent or nearby States to the south, southwest and west have been surveyed: Pennsylvania (Ortmann, 1906); New Jersey (Fowler, 1912); West Virginia (Newcomb, 1929); Ohio (Turner, 1926). These indicate that for several species or subspecies, the present study closes one of the few remaining gaps in our knowledge of their eastern and northern geographic limits.

The present study has the following aims:

1. To determine the number of species or subspecies which occur in New York State
2. To delimit the geographic ranges of the taxonomic forms occurring in New York State
3. To determine the morphological variation of the New York species, both within New York and also compared with these same forms found in other areas
4. To determine, where possible, genetic affinities and pathways of dispersal
5. To add to the often fragmentary knowledge of life histories

Materials and Methods

A major portion of this study was done as a doctoral dissertation at Cornell University (Crocker 1952). However, a considerable quantity of new data has been incorporated and the drawings have been redone.

Most of the crayfishes examined are tabulated in tables 16, 17 and 18 (pages 86-88). In addition, material has been studied at the United States National Museum (USNM) and at the Museum of Comparative Zoology (MCZ) at Harvard.

Crayfishes collected by the several Biological Surveys of the New York State Conservation Department (stream surveys) are deposited in the New York State Museum (NYSM). In 1952 I was employed by the Museum to reorganize these stream survey crayfishes and to make new collections. My report on the present organization of these specimens is an appendix to the quarterly report for October 1, 1952, of the State Zoologist to the Director of the New York State Museum, and is on file at the Museum.

To summarize the report briefly, all this material is now readily available for study. A card file in triplicate, filed by stream survey collection number, by species and by drainage system is available at the Museum as a further aid to the study of these specimens. The new collections which I made in August 1952 are NYSM catalog numbers 6977-7022 inclusive. The stream survey crayfishes are cataloged under the one New York State Museum number 6975. These are referred to in the present paper in the following form:

NYSM (year of survey): stream survey collection number.

The localities plotted on maps (figures 3-7) are all from my personal collections and the collections of the NYSM, with the single exception of the record for *Orconectes virilis* in the Raquette River which is taken from Creaser (1934: 158). The watersheds of New York and their dates of survey are illustrated in figure 2 (page 70).

The drawings of copulatory stylets and seminal receptacles (plates 1-5) were made with a camera lucida. On plate 1, figures 1-4 were drawn with a camera lucida and figures 5 and 6 were obtained by tracing on cellophane, using magnification by the method of Staniland (1953). Pubescence has been omitted from all figures. Receptacles are drawn oriented with the posterior border toward the bottom of the plate.

Collecting has been accomplished largely by seining or by turning stones and collecting by hand. Seining works best in turbid, deep or swift water. Crayfish may also be coaxed readily into a dark colored dip net by prodding with a dark stick.

In sorting specimens to permit tabulation of life history data not all specimens were measured. Therefore, for many specimens, those form II males and females, which were judged by eye to be within 1 mm. of the lower limit of size at sexual maturity (table 2), are reported as male (II?) or female (imm.?). Form II males and females measured and found to be within a few tenths of a millimeter of this value, are similarly reported.

Where "New York" is written, the State and not the city is intended. New York City will always be identified as such.

Acknowledgments

This study would not have been possible without help from many sources. Financial aid during most of my period of graduate study was provided by the people of the United States through the Federal Government under Public Law 16.

Professor Horton H. Hobbs, Jr. of the University of Virginia has been unstintingly generous of his time and materials and has given continued assistance throughout the course of the study.

The loan of Stream Survey crayfishes was obtained from the New York State Museum through the assistance of Dr. Ralph S. Palmer, State Zoologist, who has helped also in many other ways.

The Department of Conservation of Cornell University supplied maps on which the distribution data are plotted, and Professor E. C. Raney of that department has been generous with advice and criticism.

Thanks are due Dr. Waldo L. Schmitt and Dr. Fenner A. Chase, Jr. for many courtesies rendered during my visit to the United States National Museum and for the loan of specimens. Dr. Elisabeth Deichmann of the Museum of Comparative Zoology at Harvard University has very kindly loaned specimens at several different times and has put the museum collections at my disposal during my visits there.

Professor Alfred S. Romer, director of the Museum of Comparative Zoology, for several summers has generously granted me the use of table space in the Museum library, and the library staff has shown considerable patience with my many requests.

Several faculty members and numerous former students at Cornell University have contributed to my crayfish collections. To Royal D. Suttkus (now of the Department of Zoology, Tulane University) go my particular thanks for contributing perhaps as many as 5 percent of my specimens.

I am grateful to Dr. J. Seelye Bixler, president of Colby College, for two grants of money in support of my research. The Science Division of Colby College has given me a small sum of money for the purchase of publications.

I particularly wish to thank Jean-Marie J. Crocker, not only for wifely encouragement and moral support, but also for contributing materially toward the completion of this study with clerical help and assistance in the field.

The cover photograph was taken by Wendell A. Ray.

THE GEOGRAPHIC DISTRIBUTION AND SYSTEMATICS OF CRAYFISHES

Discussion

The relationship of the tribe Astacidea, to which the crayfishes belong, to other groups of the crustacean order Decapoda may be visualized by reference to figure 1. The tribe Astacidea may be separated into four families: the Nephropsidae, including the Norwegian, the European and the American lobsters; the Astacidae, which contains the European, North American and Asian crayfishes; and the Parastacidae and Austroastacidae, which contain the crayfishes of the southern hemisphere. The Nephropsidae are separable from the other three families of the tribe by the condition of the last thoracic segment, which in the Nephropsidae is fused to the carapace. The Parastacidae and Austroastacidae are most readily separated from the Astacidae by the lack in the former two families of sexual appendages (copulatory stylets) in the male.

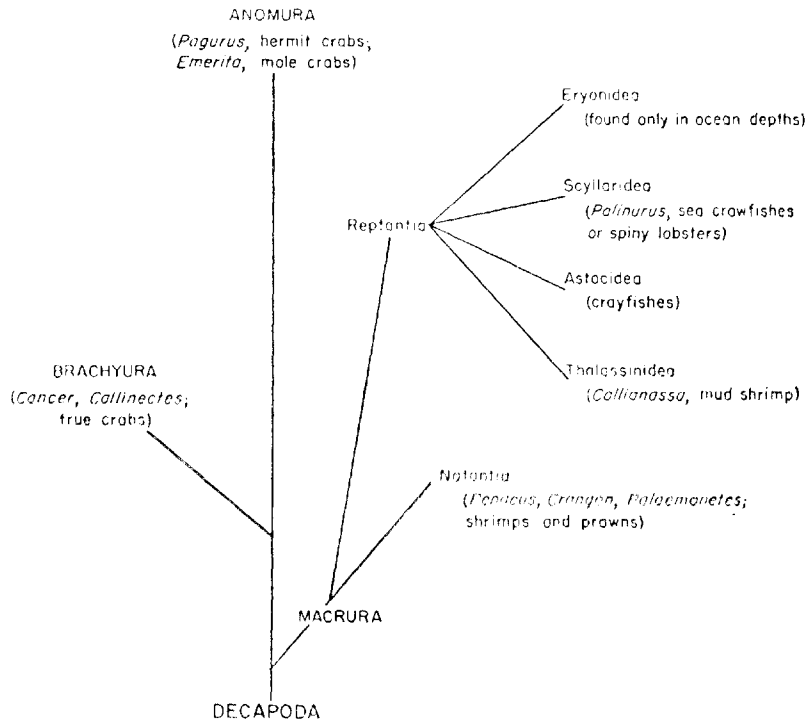


FIGURE 1. The place of crayfishes in the classification of decapod Crustacea (based on correspondence with L. B. Holthuis)

The three families of crayfishes are residents almost exclusively of fresh water (rarely brackish water), and their distributions present a striking picture. For maps of these distributions see Huxley (1880: 309), Calman (1911: 175) and Ortmann (1902: 275). Ortmann's paper contains an analysis of geologic changes which have resulted in the present distributions. These papers were written before the separation of Austroastacidae from Parastacidae by Clark (1936).

In general, the Astacidae are restricted to the Northern Hemisphere, and the Parastacidae and Austroastacidae are restricted to the Southern Hemisphere, with a tropical belt left free of any fresh water Astacidea. This tropical belt covers the area between 10 degrees north latitude and, except for the Parastacidae on New Guinea, 10 degrees south latitude. Of this distribution, Smith and Weldon (1923: 214) state the following:

> It seems reasonable to suppose that the two families of Crayfishes characteristic respectively of the Northern and Southern Hemispheres have been independently derived from marine ancestors, which have subsequently become extinct. Their complete absence in the tropics is striking, and Huxley drew attention to the fact that it is exactly in those regions where the Crayfishes are absent that the other large fresh water Malacostraca are particularly well developed, and *vice versa*. Thus the large freshwater Prawns are typically circumtropical in distribution, while the South African rivers abound with Rivercrabs, which, in general, are found wherever Crayfishes do not occur.

The family Astacidae is made up of two subfamilies. The subfamily Astacinae inhabits North America west of the Rocky Mountains, and Europe and Asia. The subfamily Cambarinae is composed of the crayfishes native to North America east of the Rocky Mountains, but a number of introductions elsewhere have occurred (Penn 1954). The Cambarinae lack gills on the last thoracic somite and are separable from the Astacinae on the basis of this character. New York State crayfishes, then, are members of the crustacean order Decapoda, suborder Reptantia, tribe Astacidea, family Astacidae, subfamily Cambarinae.

The revision of Hobbs (1942*a*) divides the subfamily Cambarinae into the following six genera: *Procambarus, Paracambarus, Troglocambarus, Cambarellus, Orconectes* and *Cambarus,* of which *Paracambarus* and *Troglocambarus* are monotypic. At the time of Hobbs' revision (1942*a*) the subfamily Cambarinae consisted of 96 species,

15 of these containing a total of 47 subspecies; a total of 128 described taxonomic forms. At present there are probably about 200 described species and subspecies. The systematic positions within the subfamily Cambarinae of the eight New York crayfishes is shown in the following list.

Systematic List of New York Crayfishes

Family **Astacidae**

Subfamily Cambarinae

Procambarus Ortmann (1905*b*: 437)
Type: *Cambarus digueti* Bouvier, 1897, subsequent designation by Hobbs (1942*a*: 341)
  Blandingi Section (Ortmann 1905*a*: 98)
    Blandingi Group (Ortmann 1905*a*: 102)
      Blandingi Subgroup (Hobbs 1942*b*: 93-94)
        Procambarus blandingi blandingi (Harlan), 1830
Orconectes Cope (1872: 419)
Type: *Orconectes inermis* Cope, 1872, by monotypy.
  Limosus Section (Ortmann 1905*a*: 108)
        Orconectes limosus (Rafinesque), 1817
  Propinquus Section (Ortmann 1905*a*: 108)
    Propinquus Group (Ortmann 1905*a*: 109)
        Orconectes propinquus propinquus (Girard), 1852
        Orconectes obscurus (Hagen), 1870
  Virilis Section (Ortmann 1905*a*: 109-110)
    Virilis Group (Ortmann 1905*a*: 110)
        Orconectes virilis (Hagen), 1870
        Orconectes immunis (Hagen), 1870
Cambarus Erichson (1846: 88)
Type: *Astacus bartoni* Fabricius, 1798, subsequent designation by Faxon (1898: 644)
  Bartoni Section (Ortmann 1905*a*: 119)
        Cambarus bartoni bartoni (Fabricius), 1798
        Cambarus robustus Girard, 1852

Systematic Characters in the Cambarinae

The copulatory stylets. By far the best indicators of relationships in this subfamily are the copulatory stylets and the disposition of copulatory hooks which occur on the ischia of the male perciopods. These are utilized in the diagnoses of genera (Hobbs 1942*a*) and even of groupings within genera (Ortmann 1905*a*).

The differences in the morphology of the stylets among different species have been homologized through the careful studies of Andrews (1910*b*) and Hobbs (1942*c* and 1945), which are in agreement in principle, although using different nomenclature. Further

studies of stylet anatomy and development have been made by Hart (1952, 1953 and 1956).

Among New York crayfishes there are two major types of copulatory stylet. In discussing these, the terms of orientation used refer to the stylet with its shaft aligned dorso-ventrally, its distal end (excluding flexures of the terminal elements) directed ventrad. Only the form I stylet is considered here (see below for a discussion of the two forms of the male).

One type has four terminal elements and of New York State crayfishes occurs only in *P. b. blandingi*. Plate 4, figure 5 is a lateral view of the right stylet of this species. In the figure, the distal end is toward the top of the plate. The names of the terminal elements, listed in sequence caudad (toward the right of the plate) are: cephalic process, central projection, caudal process and mesial process. The mesial process is so named because it originates proximally on the mesial surface of the stylet. The central projection is composed of two fused parts, the centro-cephalic process and, more caudad, the centro-caudal process. It is always the central projection which contains the duct through which the sexual elements pass.

The other major type of stylet has only two terminal elements, the central projection and the mesial process. The type has two distinct subtypes. In one (plate 2, figure 1) the terminal elements are both short and heavy and are bent caudad at about a 90-degree angle to the main shaft. The central projection is the one at the top of the figure (the more distal element). This subtype is the chief diagnostic character for the genus *Cambarus* (Hobbs 1942*a*: 354) and of New York crayfishes occurs in *C. b. bartoni* and *C. robustus*.

The remaining five New York species possess stylets which terminate in two straight (plate 3, figures 1 and 5) or gently curved (plate 4, figures 1 and 3), short (plate 3, figure 5) or long (plate 4, figure 1) elements. Such a shaped stylet is the chief diagnostic character for the genus *Orconectes* (Hobbs 1942*a*: 350). All of the figured stylets of this last subtype are drawn with the central projection toward the left of the plate and with the mesial process on the right.

The two forms of the male. One of the many complexities confronting the first American crayfish students was the two forms of the male, first noticed according to Hagen (1870: 22) by Louis Agassiz, who did not, however, publish this information. As late as 1870 it was supposed that an individual existed throughout its life either as one form or the other. In 1875 Faxon received a shipment of live crayfishes from Kentucky. One of the males moulted in the laboratory and upon comparing moult with moulted animal he found one to be

of one form and the remaining one of the other. His further observations and published account (Faxon 1884) settled the issue. It is now understood that adult males incapable of reproduction (known technically as form II) are morphologically different from males which are so capable (form I). It is also known that in a given individual the two forms alternate, the time of year and frequency of alternation varying with species. This phenomenon occurs only in the subfamily Cambarinae and in *Cambaroides* of the subfamily Astacinae (Hart 1953).

The major external morphological differences in the form I males are heavier, more corneous and slightly larger copulatory stylets (first pleopods) and larger hooks on those pereiopods which bear them.

Other useful taxonomic characters. The use of form I stylets in keys has the disadvantage of restricting identifications to form I males. Therefore, it is desirable that other morphological features be utilized for separating species. Such features, commonly used in keys and generally used for separating closely related forms, include the following: shape and armature of rostrum, shape of hand and armature of various segments of chela, shape of antennal scale, width of areola, ratio of lengths of anterior and posterior portions of carapace, shape of epistome and shape of seminal receptacle.

The seminal receptacle (annulus ventralis). The seminal receptacle which, among crayfishes, is present only in the Cambarinae, was first reported to function as such by Andrews (1895: 869-870). Hagen (1870) first called attention to the structure and noted its differing shape in the various species of the then inclusive *Cambarus*. Hagen (1870: 20) doubtfully postulated that the seminal receptacle, which he called the annulus ventralis, might function in secreting the cement by means of which the eggs are fastened to the pleopods. The varying shapes of the ridges, sinus, tubercles and fossa of the receptacle are now commonly used to differentiate closely related species of which the females might otherwise, in the present state of crayfish taxonomy, be indistinguishable. However, "As things now stand, an isolated female which does not belong to a species that is very familiar to the taxonomist, generally goes unnamed, and often cannot be determined as to genus." (Hobbs 1942*a*: 340).

Andrews has extensively studied the seminal receptacle and has published on its ontogeny (1906*c*) and its morphology in the adult (1906*b*). He has also pointed out that in *Orconectes limosus, O. virilis, Cambarus b. bartoni* and *Procambarus clarki,* the receptacle

occurs in two forms, one a mirror image of the other, a fact not generally mentioned in taxonomic works, but one that should be remembered by anyone attempting to identify female Cambarinae. In a species such as *C. robustus* there is a ridge of the receptacle which in one of the two forms runs somewhat obliquely to the animal's right

TABLE 1

Crayfishes for which quantitative data are available for the occurrence of left- and right-handed seminal receptacles

SPECIES	LOCALITY	NO. FEMALES EXAMINED	NO. RIGHT HANDED	NO. LEFT HANDED	AUTHORITY
Procambarus clarki[1]	New Orleans, La.	29	16	13	Andrews (1906*b*: 465)
Cambarus b. bartoni	Baltimore Co., Md.	12	8	4	Andrews (1906*b*: 468)
C. robustus	11 localities in vicinity of Ithaca, N. Y.	109	84	25	Author
Orconectes limosus	not given		majority	few	Andrews (1906*b*: 443)
	not given	41	38	3	Andrews (1906*c*: 131)
	two localities in Catatonk Creek, Tioga Co., N. Y.	39	30	9	Author
Orconectes virilis[2]	from Chicago markets	25	4	21	Andrews (1906*b*: 459)
Orconectes immunis[3]	Cornell Univ. Fish Hatchery Ponds, Tompkins Co., N. Y.	137	135	2	Author

[1] Not present in New York State.

[2] After making certain assumptions regarding the homologies of component parts of the seminal receptacles of *Cambarus virilis* (= *Orconectes virilis*) and *C. affinis* (= *O. limosus*), Andrews (1906*b*: 461) says, "On these assumptions a right-handed *C. virilis* would be fundamentally like a left-handed *C. affinis* and in both species these seem to be the rarer form."

[3] Andrews (1906*b*) studied the receptacle of *O. immunis*, but, although he did not report left-handed forms, neither did he specifically state nor even definitely infer that he searched for them. He does say, however, (Andrews 1906*b*: 477), "The inversion of symmetry in the annuli of different individuals may well be general in *Cambarus* [= family Cambarinae]."

and then dips dorsad into a cavity or fossa. This, Andrews (1906*b* and 1906*c*) calls a right-handed seminal receptacle In the left-handed form the ridge runs obliquely to the animal's left and then dips into the fossa. Plate 2, figures 3 and 4 show these two receptacle shapes. Table 1 summarizes the available published information and adds new data concerning the relative abundance of the two shapes in various crayfish species.

The occurrence of the two receptacle forms presents an interesting problem in genetics which, at least as regards rearing a suitable animal in captivity, should not be difficult of solution. Andrews (1907: 68) states of *O. limosus,* "...there would seem to be no obstacle to the establishment of a permanent race of domesticated crayfish bred in captivity." It is also a question whether or not the male acts differently toward the two forms of the receptacle.

Aside from the phenomenon of the two mirror-image forms, however, Andrews suggests other interesting speculations relating to the seminal receptacle. Are the stylets of the male, and the female receptacle closely adjusted to one another in each species or not? If so, how then does it happen that the receptacles in two species such as *C. b. bartoni* and *O. immunis* are so similar when the stylets of the male are so different? Of what survival value is the seminal receptacle, a structure present only in the more advanced of the two subfamilies of the Astacidae, the subfamily Cambarinae, and yet a structure which has been evolved independently in this subfamily and in the marine genus (of the family Nephropsidae) *Homarus*? These questions are not answered in this paper, but are presented to demonstrate how little is yet known of the natural history of crayfishes, even in the relatively well-worked subject of crayfish reproduction.

Key to Adults of Crayfishes Known from New York

The following key is designed to separate mature New York crayfishes without reference to copulatory stylets or to seminal receptacles. The male I stylets are usually the best diagnostic feature of a species and it is preferable that, if form I males are present, their stylets be used in making the identification by comparing them with the stylet figures on plates 2-4.

Form II stylets are less distinctive and the seminal receptacles are in some species confusingly similar. It is for the identification of form II males and females that the key will be most useful. Reference may then be made to the appropriate figures on plates 2-5.

The identification of immature specimens should not be attempted by the nonspecialist. Shapes of various structures, particularly the

rostrum and hand, are different in immature and in mature individuals. The key has not been designed to include immatures. The minimal known carapace lengths of sexually mature individuals are listed in table 2. Because some immature individuals are known to exceed these values, it would be well to add one or two millimeters to each value and to key no specimens smaller than this.

TABLE 2

Minimal carapace lengths in mm. of sexually mature crayfishes in New York

	MALE	FEMALE
Procambarus b. blandingi	31-32(?)	31-32(?)
Orconectes immunis	23.2	23.0
Orconectes virilis	probably similar to *O. immunis*	
Orconectes limosus	23.5 (approx. 19 mm. in Penna.; Ortmann, 1906:477)	22.5
Orconectes p. propinquus	16.2	16.5
Orconectes obscurus	19.9	23.1 (approx. 20 mm. in Penna.; Ortmann, 1906:471)
Cambarus b. bartoni	18.5	(approx. 24 mm. in N. J.; Ortmann, 1906:486)
Cambarus robustus	31.7	31.2

The ratio, length of areola / width of areola, used in the first pair of alternatives (*A* and *AA*) in the key, is based on measurements of the few mature New York specimens of *O. virilis* and *P. b. blandingi* in my personal collections or in NYSM 6976 (stream survey collections). Of the other six species, 30 specimens each were measured (half males and half females). The critical figure (9.6) is the mean of two values: (1) the smallest ratio (11.4) obtained for the three species in the first division of the key, *A*; (2) the largest ratio (7.9) obtained for the five species in the second division, *AA*. The measurement of areola width cannot be made with dividers with sufficient accuracy. It must be made under magnification with an ocular micrometer, or better, with a camera lucida, marking the limits of the narrowest part of the areola on paper and dividing the measurement of this by the power of magnification.

A. The ratio, length of areola/width of areola, greater than 9.6; a narrow areola usually permitting no more than two punctations to occur side-by-side in its narrowest portion.

B. Carapace covered with tubercles of such height that the surface feels definitely granular.
. . . . . *Procambarus b. blandingi.*

BB. Surface of carapace smooth except for low tubercles on lateral surfaces of anterior portion and except for setae.

C. Movable finger (dactyl) of hand with a notch at its base on the inner side. . . . . *Orconectes immunis*

CC. Inner side of movable finger of hand straight.
. . . . . *Orconectes virilis*

AA. The ratio of length to width of areola, less than 9.6; areola relatively broad, permitting at least three punctations to occur in a horizontal row in its narrowest portion.

B. Rostrum with spines (often only tubercles in large specimens) at base of acumen.

C. Lateral surface of carapace ahead of cervical groove with two or more sharp spines.
. . . . . *Orconectes limosus*

CC. Lateral surface of carapace ahead of cervical groove with tubercles only.

D. Rostrum usually with a distinct median carina. Distal margin of ventral surface of carpus of chela usually without either spine or tubercle. . . . . *Orconectes p. propinquus*

DD. Rostrum usually without median carina. Distal margin of ventral surface of carpus of chela with tubercle and usually a spine. . . . . *Orconectes obscurus*

BB. Margins of rostrum not interrupted by spines.

C. Inner margin of palm with a single row of low tubercles; hand inflated, without conspicuous depression near outer margin (plate 1, figure 6). Rostrum tapering acutely to its tip (plate 1, figure 2). Areola with relatively few large punctations, tending to fall into three cephalocaudal rows (plate 1, figure 3). Carapace without lateral spines. Inner border of antennal scale usually directed rather abruptly caudad (plate 1, figure 2).
. . . . . *Cambarus b. bartoni*

CC. Inner margin of palm with two rows of low tubercles; hand with depression, visible both from the dorsal and ventral sides, near its outer margin (plate 1, figure 5). Rostrum tapering less abruptly to its tip (plate 1, figure 1). Areola with smaller more numerous punctations which do not tend toward an arrangement in three rows (plate 1, figure 4). Carapace often with lateral spines. Inner border of antennal scale usually directed mesiad before turning caudad (plate 1, figure 1). . . . . *Cambarus robustus*

PLATE 1

Illustrations of structures used to distinguish between *Cambarus b. bartoni* and *Cambarus robustus.*

Cambarus b. bartoni, male I; carapace length 33.5 mm.; DWC 59; N. Y., Tompkins County, Buttermilk Creek at outlet of Treman Lake; coll. by DWC, Sept. 17, 1950. A copulatory stylet of this specimen is drawn on plate 2, figure 5.

Figure 2. Dorsal view of head region showing rostrum, eye and antennal scale

Figure 3. Areola, showing punctations

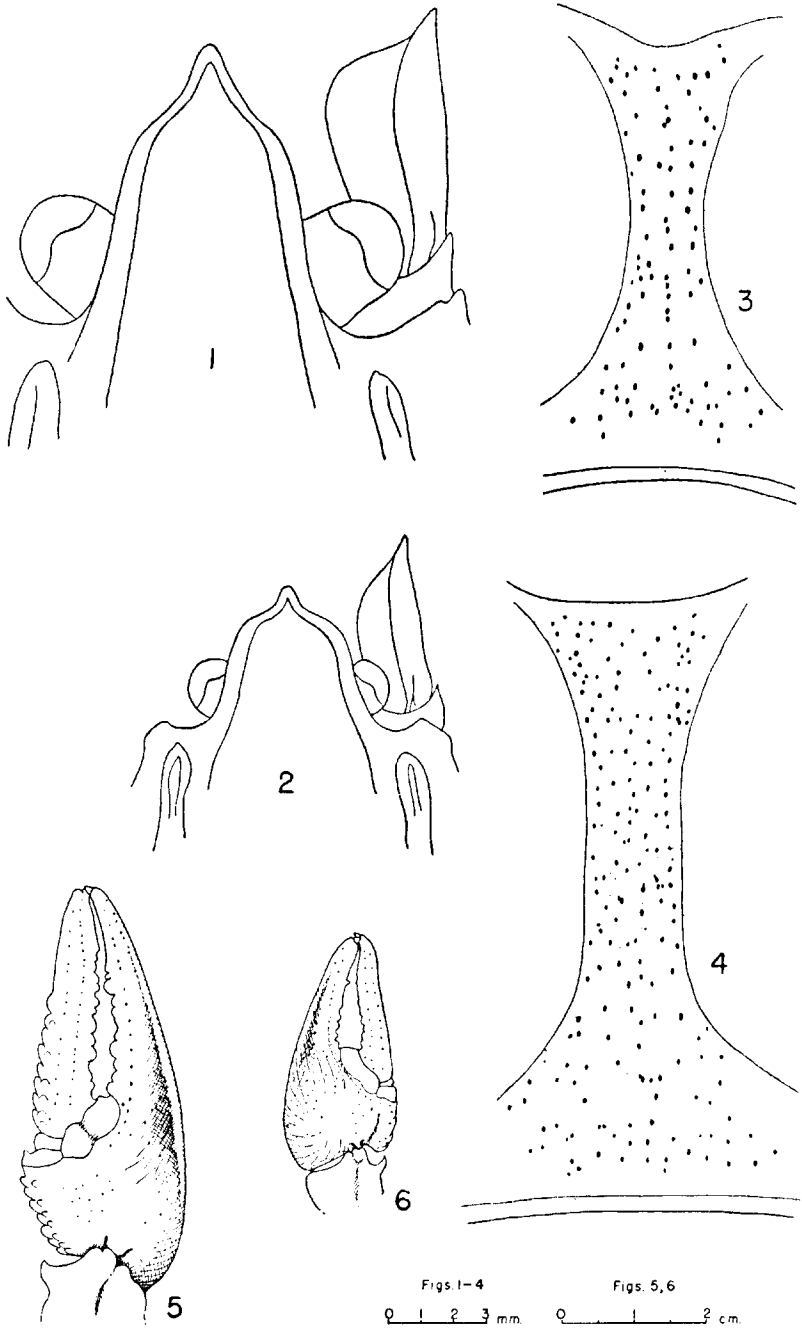
Figure 6. Dorsal view of hand and fingers of left chela

Cambarus robustus, male I; carapace length 50.0 mm.; DWC 12; N. Y., Schuyler County, tributary of Taughannock Creek, 1.4 miles N. W. of Perry City; coll. by R. D. Suttkus, Oct. 8, 1949.

Figure 1. Dorsal view of head region showing rostrum, eye and antennal scale

Figure 4. Areola, showing punctations

Figure 5. Dorsal view of hand and fingers of right chela


1
2
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Figs. 1–4
0 1 2 3 mm.
Figs. 5, 6
0 1 2 cm.

PLATE 2

Copulatory stylets and seminal receptacles of *Cambarus b. bartoni* and *Cambarus robustus*.

Figures 1-4. *Cambarus robustus;* DWC 91; N. Y., Oswego County, Oswego River drainage, Scriba Brook (a tributary of Oneida Lake) at N. Y. State Fish Hatchery dam at Constantia; coll. by R. L. Wigley, May 6, 1951.

Figure 1. Stylet of male I; carapace length 41.5 mm. A photograph of this specimen appears in the frontispiece.

Figure 2. Stylet of male II; carapace length 38.7 mm.

Figure 3. Right-handed seminal receptacle of female; carapace length 41.0 mm.

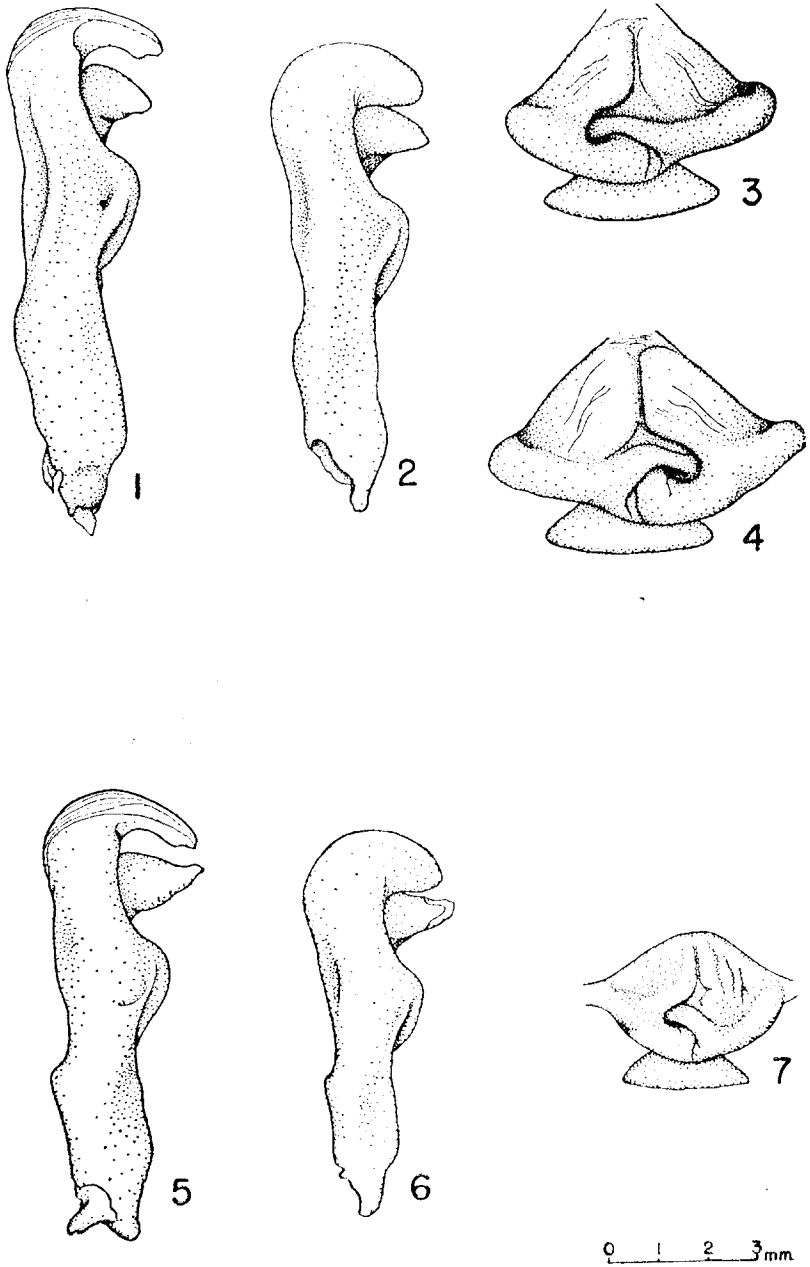
Figure 4. Left-handed seminal receptacle of female; carapace length 41.8 mm.

Figure 5. *Cambarus b. bartoni,* stylet of male I; carapace length 33.5 mm.; DWC 59; N. Y., Tompkins County, Buttermilk Creek at outlet of Treman Lake; coll. by DWC, Sept. 17, 1950. Figures 2, 3 and 6 on plate 1 are drawn from this same specimen.

Figure 6. Same, stylet of male II; carapace length 30.0 mm.; DWC 28; N. Y., Tompkins County, Oswego R. drainage, Fishkill Creek in Robert Treman State Park at Enfield; coll. by DWC, June 5, 1950.

Figure 7. Same, seminal receptacle of female; carapace length 31.7 mm.; DWC 77; same locality as figure 5; coll. by DWC, April 22, 1951.

All stylets are right stylets seen in lateral view.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7
0 1 2 3mm

PLATE 3

Copulatory stylets of three New York species of *Orconectes.*

Figure 1. *Orconectes p. propinquus,* male I; carapace length 36.5 mm.; DWC 108; N. Y., Herkimer County, Black River drainage, outlet of Fulton chain of lakes at town of Old Forge; coll. by DWC and J. A. Gustafson, May 19, 1951.

Figure 2. Same, male II; carapace length 27.7 mm.; DWC 33; N. Y., Tompkins County, Oswego River drainage, Fall Creek at McLean; coll. by DWC, June 21, 1950.

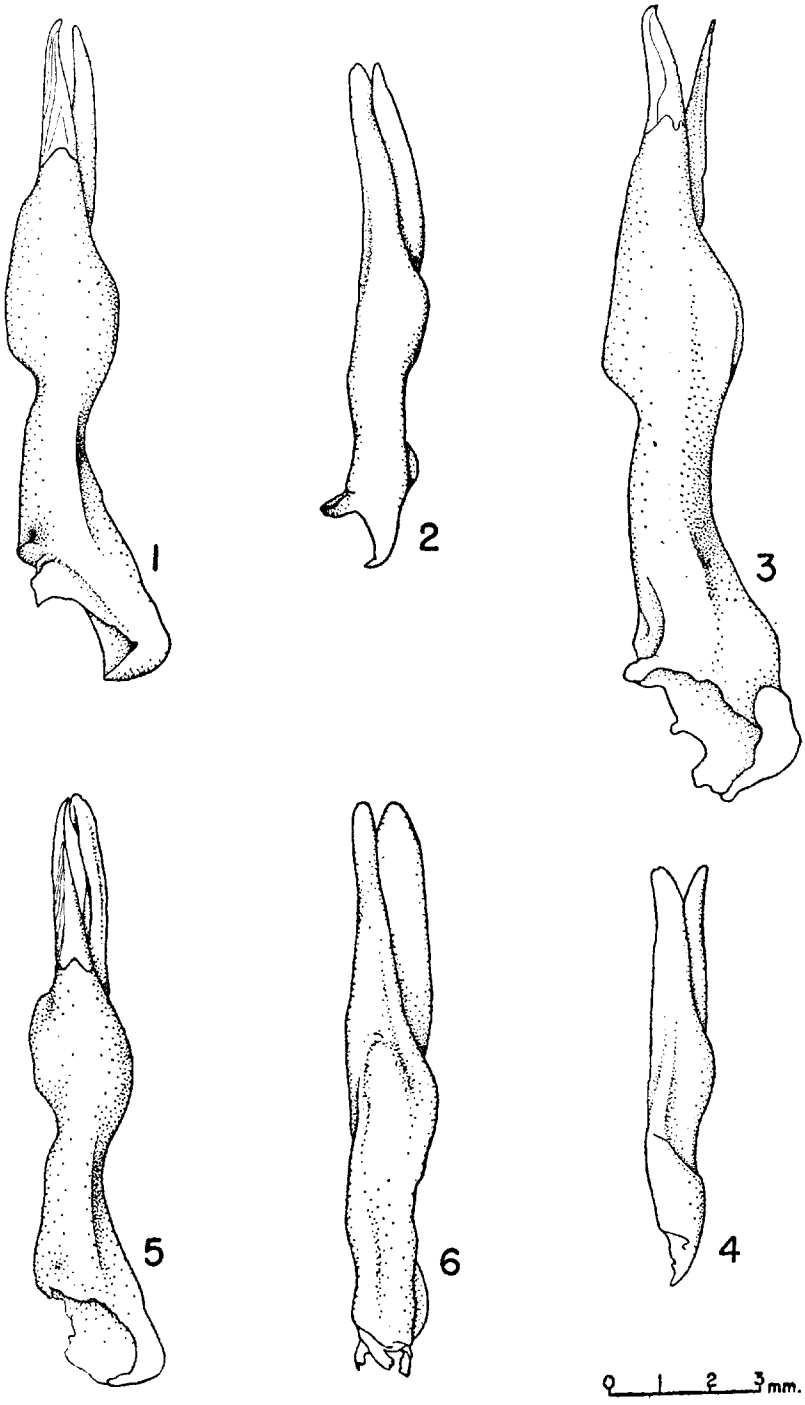
Figure 3. *Orconectes limosus,* male I; carapace length 43.5 mm.; DWC 20; N. Y., Ulster County, Hudson River drainage, Esopus Creek near W. city limits of Kingston; coll. by Theodore Weyhe, Feb. 18, 1950.

Figure 4. Same, male II; carapace length 27.4 mm.; DWC 132; N. Y., Columbia County, Hudson River drainage, Kinderhook Creek between Valatie and Kinderhook; coll. by J. A. Gustafson and Earl Deubler, Jr., June 1, 1951.

Figure 5. *Orconectes obscurus,* male I; carapace length 32.0 mm.; DWC 94; N. Y., Cattaraugus County, tributary of Allegheny River, 5.4 miles W. of town of Allegheny; coll. by C. R. Robins, May 12, 1951.

Figure 6. Same, male II; carapace length 36.6 mm.; DWC 140; N. Y., Chautauqua County, Allegheny River drainage, W. branch of French Creek, 1 mile N. of town of Findley Lake; coll. by John G. New, June 15, 1951.

All are right stylets seen in lateral view. A photograph of the specimen from which the stylet shown in figure 1 was taken appears in the frontispiece along with a photograph of a form I male of *O. limosus* (carapace length 44.7 mm.) from the same collection as figure 3.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0 1 2 3 mm.

PLATE 4

Copulatory stylets of two *Orconectes* species and of *Procambarus b. blandingi.*

Figure 1. *Orconectes virilis,* male I; carapace length 43.9 mm.; DWC 170; N. Y., Saratoga County, Hudson River drainage, stream (probably Kayaderosseras Creek) at bridge on U. S. Route 9, 2.3 miles S. of city limits of Saratoga Springs; coll. by DWC, Aug. 19, 1952.

Figure 2. Same, male II; carapace length 36.5 mm.; same collection as figure 1.

Figure 3. *Orconectes immunis,* male I; carapace length 36.8 mm.; DWC 75*b*; N. Y., Tompkins County, Oswego River drainage, ponds at Cornell University Experimental Fish Hatchery; coll. by Milton Potash and L. C. Cole, April 13, 1951.

Figure 4. Same, male II; carapace length 38.2 mm.; DWC 138; N. Y., Cayuga County, Oswego River drainage, Duck Lake outlet at town of Spring Lake; coll. by E. C. Raney, May 20, 1951.

Figure 5. *Procambarus b. blandingi,* male I; carapace length 42.8 mm.; DWC 173; N. Y., Westchester County, Bronx River at White Plains North Railroad Station; coll. by DWC, Aug. 25, 1952.

Figure 6. Same, male II; carapace length 45.5 mm.; same collection as figure 5.

All are right stylets seen in lateral view. Photographs of the specimens from which the form I stylets were taken appear in the frontispiece.

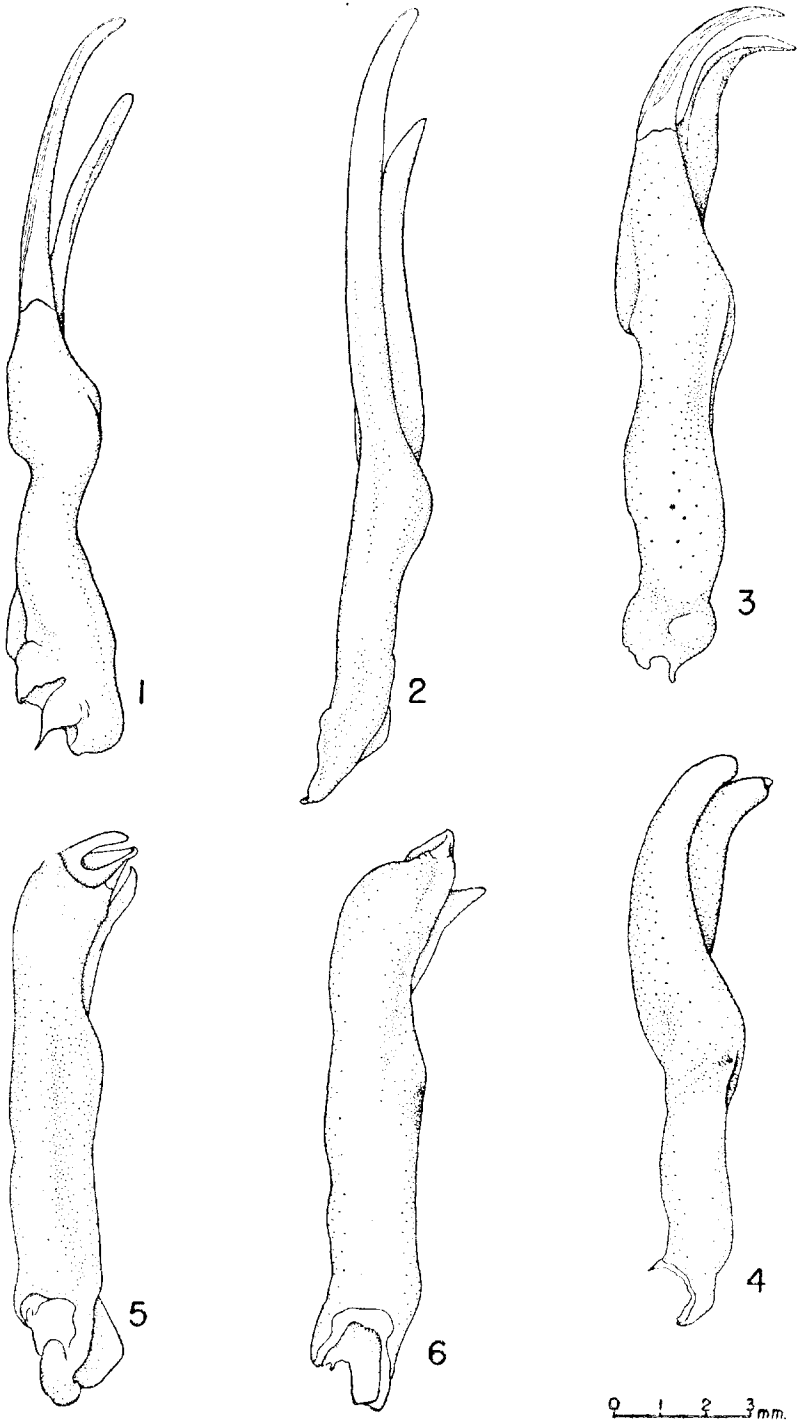
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PLATE 5

Seminal receptacles of the New York species of *Orconectes* and *Procambarus*.

Figure 1. *Orconectes p. propinquus;* carapace length 35.6 mm.; DWC 108; N. Y., Herkimer County, Black River drainage, outlet of Fulton chain of lakes at town of Old Forge; coll. by DWC and J. A. Gustafson, May 19, 1951.

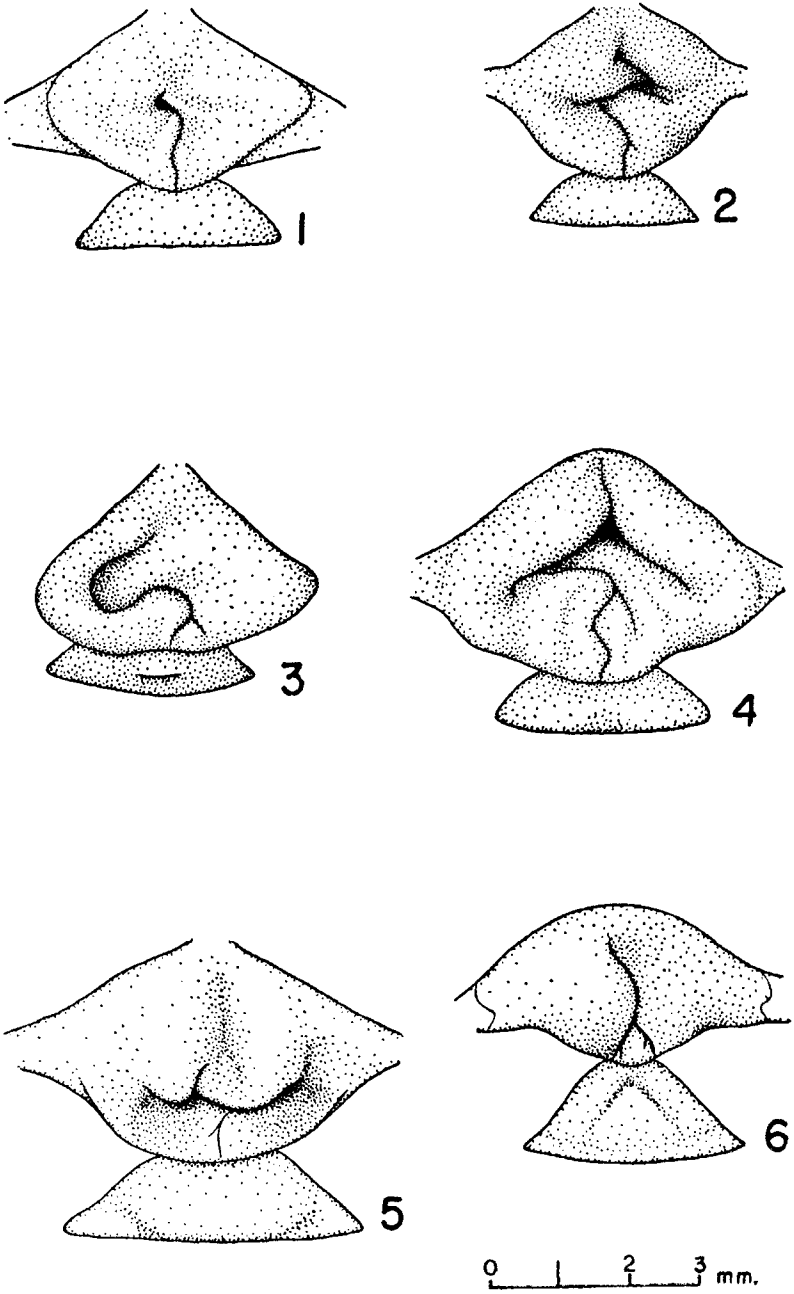
Figure 2. *Orconectes obscurus;* carapace length 28.3 mm.; DWC 140; N. Y., Chautauqua County, Allegheny River drainage, W. branch of French Creek, 1 mile N. of town of Findley Lake; coll. by John G. New, June 15, 1951.

Figure 3. *Orconectes immunis;* carapace length 39.5 mm.; DWC 72 (specimen no. 15); N. Y., Tompkins County, Oswego River drainage, ditch tributary to Cayuga Inlet in Ithaca; coll. by H. Evans and R. D. Suttkus, July 17, 1950.

Figure 4. *Orconectes virilis;* carapace length 38.1 mm.; DWC 170; N. Y., Saratoga County, Hudson River drainage, stream (probably Kayaderosseras Creek) at bridge on U. S. Route 9, 2.3 miles S. of city limits of Saratoga Springs; coll. by DWC, August 19, 1952.

Figure 5. *Orconectes limosus;* carapace length 45.1 mm.; DWC 20; N. Y., Ulster County, Hudson River drainage, Esopus Creek near W. city limits of Kingston; coll. by Theodore Weyhe, Feb. 18, 1950.

Figure 6. *Procambarus b. blandingi;* carapace length 44.6 mm.; DWC 173; N. Y., Westchester County, Bronx River at White Plains North Railroad Station; coll. by DWC, Aug. 25, 1952.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mm.

DESCRIPTIONS

Procambarus blandingi blandingi (Harlan)

(FRONTISPIECE; PLATE 4, FIGURES 5 AND 6; PLATE 5, FIGURE 6)

Astacus blandingi Harlan, 1830: 464-465.
Astacus (Cambarus) blandingi Harlan. Erichson 1846: 98, 99.
Cambarus blandingi Harlan. Hagen 1870: 43-45; pl. I, figs. 63 and 64; pl. III, figs. 140*a*, *b* and *c*.
Cambarus acutus Girard var. B. Hagen, 1870: 36, 37, 39; pl. III, figs. 144*a*, *b* and *c*.
Cambarus acutus Girard. Abbott 1873: 80-84.
Cambarus (Cambarus) blandingi (Harlan). Ortmann 1905*a*: 96-97.
Cambarus (Ortmannicus) blandingi (Harlan). Fowler 1912: 340, 341, pls. 106, 107.
Cambarus blandingi acutus Harlan (in part). Faxon 1914: 367.
Procambarus blandingi blandingi (Harlan). Hobbs 1942*a*: 341, 342.
(not) *Cambarus blandingi* (Harlan). Girard 1852: 91 (authority of Hagen 1870: 45).

Taxonomic remarks: The record of *C. b. acutus* from Fulton County, Md. (Faxon 1914: 367) should be referred to *P. b. blandingi* on the basis of the locality. Hagen (1870: 45) believes that the record of *C. blandingi* from Summerville, S. C., given by Girard (1852: 91), is *C. troglodytes* (=*Procambarus troglodytes*). Harlan (1835) repeats his original description and provides a figure.

It has been pointed out by Hobbs (1942*b*: 94) that many of the references to this species in the literature are unreliable and that the *blandingi* complex is in need of considerable work before the relationships among the various taxonomic forms are clearly understood.

Type: "Acad. Nat. Sci. Philad. (1 male)." Faxon (1914: 413).

Type locality: "Marshes and rivulets, Southern United States [Camden, Kershaw Co., S. C.?]." Faxon (1914: 413). Square brackets are Faxon's.

DESCRIPTION

By touch alone the tuberculated surface of the carapace separates this crayfish from the other New York species.

Male I. The following description is based on the only form I male in NYSM 1936: 3576, from New York, Westchester County, East River drainage, Bronx River. For terminology and method of taking measurements see Hobbs (1942*b*: 24, text figure b). The description is designed so that comparisons may be made between these specimens and the excellent descriptions of the holotype and

paratypes of *P. b. cuevachicae* (Hobbs 1941: 1-4). Because *P. b. blandingi* has not been adequately described, the following description is given in detail:

Carapace evenly tuberculated except on dorsal surface of anterior portion (ahead of cervical groove) where tubercles are lacking. Postorbital tubercles directed somewhat laterad which, together with the mesially directed bases of the postorbital ridges, present a lyre-shaped figure. Areola narrow, bearing a single row of punctations in its narrowest portion. Single, small lateral spine on each side of carapace.

Rostrum elongate and concave, lateral margins sharp. Broad at base, margins slightly convex just distad of base, tapering gradually to a short, but not broad, acumen. Small spines at base of acumen. Margins of acumen densely setose. Rostral surface sparsely punctate at base, non-setose except for a row of setae just inside lateral margins.

Antennal scale bearing a small spine at distal end of lateral border. Very short anterior margin, bending at about a 45-degree angle to form the antero-mesial border which in turn bends near the antero-posterior midpoint of the scale to form a postero-mesial border. The antero-mesial and postero-mesial borders are about equal in length.

Epistome sagittiform, margins slightly elevated, lacking tubercle on median cephalic border, slight depression in midline at base.

Flagellum of right **antenna** reaches to midway on posterior section of telson. Distal third hairlike in thinness.

Right **chela** long and relatively slender. Dorsal and ventral surfaces of propus with few low tubercles. These increase in number and slightly in diameter, but not in height, toward the outer margin. The row of low tubercles on the outer margin is transformed gradually into a row of setiferous punctations on the immovable finger. Toward the inner margin there is a similar increase in number and diameter and a great increase in height. The highest form a row of seven on the exact mesial margin.

Immovable finger (of propus) of right chela with a shallow longitudinal furrow on both dorsal and ventral sides running laterad of the midline and bearing setiferous punctations. A row of 15 tubercles extends from the base of the immovable finger to slightly less than halfway from the tip. This row is situated slightly dorsad of the mesial border. The third tubercle (from the base) is much larger than the others. Slightly ventrad of the mesial border in the distal third of the immovable finger is a row of three tubercles, the most distal being largest. When the fingers are apposed, the proximal enlarged tubercle lies on the dorsal side of the movable finger and the distal enlarged tubercle on the ventral side.

Movable finger (dactyl) of right chela sigmoid, bearing tubercles on basal third, the largest three form a row on the lateral margin. Just dorsal and just ventral to the mesial border is a row of tubercles, the dorsal row containing 21, the ventral row 9. The second tubercle in the ventral row is conspicuously enlarged. The meeting surfaces of both the movable and immovable fingers are flattened and bear, particularly on their distal halves, a dense pile of flattened, bladelike setae.

Carpus of right chela lacking tubercles on lateral border and on lateral halves of dorsal and ventral surfaces except for a single tubercle at a peak of the distal edge on the ventral side about midway between the midline and the lateral margin. Of the tubercles on the remaining surfaces, the two largest are situated, one on the distal edge on the ventral side at the midline, the other on the mesial surface. A shallow, slightly arcuate furrow is present on the dorsal side.

Merus of right chela with mesial and lateral surfaces free of tubercles except on the distal third of the mesial side where they are weakly developed. On the narrow dorsal surface there are 18 tubercles arranged in a single row proximally, but tending toward two rows in the distal half. On the slightly wider ventral surface are two tubercle rows, one mesial and one lateral, with 22 somewhat irregularly aligned tubercles in the former and 14 in the latter. Three small tubercles on the ventral side diverge from the lateral row and follow proximally the lateral arm of the U-shaped distal edge. The end of the arm possesses a well-developed tubercle with a corneous tip.

Anterior section of **telson** with each postero-lateral corner ending in a spine. A second spine occurs on each side mesiad of the corner spine.

Copulatory stylets terminating in four distinct elements (see plate 4, figure 5 drawn from a different specimen), reaching a point just cephalad of caudal border of coxae of third pereiopods when the abdomen is flexed. The cephalic process, central projection and caudal process are corneous. Mesial process not so. All elements are gently curved so that the tips are directed laterad. A conspicuous knob at the base of the cephalic process bears a dense cluster of long setae.

Hooks on ischia of third and fourth pereiopods. Coxae of fourth pereiopods bearing a large, slightly compressed knoblike protuberance.

Measurements: The following measurements in mm. were made on the form I male described above:

Carapace, greatest height – 20.6; greatest width – 22.8; total length – 47.5; length of cephalic section – 31.3
Areola length – 17.1; width – 1.4
Rostrum, width at base – 7.6; length – 11.9
Abdomen length – 42.9

Right chela, length of inner margin of palm – 18.4; width of palm – 14.8; length of outer margin of hand – 51.1; length of movable finger – 29.5

Male II. Plate 4, figure 6 shows a form II stylet from DWC 173 (Bronx River). As compared with the form I stylets, the four terminal elements are not corneous and are shorter, more rounded and softer.

Female. This description is based on the only female in USNM 74,747, from New York, Westchester County, East River drainage, Bronx River. Similar to male I, but chelae proportionately much smaller and less elongate; tubercle count different. Fingers with only a single row of tubercles on the opposable margin of each. Movable finger of hand with conspicuous notch at base of mesial border.

Seminal receptacle (see plate 5, figure 6 drawn from a different specimen) subovate with three tubercles; left, right and caudal. Right tubercle much higher than the other two and curved to the left, creating a deep fossa. Left tubercle gives rise to a ridge which runs to the right on the floor of the fossa and which is largely hidden from view by the overhang of the right tubercle. At the caudal border the sinus originates to left of caudal tubercle. It curves to the right following the caudal edge of the above mentioned ridge and disappears under the overhang of the right tubercle. I am not able to detect its reappearance at the cephalic border of the receptacle. It is very different from the figure given by Hobbs (1941: 3, text fig. 1*G*) for *P. b. cuevachicae*; more similar to, but still different from the figures given by Turner (1926: 195, pl. xx, fig. 25) and Pearse (1910: pl. I, fig. *B*) for *P. b. acutus*.

Orconectes virilis (Hagen)

(Frontispiece; plate 4, figures 1 and 2; plate 5, figure 4)

Cambarus virilis Hagen, 1870: 63-65.
Cambarus debilis Bundy, 1876: 24 (authority of Faxon 1885*b*: 97).
Cambarus couesi Streets, 1877: 803 (authority of Faxon 1885*b*: 97).
Cambarus (Faxonius) virilis Hagen. Ortmann 1905*a*: 107.
Orconectes virilis (Hagen). Hobbs 1942*a*: 352.

Types: "*Types*, M. C. Z., No. 1,151; *paratypes*, M. C. Z., Nos. 194 and 203 (Lake Superior), No. 196 (Quincy, Ill.), No. 3,342 (Lake Winnipeg), No. 3,343 (Red River of the North), No. 3,344 (Saskatchewan River); Mus. Hist. Nat. Paris (Lake Superior); Wurzburg Mus. (Lake Superior); Australian Mus., Sydney." Faxon (1914: 420). I have examined the types and the MCZ paratypes.

Type locality: Lake Superior; designation by Faxon (1914: 420).

Description

The best description of this species is that given by its author, Hagen (1870: 63-64). Because I have seen so few specimens from New York (tables 16, 17 and 18), no account of the extent of its variation can be given.

It is readily separated from *Orconectes immunis*, the crayfish which in New York is most similar to it, by the presence in *O. immunis* of a notch at the inner base of the movable finger. The rostral shape is also different, *O virilis* having straighter sides, a longer acumen and a more shallow excavation in the middle than has *O. immunis*. The shapes of first form stylets should readily separate these two species (plate 4, figures 1 and 3). The male I stylets in *O. virilis* reach just to the caudal border of the bases of the chelae when the abdomen is flexed, while those of *O. immunis* reach only to a point just cephalad of the caudal border of the second pereiopods.

The male II stylets (plate 4, figures 2 and 4) and the seminal receptacles (plate 5, figures 3 and 4) are also different, but less obviously so.

Orconectes immunis (Hagen)

(Frontispiece; plate 4, figures 3 and 4; plate 5, figure 3)

Cambarus immunis Hagen, 1870: 71-73 (in part only, authority of Faxon 1885*b*: 100).
Cambarus signifer Herrick, 1882: 253 (authority of Faxon 1885*b*: 99).
Cambarus immunis spinirostris Faxon, 1885*a*: 146.
Cambarus (*Faxonius*) *immunis* Hagen, Ortmann 1905*a*: 113.
Faxonius immunis immunis (Hagen), Creaser 1933*a*: 13.
Faxonius immunis pedianus Creaser, 1933*a*: 14-16.
Orconectes immunis immunis (Hagen), Hobbs 1942*a*: 352.

Types: "*Types*, M. C. Z., No. 188; *paratypes*, M. C. Z., No. 3,355 (Belleville, Saint Clair Co., Ill.); Mus. Hist. Nat. Paris (Lawn Ridge, Ill., 1 male)." Faxon (1914: 421).

Type locality: Lawn Ridge, Illinois; designated by Faxon (1914: 421).

Taxonomic remarks: I agree with Creaser (1931: 262 and 1933*a*: 13-14) and Ortmann (1931: 93, 94) that *C. i. spinirostris* is but a variant form. See also Rhoades (1944*a*: 132, 133). Williams and Leonard (1952: 1003-1005) present data which indicate that Creaser's *O. i. pedianus* is but one extreme of a clinal variation.

Description

O. immunis is a pond crayfish which is often called the "grass-crab" or "butter-crab" by bait dealers and fishermen. The latter name may be due to its smooth surface which is often slippery, particularly in newly moulted specimens.

The most detailed description of this species is the one given by its author (Hagen 1870: 71-73). The characters which separate it from *O. virilis*, the only New York species likely to be confused with it, are given under the description of *O. virilis*.

Orconectes propinquus propinquus (Girard)

(Frontispiece; plate 3, figures 1 and 2; plate 5, figure 1)

Cambarus propinquus Girard, 1852: 88.
Cambarus (Faxonius) propinquus Girard. Ortmann 1905*a*: 107.
Faxonius propinquus (Girard). Creaser 1933*b*: 4.
Orconectes propinquus propinquus (Girard). Hobbs 1942*a*: 352.

Types: Hagen, in preparing his monograph, borrowed what he called Girard's "types" from William Stimpson (Hagen 1870: 7), and gave figures in his monograph of the first and second form copulatory stylets. It is to be remembered, however, that in 1870 the word "types" did not necessarily have the connotations which it has today. The word merely meant specimens identified by some student of the group, the specimens then being called that person's types of a given species. Whether or not Hagen saw specimens of *O. p. propinquus* which came from a locality listed by Girard, which were used by Girard in writing his original description and which we would now call strictly Girard's types, cannot be known. Hagen does not give localities for the specimens figured.

It is generally believed that Hagen returned the specimens to Stimpson and that they, along with the majority of Girard's material from which a neoholotype might be selected, were destroyed in the great Chicago fire of 1871 (Faxon 1914: 417). At least, at present they cannot be located.

There is a specimen of *O. p. propinquus* in the Academy of Natural Sciences of Philadelphia which has Girard's name on the label followed, however, by a question mark (Hagen 1870: 7; Faxon 1914: 417). This specimen is from Garrison Creek, Sackett's Harbor, N. Y., a locality given by Girard. In view of the fact that Girard's name is followed by a query, that there is a single specimen and that the identity of Garrison Creek is not certain (see below), this is probably not suitable material from which to select a type. Apparently, there are no specimens now in existence of *O. p. propinquus*, which are known with certainty to have been identified as such by Girard, nor have new types been selected.

Type locality: The following three localities are given by Girard (1852:88):

1. "Lake Ontario, four miles from the shore, opposite to Oswego [Oswego Co., N. Y.], found in the stomach of Lota maculosa."
2. "Garrison Creek, Sacketts Harbor [Jefferson Co., N. Y.]."
3. "Four Mile Creek, Oswego [Oswego Co., N. Y.]."

The first locality is listed (as Oswego, Oswego County, N. Y.) as type locality by Ortmann (1906: 363) without selection of new types.

The second locality is given (again without a selection of new type specimens) as the type locality by Faxon (1914: 417) along with locality number 3. After consulting numerous old maps, county histories and gazetteers of Jefferson County, N. Y., I am unable to locate Garrison Creek. It is probable that the stream intended is the one known to the inhabitants of Sacketts Harbor and in the literature as Mill Creek. There is a garrison (Madison Barracks) at its mouth. It is not possible at present, however, to demonstrate conclusively that the two stream names are synonymous.

I have not visited Four Mile Creek nor do I know of existing collections from it. It appears that the first locality as listed by Ortmann is the type locality. This subspecies is described in a comparison between it and *O. obscurus* (given under *O. obscurus*). Hybridization of *O. p. propinquus* is discussed under that heading as a separate section of the study.

Orconectes obscurus (Hagen)

(PLATE 3, FIGURES 5 AND 6; PLATE 5, FIGURE 2)

Cambarus obscurus Hagen, 1870: 69, 70.
Cambarus propinquus var. *obscura* Hagen. Faxon 1885*b*: 92-94.
Cambarus obscurus Hagen. Faxon 1898: 652.
Cambarus (Faxonius) obscurus Hagen. Ortmann 1905*a*: 107.
Orconectes obscurus (Hagen). Hobbs 1942*a*: 352.
Cambarus propinquus Girard. Williamson 1901: 13 (authority of Ortmann 1905*b*: 387, 388).
Cambarus rusticus Girard. Williamson 1901: 13 (authority of Ortmann 1905*b*: 387, 388).

Types: "*Cotypes*, M. C. Z. No. 181, 3,353, 3,354; U. S. N. M. No. 4,971; Mus. Hist. Nat. Paris; Wurzburg Mus.; Australian Mus., Sydney." Subsequent designation by Faxon (1914: 418). I have examined the cotypes in MCZ and USNM.

Type locality: Genessee River, Rochester, Monroe County, N. Y. (Hagen 1870: 70).

DESCRIPTIONS OF *Orconectes p. propinquus* AND *O. obscurus*

Ortmann (1906: 358-362, 365-372) has given detailed descriptions for these two species in Pennsylvania and, because my materials are similar, the descriptions here will be limited to pointing out differences between New York State and Pennsylvania populations. These two species are so close morphologically that comparisons between them will be made wherever there appear to be differences.

The possibility of assigning all specimens to one or the other of these two species is probably limited to localities where they do not occur together for, as discussed under a separate heading below,

hybridization appears to occur between them. None of the discussion of these two species under the present heading of "Descriptions" applies to localities where they occur together (figure 5).

Ortmann found the majority of morphological features to be almost identical in these two species. It is in the features which he found best to show differences that my materials appear to vary from Ortmann's. These features are:

1. Presence or absence of a median keel (carina) on the rostrum
2. Armature of carpus of chela
3. Armature of merus of chela
4. Shape of seminal receptacle
5. Shape of copulatory stylets

Rostral carina. Of the rostrum in *O. p. propinquus*, Ortmann (p. 359) says, "Surface concave, with a more or less distinct, low, longitudinal median keel toward the tip." Of *O. obscurus*, he says (p. 369), "Rostrum similar to that of *C. propinquus*, but always without any trace of a median keel." In New York *O. p. propinquus*, the median carina is indeed usually distinct, but some mature or immature specimens in most large collections show hardly a trace of it and it is only by having the rostrum thoroughly dry and the light source properly directed that it can be made out.

Furthermore, occasional specimens of *O. obscurus*, from widely separated localities, show a relatively broad, slightly raised region in the midline of the rostrum, and considering rostrum alone, they could hardly be separated from specimens of *O. p. propinquus* showing minimal development of the carina. Five of 12 specimens of *O. obscurus* on loan from Dr. H. H. Hobbs, Jr., which were taken in Pendleton County, W. V. (Hobbs' collection 7-3149-3*a*) show a distinct although small median rostral carina.

Presence or absence of rostral carina can not be used as a character for completely separating these two species, even though it will correctly assign to species the majority of individuals.

Armature of carpus of chela. Of the carpus of the chela of *O. p. propinquus* Ortmann (p. 360) says, "Lower surface with a low and broad tubercle in the middle of the anterior margin, which is very rarely subspiniform. . ." Again (p. 364) he says, "The anterior margin is often without any spine, or even tubercle; there is, however, a low tubercle developed in many cases, and in two cases it was spiniform. . ." Of *O. obscurus* he says (p. 370), "The *carpopodite* differs from that of *C. propinquus* in the development of a strong tubercle on the anterior margin of the lower side. This tubercle very rarely

is indistinct (chiefly so in regenerated claws); generally it ends in a distinct, stout, conical spine."

New York *O. obscurus* conform with Ortmann's description given above. In *O. p. propinquus,* however, I have several specimens from widely separated localities, with well-developed spines on the lower distal border of the carpus of each chela and a number of others with spines less well developed, often occurring unilaterally. All degrees of development of the tubercle occur, from none at all to one quite distinct. By far the greatest proportion of specimens, however, have no tubercle or one which is at best barely perceptible.

Of these two species, data on hand show that if a specimen has no tubercle or spine on the lower distal border of the carpus, it is *O. p. propinquus.* The presence of a tubercle, however, does not indicate that the specimen is *O. obscurus.* The character will not give complete separation of these species.

Armature of merus of chela. Of the spines on the lower side of the merus in *O. p. propinquus,* Ortmann (p. 364) says that they are generally represented by only two spines, the distal spine of each row being alone present. He then points out his only localities where additional spines occur.

Of *O. obscurus* Ortmann (p. 370) says, "The *meropodite* differs from that of *C. propinquus* by the constant presence of a series of 4-8 small tubercles, or teeth, behind the distal spine on the inner lower margin. These teeth are never wanting in any of my specimens. The outer lower margin has one or two spines. The lat[t]er number is comparatively rare."

New York *O. obscurus* agree with those of Ortmann. In *O. p. propinquus* however, specimens with a distinct row of low spines on the inner lower margin far outnumber those which show only the single distal-most spine. All degrees of variation occur even in single large collections. I have found as many as four spines in the outer row.

Shape of seminal receptacle (plate 5, figures 1 and 2). Ortmann (p. 361) says of *O. p. propinquus* that its seminal receptacle is flat, slightly depressed in the middle, has no tubercles on the anterior margin and (p. 365) that only slight differences due to age are noticeable. He differentiates the receptacle of *O. obscurus* by its having a "well-marked" depression in the middle and two subconical tubercles in the anterior part (p. 371).

New York *O. p. propinquus* differ from this description in that two tubercles frequently occur near the anterior border of the receptacle. The highest of these tubercles are as high as the lowest tubercle found in *O. obscurus.* However, it is always possible to distinguish

the one species from the other, for in *O. obscurus* the whole receptacle is generally more nearly round and the two tubercles are not only more distinctly conical, but are fused at the midline, which has never been seen to occur in *O. p. propinquus*. The shape of the seminal receptacle is then, at least in New York State material, a character which will give complete separation. Unfortunately the differences are qualitative and no way has as yet been found of expressing them in numbers.

Shape of copulatory stylets (plate 3, figures 1, 2, 5 and 6). The first form copulatory stylets of these species are distinguished by Ortmann (p. 365) as follows, "... there is a tendency in the Pennsylvania specimens [of *O. p. propinquus*] toward the development of a slight notch on the anterior margin in the place where *C. obscurus* has a shoulder... The notch never assumes the shape of the 'shoulder' of *C. obscurus*, and the sexual organs differ in other respects from the lat[t]er species, chiefly in that the tip of the inner part [mesial process] is never blunt or dilated."

Ortmann had only 18 males I of *O. p. propinquus* and of these, seven had a notch. This appears to be more than a tendency toward its formation. I have not kept a record of numbers of New York State specimens with or without a notch on the stylet, but a large proportion have it. This is true throughout the range in New York of this species and in individual collections.

However, these two species are rapidly separated on the basis of this character, for the notch of *O. p. propinquus* is never more than a suggestion of the well-developed, right-angled shoulder on form I stylets of *O. obscurus*. *O. obscurus* males I have never been observed without the shoulder.

The other stylet character which appears to separate completely these species is the shape of the tip of the mesial process both in form I and form II males. In *O. p. propinquus* the mesial process in both forms of the male ends as a relatively sharp point. In *O. obscurus*, on the other hand, the mesial processes in both form I and form II stylets are rounded off at the tip or are even slightly inflated. A few of my males I of *O. obscurus* from the Allegheny River drainage have the distal quarter of the mesial process directed mesiad at about a 45-degree angle. This appears to be an aberrant shape.

O. p. propinquus appears to be a much more variable species than is *O. obscurus*. See the section "Hybridization" for a discussion of possible hybrids between these two species.

Orconectes limosus (Raf.)

(FRONTISPIECE; PLATE 3, FIGURES 3 AND 4; PLATE 5, FIGURE 5)

Astacus limosus Rafinesque. (Nov.) 1817: 42.
Astacus affinis Say. (Dec.) 1817: 168.
Astacus (Cambarus) affinis Say. Erichson 1846: 96.
Cambarus affinis (Say). Girard 1852: 87.
Cambarus pealei Girard, 1852: 87.
Cambarus (Faxonius) limosus (Rafinesque). Ortmann 1905*a*: 107.
Orconectes limosus (Rafinesque). Hobbs 1942*a*: 352.
Astacus bartoni Fabricius. Milne-Edwards 1837: 331.

Types: ". . . types not extant." (Faxon 1914: 417).

Type locality: Designated by Faxon (1914: 417) as: ". . . the muddy banks of the Delaware River, near Philadelphia, Pennsylvania."

Taxonomic remarks: Holthuis (1954) quotes Rafinesque's original description in full.

DESCRIPTION

Ortmann (1906: 352-356) has described *O. limosus* in detail. In the materials I have seen from New York there appear to be no differences. It is readily separated from the other New York State species by the presence of at least two spines on each side on the cephalic section of the carapace. These are present even in young immatures. The divergent tips of the copulatory stylets (plate 3, figures 3 and 4) are a constant character which, in both form I and form II males, separates this from the other New York State species. A relatively dense pubescence, particularly on carapace and claws is typical of specimens up to 30 mm. carapace length. In larger specimens it becomes less noticeable.

Apparent hybridization between this species and *O. p. propinquus* is discussed under the heading "Hybridization" in a separate section.

Cambarus robustus Girard

(FRONTISPIECE; PLATE 1, FIGURES 1, 4 AND 5; PLATE 2, FIGURES 1, 2, 3 AND 4)

Cambarus robustus Girard, 1852: 90.
Cambarus bartoni var. *robusta* Girard. Faxon 1885*c*: 358.
Cambarus bartoni robustus Girard. Faxon 1890: 622.
Cambarus (Bartonius) bartoni robustus Girard. Ortmann 1905*a*: 117.
Cambarus (Bartonius) robustus Girard. Creaser 1931: 260.
Cambarus (Cambarus) robustus (Fabricius). Fowler 1912: 340, 341.
Cambarus bartoni (Fabricius). Williamson 1905: 310 (authority of Ortmann 1906: 388).

Types: "*Type* probably destroyed in the Chicago fire in 1871; *paratype* (?). Acad. Nat. Sci. Philad. (1 male)." (Faxon 1914: 423).

Type locality: Humber River, near Toronto, Canada. Subsequent designation by Faxon (1914: 423) from Girard's first-named locality.

Taxonomic remarks: The current restricted use of *Cambarus* (see Hobbs 1942*a*: 354) makes Ortmann's subgenus *Bartonius* (see synonymy above) identical to it. No subgenera for *Cambarus* (*sensu stricto*) have been proposed.

The opinion of Creaser (indicated in the synonymy above) that *C. robustus* is not a subspecies of *C. bartoni* seems indisputable when the ranges of *C. robustus* and *C. b. bartoni* are compared (figures 6 and 7). The fact that the two can occupy so much territory in common, often the same streams, and still maintain their identity, makes it difficult to conceive of them as subspecies of the same species.

They do, however, have different habitat preferences, which in the case of the mountain stream (headwater) species, *C. b. bartoni*, appear to be rather strict. Assuming *C. b. bartoni* became established first in the New York stream systems which both it and *C. robustus* now occupy together, then perhaps one can view these two taxa as conspecific subspecies living in the same streams, kept fairly well apart by different habitat preferences, but intergrading in those areas where they actually come in contact.

This view does not seem to be supported by the fact that, although 10 percent of localities (29 of 289) from which *Cambarus* was taken produced both *C. robustus* and *C. b. bartoni*, only 14 percent of these 29 (four collections; DWC 35, 92, 95 and 96) contained any specimens which appeared morphologically intermediate. (The single specimen, a female (imm.?), in NYSM 1937: 172 also appears intermediate.) This can be put more strongly by stating that of the 419 specimens of this genus in these 29 collections containing both taxa, only about 2 percent of the individuals (10) appeared intermediate. It seems then that these crayfishes have diverged to the degree that, even when living in the same habitat, they rarely interbreed to produce viable offspring. It is on this basis that I choose, for the moment, to consider these two taxa as belonging to different species. The situation obviously requires detailed study.

I believe that *C. robustus* has its closest affinities with *Cambarus montanus montanus* and its so-called subspecies, *Cambarus montanus acuminatus*, and with *Cambarus bartoni sciotensis* Rhoades.

Of *C. m. montanus*, Faxon (1914: 387) says, "From *Cambarus bartonii montanus* the passage is easy to *C. b. robustus* . . ." Again on p. 388, in speaking of "very nearly typical examples of *C. b. robustus*," from West Virginia, he says, ". . . they show an approach to *C. b. montanus*, from which the form *robustus* is probably derived."

A comparison of some of my New York *C. robustus* with *C. m. montanus* collections at USNM brings out striking similarities. The resemblances are far closer than between *C. robustus* and *C. b. bartoni* and one is practically compelled by the visual evidence to concede a close relationship between *C. m. montanus* and *C. robustus.*

C. robustus is apparently also close to another *C. montanus* subspecies. Faxon (1885*b*: 68), says that specimens of *C. m. acuminatus* from North Carolina approach *C. robustus.*

C. b. sciotensis types have been examined at the United States National Museum and this form may well turn out to be a subspecies of *C. montanus.* Of his subspecies Rhoades (1944*b*: 97) says, "This subspecies is intermediate between *C. m. montanus* of the Appalachians and the *C. b. robustus* of the St. Lawrence drainage."

C. montanus and *C. b. sciotensis* are in need of considerably more taxonomic study before the relationships between them, and of *C. robustus* to them, can be accurately known.

C. robustus is described in a comparison between it and *C. b. bartoni*, given under *C. b. bartoni.*

Cambarus bartoni bartoni (Fab.)

(Plate 1, figures 2, 3 and 6; plate 2, figures 5, 6 and 7)

Astacus bartoni Fabricius, 1798: 407.
Astacus ciliaris Rafinesque, 1817: 42 (authority of Faxon 1914: 423).
Astacus pusillus Rafinesque, 1817: 42 (authority of Faxon 1914: 423).
Astacus affinis Say, Milne-Edwards 1837: 332.
Cambarus bartoni (Fabricius), Girard 1852: 88.
Cambarus (Bartonius) bartoni (Fabricius), Ortmann 1905*a*: 117.
Cambarus (Cambarus) bartoni (Fabricius), Fowler 1912: 340, 341.

Type: "(fragment only), Kiel Museum" (Faxon 1914: 423).

Type locality: "Habitat in America Boreali" (Fabricius 1798: 407).

Taxonomic remarks: Milne-Edwards, in confusing *A. affinis* Say with *A. bartoni* Fabricius was apparently misled by a transposition of the figure numbers for these species in Harlan (1835).

The current restricted use of *Cambarus* (Hobbs 1942*a*: 354) makes Ortmann's subgenus *Bartonius* (and Fowler's new name) identical to it. No subgenera for *Cambarus* (*sensu stricto*) have been proposed.

Faxon's list (1914: 423-425) contains 12 subspecies of *C. bartoni.* Some of these have subsequently been considered full species or removed to other species, but all of the 12 are in need of detailed study before their taxonomic status can be at all certain.

Faxon (1885*b*: 65) says that Professor Smith Barton, the collector, lived in Philadelphia and also (Faxon 1914: 423) suggests that the

type locality is probably Philadelphia, but he does not specifically designate a restricted type locality.

I am unable to explain the inclusion by Fowler (1912: 344) of "*Cambarus acutus* (nec Girard) var. b. Hagen" in his synonymy of *C. bartoni*. Hagen's description (1870: 36-37) and his figure of the antennal scale (plate 3, figure 144*a*) cannot possibly be *C. bartoni* and Hagen himself says that his variety may be *C. blandingi* (Hagen 1870: 37).

Holthuis (1954) reproduces Rafinesque's descriptions of *A. ciliaris* and *A. pusillus*.

Comparison between *Cambarus bartoni bartoni* and *Cambarus robustus*

Ortmann (1906: 377-381, 386-393) gives detailed descriptions for these two species and New York material does not differ. The discussion here is intended to point out the differences between these morphologically similar species. Hybrid individuals probably occur, but are considered elsewhere.

The first character listed in the key is believed to give complete separation. It must be stated, however, that all of my specimens of *C. robustus* have not been checked for the presence of the two rows of tubercles on the inner side of the palm. At first I disregarded this character given by Ortmann, but now believe that I was led astray by the fact that some specimens with regenerated claws were examined and these do not always show it. Subsequent spot checking in numerous collections from a wide range of localties has produced no *C. robustus* with normal claws which lack the two rows (plate 1, figure 5). A regenerated claw can be identified by its greater length of fingers in proportion to palm length and by its being thinner and generally more weakly formed. All of my *C. b. bartoni* have but a single row of tubercles on the inner margin of the palm (plate 1, figure 6).

The depression near the outer margin of the hand in *C. robustus* is always present, even in regenerated claws and in immature specimens. On the dorsal side of *C. b. bartoni* claws there are fewer and larger punctations than in *C. robustus*, and these may sometimes be so closely grouped that they partially fuse. The effect produced is a depression, but the ventral side usually will be fully rounded.

Rostral shapes in the very young of these two species are nearly identical but, as growth proceeds, differences develop resulting typically in the conditions shown on plate 1, figures 1 and 2. Again, however, there appear to be intermediates.

The punctations in the areola are variable in the two species and, although conditions such as are shown in plate 1, figures 3 and 4, leave little cause for doubt, there are other cases where a species determination on the basis of this character alone is hardly possible.

The same may be said for the lateral spine of the carapace. Although all *C. b. bartoni* lack it, not all *C. robustus* possess it and some even lack a tubercle in its place. The newly hatched young of *C. robustus* lack this spine at least up to third stage and its greatest frequency appears to be in individuals between 20 and 30 mm. carapace length.

In plate 1, figures 1 and 2, the shapes of the antennal scale are obviously different, yet measurements of length and width do not show it when a ratio of the two measurements is obtained. Possibly measurements of the angle formed by the cephalic border and the lateral margin will show the difference, but until the range of the variation is shown by measurement, it can hardly be used to give complete separation.

In addition to the characters listed in the key, there are two others which appear to give complete separation. Plate 2, figures 3, 4 and 7, show that where *C. b. bartoni* has the caudal border of the seminal receptacle smoothly rounded, this border, although rounded in *C. robustus*, is less smoothly so. Variants from the figures occur, but I have tested the character by having receptacles of these two species shown me under the microscope. The species were identified previously on the basis of the sum total of their morphology, yet on the basis of receptacle alone the same identifications were made.

Eye size may also be a useful character. The ratio of length of caudal section of carapace to eye diameter in 10 specimens of each species has given complete separation, but many more individuals must be measured before it can be utilized with confidence.

HYBRIDIZATION

Hybridization between *O. p. propinquus* and *O. limosus*

I have two specimens which appear to be intermediate between *O. p. propinquus* and *O. limosus*. This is particularly interesting because *O. limosus* is a rather isolated species both geographically and morphologically.

One of the supposed hybrids is a male I, taken from Catatonk Creek at Candor, Tioga County, N. Y. on May 25, 1951 by Dr. E. C. Raney (DWC 139). The collection contains in addition, specimens of *C. b. bartoni* and one form I male each of *O. p. propinquus* and *O. limosus*. A previous collection from this same locality (DWC 16) produced 40 *O. limosus*.

The features which most indicate the possibility of this specimen being hybrid are rostrum, stylets, armature of merus of chela and spines on lateral surface of carapace ahead of cervical groove.

The rostrum has a low median carina. It is definitely a carina, however, not a broad raised area. I have never before observed this *propinquus* characteristic in *O. limosus*. In contrast, the acumen is long, more like *O. limosus*.

The stylets appear distinctly intermediate. The terminal elements are more divergent and shorter than in *O. p. propinquus*. The mesial process is directed more laterad. All these conditions are an approach to *O. limosus*, but the appearance is no more of one species than the other. Measurements have been made of the length of the free tip of the mesial process (*B*) and of the distance from tip of mesial process to orifice (*A*). Only five specimens each of *O. p. propinquus* and *O. limosus* were measured. The ratios of A/B are as follows:

O. p. propinquus	2.0 – 2.3, mean 2.1
O. limosus	3.0 – 3.1, mean 3.0
Hybrid (?)	2.6

It will be seen that the hybrid (?) is intermediate as are many hybrids on their measurable characters.

The spines of the inner row of the merus of the left chela are rather long as in *O. limosus*. Those of the right chela are shorter and more like *O. p. propinquus*.

There are two spines on the left side of the carapace ahead of the cervical groove. On the right side, no spines are present but there are several reddish-brown spots which probably represent places where some protuberance has broken off or been worn away.

The general appearance of the specimen is as in *O. p. propinquus*, the pubescence of *O. limosus* being absent.

Intensive collecting in this same area on August 29, 1952 has produced one more male I (NYSM 7014) which appears similarly intermediate. Two collections (NYSM 7006 and 7011) from the Unadilla River (Chenango-Otsego Co., Susquehanna R. drainage) contain both these species, but there are no signs of hybridization.

Hybridization between *O. p. propinquus* and *O. obscurus*

The combined descriptions of *O. p. propinquus* and *O. obscurus* show that some of the variations in *O. p. propinquus* tend in the direction of *O. obscurus*. Most of these are found in localities distant from where *O. obscurus* is at present known to occur, and are apparently within the normal range of variation of *O. p. propinquus*, unless perhaps a one-way introgression is occurring. Neither Ortmann (1906) nor Turner (1926) has been able to find hybrids between these species. In fact, I can not find reference to certain hybridization between any crayfish species.

I was unable to find these two species together in the same restricted habitat until 1952 when, knowing the general picture of distribution, I was able to do so in three localities.

Two of these three collections (from localities about 15 miles apart) appear to contain hybrids, for in these collections I am unable to sort out the majority of specimens into one or the other species. Because of this, these two collections are not shown in figure 5. They are:

(1) NYSM 6994 (32 specimens of these two species, including three males I and three females) from New York, Oneida Co., Oswego R. drainage, Fish Creek five miles east of Vienna. This collection also contains *C. robustus*.

(2) NYSM 6996 (109 specimens of these two species; 67 males I and 42 females) from New York, Oneida Co., Mohawk R. drainage, Deans Creek at Westmoreland. This collection also contains *C. robustus* and *O. immunis*.

I am not yet able to show the intermediacy of these supposed hybrids on the basis of measurable characteristics.

Collection NYSM 7022 from Otisco L. outlet, Oswego R. drainage, Onondaga Co., N. Y., contains both species, but none of the specimens appears definitely intermediate. Other recent (1952) collections from this general area inhabited by these two species contain only one or the other species and the majority of specimens sort readily (NYSM 6992, 6993 and 6997).

Hagen (1870: 69) reports a mixed collection of *O. obscurus* and *O. p. propinquus* from Rochester, N. Y. It is not stated whether or not these were from the same restricted locality. I have been able to take only *O. p. propinquus* and *O. immunis* at Rochester (DWC 53, 101), which is unfortunate because Rochester is the type locality for *O. obscurus.*

Hybridization between *C. robustus* and *C. b. bartoni*

In the section "Descriptions," under *C. robustus* it is stated that in collections containing both *C. robustus* and *C. b. bartoni,* about 2 percent of individuals appear morphologically intermediate between these two species. These specimens are intermediate in some or all of the four major distinguishing features: hand, areola, rostrum and antennal scale. See the above mentioned section for a brief discussion of the taxonomic status of these two taxa.