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The Crayfishes and Shrimps (Decapoda) of Illinois

Lawrence M. Page

STATE OF ILLINOIS
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Frontispiece: *Orconectes illinoiensis* form I male from Gibbons Creek, Herod, Pope County, Illinois, 4 March 1973.

This report is dedicated to

MRS. BERNICE SWEENEY

on the occasion of her retirement and in honor of her 22 years of service to the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Her numerous helpful contributions to this and other studies are sincerely appreciated.

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The Crayfishes and Shrimps (Decapoda) of Illinois

Lawrence M. Page

Crayfishes and shrimps (Decapoda) are conspicuous components of the aquatic environments of Illinois. Although only 23 species are known to inhabit the state (Table 1), they are among our largest aquatic invertebrates and often are present in large populations.

HISTORICAL STUDIES OF ILLINOIS DECAPODS

Most of the historical information available on crayfishes and shrimps of Illinois is that published by Forbes (1876), Rietz (1912), and Brown (1955). The "List of Illinois Crustacea" was, as Forbes (1876) noted, "a first contribution to the knowledge of our crustacea," and contained the "results of a single season's work." Included in the list were *Macrobrachium ohione, Palaemonetes kadiakensis* (as *P. exilipes*), *Procambarus acutus* (including *Cambarus stygius*), *P. gracilis, Orconectes immunis, O. propinquus, O. rusticus* (as *O. placidus*), *O. virilis* (including *O. wisconsinensis*), and *Cambarus diogenes* (as *C. obesus*). Hagen, in his earlier (1870) monograph on North American crayfishes, had noted the occurrence in Illinois of all of the above crayfishes except *P. gracilis*. Hagen erroneously also recorded for Illinois *P. troglodytes*, an Atlantic Coast species.

A bachelor's thesis submitted to the University of Illinois in 1912 (Rietz 1912) and entitled *Ecological Relations of the Crawfishes of Illinois* added to the list of Illinois species *O. indianensis, C. robustus* (also listed for Illinois by Faxon 1885), *C. tenebrosus* (as *C. bartoni brevis*), and *Fallicambarus fodiens* (as *C. argillicola*, also listed for Illinois by Faxon 1890).

A doctoral dissertation submitted to the University of Illinois in 1955, *The Biology of the Crayfishes of Central and Southeastern Illinois* (Brown 1955), was based on extensive collecting (at 410 stations) in the Sangamon, Wabash, and

Table 1.—Classification of the crayfishes and shrimps of Illinois, primarily following Holthuis (1952) and Hobbs (1974b).

Order Decapoda
- Family Palaemonidae
  - Genus *Macrobrachium*
    1. *M. ohione* (Smith)
  - Genus *Palaemonetes*
    2. *P. kadiakensis* Rathbun
- Family Cambaridae
  - Subfamily Cambarellinae
    - Genus *Cambarellus*
      - Subgenus *Dirigicambarus*
        3. *C. shufeldtii* (Faxon)
      - Subgenus *Pandicambarus*
        4. *C. puer* Hobbs
  - Subfamily Cambarinae
    - Genus *Procambarus*
      - Subgenus *Girardiella*
        5. *P. gracilis* (Bundy)
      - Subgenus *Ortmannicus*
        6. *P. acutus* (Girard)
        7. *P. viaeviridis* (Faxon)
      - Subgenus *Scapulicambarus*
        8. *P. clarkii* (Girard)
    - Genus *Orconectes*
      9. *O. illinoiensis* Brown
      10. *O. immunis* (Hagen)
      11. *O. indianensis* (Hay)
      12. *O. kentuckiensis* Rhoades
      13. *O. lancifer* (Hagen)
      14. O. placidus (Hagen)
      15. *O. propinquus* (Girard)
      16. *O. rusticus* (Girard)
      17. *O. stannardi* Page
      18. *O virilis* (Hagen)
    - Genus *Fallicambarus*
      - Subgenus *Creaserinus*
        19. *F. fodiens* (Cottle)
    - Genus *Cambarus*
      - Subgenus *Erebicambarus*
        20. *C. tenebrosus* Hay
        21. *C. rusticiformis* Rhoades
      - Subgenus *Lacunicambarus*
        22. *C. diogenes* Girard
      - Subgenus *Puncticambarus*
        23. *C. robustus* Girard

This paper is published by authority of the State of Illinois and is a contribution of the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Dr. Lawrence M. Page is a Zoologist in the Section.

Ohio river systems. To the growing list of Illinois species, including *Cambarellus shufeldtii* and *O. lancifer* reported in the interim by Faxon (1914), Brown added *P. clarkii*, *O. kentuckiensis*, and *O. illinoiensis* (described by Brown in 1956).

Statewide collections made for the present survey have added *Cambarellus puer*, *P. viaeviridis*, *O. placidus*, *O. stannardi*, and *Cambarus rusticiformis* to the list of Illinois species. The list of Illinois shrimps and crayfishes now stands at 23 species.

METHODS

Collecting for the present survey of Illinois decapods spanned a decade (March 1972 to September 1982). Collections were made at 1,294 localities (Fig. 1) in all counties of the state (Fig. 2), but were most heavily concentrated in southern Illinois, where the largest diversities of habitats and species occur. All species of aquatic Malacostraca (Isopoda, Amphipoda, Decapoda) present at each site were collected. A plethora of taxonomic problems among the isopods and amphipods prevent their inclusion in this report. Lewis & Bowman (1981) and Lewis (1982) recently have published distributional studies on the subterranean isopods of Illinois.

A dot on Figure 1 indicates that one or more malacostracans were collected at that locality. Stations sampled at which no species were found are not shown on the map. Although the absence of malacostracans at a site can be informative, it may indicate only that insufficient time was spent in searching. Old records (pre-1972) are included on the species distribution maps when they document significant changes in distribution (e.g., for *Macrobrachium ohione*). A few recently (1984) discovered localities are plotted for *O. rusticus* and *O. stannardi*.

Because ecological analyses were attempted for each species, all individuals encountered usually were preserved; if large numbers were encountered, only the early portion of the sample was preserved, and subsequently collected individuals were returned to the water.

Specimens usually were collected by dipnetting, minnow seining, or by digging them from their burrows. Malacostraca require cover, and the most successful method of collecting was to place a dip net downstream from, or (in standing water) next to, accumulations of stones, brush, living vegetation, etc., and to kick through the material, thereby dislodging specimens into the dip net. The most successful method of collecting burrowers was to dig into the burrow down to the water table, splash the water, wait for the curious crayfish to investigate the disturbance, and grab it. This worked well in the relatively shallow burrows of *C. diogenes* but less well in the deeper burrows of *P. gracilis*, *P. viaeviridis*, and *F. fodiens*.

Specimens were placed in 10-percent formalin if large, in 70-percent ethyl alcohol if small enough to go into a 3-dram vial. In the laboratory, specimens were washed in water, identified, counted, sexed, and placed in 70-percent ethyl alcohol for permanent storage in the Illinois Natural History Survey collection. Records were kept on the presence of form I males and of females carrying eggs or young.

Measurements of crayfishes are given in millimeters of carapace length (CL). Length-frequency distributions are presented for those species for which no published growth or longevity data are available and of which large collections were made in Illinois. Keys, diagnoses, and descriptions are based on Illinois populations only. Taxa are arranged phylogenetically, except within *Orconectes* where species are arranged alphabetically because of our present lack of understanding of interspecific relationships.

EXTRALIMITAL SPECIES AND STUDIES

Several species of crayfishes not found

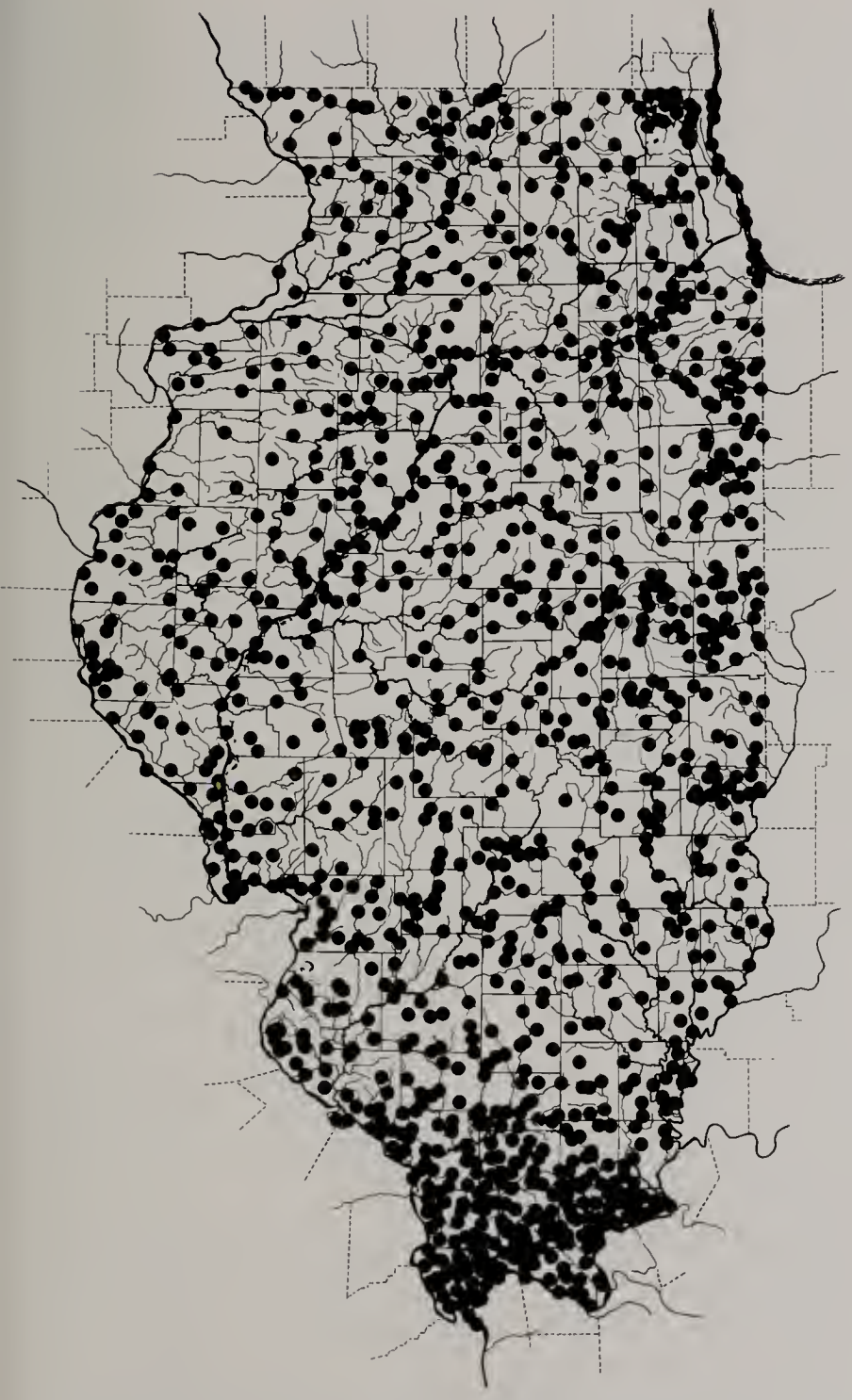

Fig. 1.—Localities in Illinois where aquatic Malacostraca were collected between March 1972 and September 1982.

in Illinois live in eastern Missouri and western Kentucky in streams draining directly into the Mississippi and Ohio rivers, and they eventually may be found, presumably as waifs, in Illinois. In Missouri, these are *Orconectes harrisoni, O. hylas, O. luteus, O. medius, O. nais, O. peruncus, P. punctimanus, O. quadruncus,* and *Cambarus hubbsi,* and in Kentucky, *O. bisectus* and *O. tricuspis.* It is more likely, however, that additions to the Illinois fauna will result from human introductions, deliberate or otherwise, and could originate from anywhere.

Regional publications on freshwater decapods of North America are available for Alabama (Bouchard 1976),

Fig. 2.—Counties of Illinois.

Arkansas (Bouchard & Robison 1980), California (Riegel 1959), Colorado (Unger 1978), Florida (Hobbs 1942), Georgia (Hobbs 1981), Indiana (Hay 1896; Eberly 1955), Iowa (Phillips 1980), Kansas (Williams & Leonard 1952), Kentucky (Rhoades 1944a), Louisiana (Penn 1952, 1956, 1959; Penn & Marlow 1959), Maryland (Meredith & Schwartz 1960), Michigan (Pearse 1910; Creaser 1931), Nebraska (Engle 1926), New Jersey (Fowler 1912; Francois 1959), New York (Crocker 1957), Ohio (Turner 1926; Rhoades 1944b), Oklahoma (Creaser & Ortenburger 1933; Reimer 1969), Ontario (Crocker & Barr 1968), Pennsylvania (Ortmann 1906), Texas (Penn & Hobbs 1958), West Virginia (Newcombe 1929), Wisconsin (Creaser 1932), the Cumberland Plateau and Cumberland Mountains (Bouchard 1976), New England (Crocker 1979), the Ozark Plateaus and Ouachita Provinces (Williams 1954), the Southern Appalachians and Cumberland Plateau (Ortmann 1931), and Mexico (Villalobos 1983).

Extremely useful publications on crayfishes are Hobbs' key and checklist to all described crayfishes of North America (Hobbs 1972a, 1974b).

GEOLOGICAL HISTORY OF ILLINOIS AND ZOOGEOGRAPHY OF NATIVE ILLINOIS DECAPODS

Prior to settlement by Europeans, Illinois was covered by oak-hickory forest, maple-basswood forest, and bluestem prairie. Today much of Illinois has been cleared and developed, primarily for agriculture and urbanization.

The oldest prominent physiographic features of Illinois are remnants of the Appalachian Revolution near the close of the Paleozoic. The intense folding and faulting during the formation of the Appalachian Mountains, and the more moderate folding and tilting to the west, created the template for the topographic diversity present today in southern Illinois (Fenneman 1938). During the Mesozoic, the seas enlarged, and by the Cretaceous they inundated the Coastal Plain as far north as southern Illinois. The subsequent uplifting of the continent in the late Cretaceous exposed much of the Coastal Plain, including the flatlands persisting today as swamps along the lower Ohio River in southern Illinois (Fenneman 1938).

In the late Tertiary the Mississippi River ran along the western edge, and the lowermost Ohio River followed the eastern edge, of Crowley's Ridge (a ridge on the Coastal Plain of southeastern Missouri and northeastern Arkansas). The two great rivers met near where Helena, Arkansas, is now (Fenneman 1938; Fisk 1944). The Ohio River was comparatively small, had its headwaters in southern Indiana and central Kentucky (Wayne 1952), meandered across southern Illinois through the present Cache River valley, and, after being joined by the Cumberland and Tennessee rivers, flowed south to its confluence with the Mississippi. It is uncertain whether the Tennessee River joined the Ohio above the entrance of the Ohip into the Cache lowland or whether it flowed from its present mouth down the present course of the Ohio and Mississippi rivers and joined the Ohio near southern Tennessee.

The Mississippi River followed much of its present course in Minnesota and Wisconsin, then cut through northern Illinois (Willman & Frye 1970), where it was joined by its major tributary, Teays River, and flowed south along the present course of the Illinois River. The Teays River began along the western side of the Blue Ridge Mountains of Kentucky, Virginia, and West Virginia, flowed northward to central Ohio, then turned west across central Indiana and Illinois through the Mahomet Valley to the Mississippi (Horberg 1945; Wayne 1952; Teller 1973); or in Indiana turned south through the present Wabash Valley to the Ohio River (Fidlar 1948). It may be that an early Pleistocene ice advance blocked the original course of

the Teays through the Mahomet Valley and diverted it into the Wabash Valley (Wayne 1952).

In the Pleistocene, continental ice caps advanced in stages and interrupted the progress of post-Tertiary erosion cycles. In glaciated areas, topographic diversity was reduced, valleys were obstructed, and river courses were altered. Areas of low relief, including the Central Lowlands, were covered by deep deposits of drift, forming undulating till plains.

The earliest glacial invasions, the Nebraskan and the Kansan, extended into northern Missouri, southern Illinois, southern Indiana, and south-central Ohio. Streams which formerly had drained northward into Hudson Bay and eastward to the Atlantic Ocean were blocked and diverted to the Mississippi basin. The lower Teays River was eliminated, and its tributaries were diverted into the ancestral Ohio River (Flint 1971; Hocutt, Denoncourt, & Stauffer 1978), greatly increasing the area drained by the Ohio.

To the west of the Mississippi River the Kansan ice cap extended farther south than other Pleistocene glaciers and terminated in Missouri, approximately along the present course of the Missouri River. East of the Mississippi River the Kansan ice cap was exceeded in its southern extent by the later Illinoian glacier, which in some areas reached the present course of the Ohio River. The Illinoian leveled or buried in drift most of Illinois. Because it was the last of the glaciers, drift of the Wisconsinan covers a large area of Illinois (Fig. 3) and its ecological impact is enormous.

As the ice caps retreated, huge quantities of drift were left behind, filling river channels and valleys. Mounds of drift (moraines) sometimes reached heights of 30 m or more and widths of several kilometers. Moraines generally were concentric to one another and, when they formed extensive lakes, lacked drainage outlets. Ultimately, low

Fig. 3.—Glacial boundaries and major physiographic features in Illinois.

points of the moraines became drainage outlets. Water flowing from one lake to another along the concentric moraines gradually formed streams and, eventually, complete drainage systems. With drainage, the process of erosion began. As sediments were carried into lakes, the coarser particles (sand and gravel) were deposited and the smaller particles (silt and clay) were carried away. Eventually, the lakes became marshes and, later, prairies. Thick layers of sand were sometimes left behind, such as those found today in the Kankakee River system of Illinois and Indiana. Dunes were subsequently formed as the wind piled sand into hills.

Throughout the Pleistocene, an area of southwestern Wisconsin and northwestern Illinois remained unglaciated.

This "Driftless Area" supports a topographic diversity, due in part to recent erosion, absent in the glaciated region. Interglacial periods, the Aftonian, Yarmouth, and Sangamon, were characterized by warmer and drier climates similar to that of today (Braun 1950).

The Wisconsinan ice cap was up to 3 km thick and in some areas, melting, interrupted by periodic advancement, took more than 10,000 years (Clark & Stearn 1960). New drainage systems eroded the glaciated area, and the junction of the Ohio and Mississippi rivers moved progressively northward (Matthes 1933; Fisk 1944). The Great Lakes were formed as water was impounded in the former Laurentian River basin. The present drainages of Illinois (Fig. 4) are discussed in detail by Forbes & Richardson (1908) and Smith (1971).

Pleistocene glaciers that covered most of Illinois had profound effects on the distributions of organisms. The principal zoogeographic effects were the elimination of populations (probably including entire species) and the displacement of species farther south than they had occurred preglacially. Principal postglacial zoogeographic events were the reinvasions of glaciated regions and the crossing of previously insurmountable basin divides through the newly established drainage systems.

The Illinoian glaciation reached within 30 km of the northern boundary of the Mississippi Embayment in southern Illinois (Willman & Frye 1970). A few species may have maintained populations in the surviving uplands, the Shawnee Hills of southern Illinois (Fig. 3).

It must have been easy for animals to invade the new drainages of the glaciated region of Illinois as they became connected to the existing Ohio and Mississippi rivers. Postglacial invasions (or reinvasions) undoubtedly were mostly from the south; i.e., the Ozark Plateau, Mississippi Embayment, Interior Lowland, Appalachian Plateau, and ephemeral drainages along the southern edges of the glaciers. Because all of northern North America (48° and north) except a large part of Alaska was covered by ice, the only possible nonsouthern postglacial origins of the decapod fauna of Illinois are east coast drainages (presumably via the Susquehanna Outlet connecting the eastern Great Lakes and the Susquehanna River), the Driftless Area of northwestern Illinois, and the upper Missouri River drainage. Some species may have invaded from more than one refugium.

Species likely, because of their present distributions, to have invaded from the south are *M. ohione*, *P. kadiakensis*, *P. acutus*, *F. fodiens*, and *C. diogenes*. All but *C. diogenes* are sluggish-water inhabitants that probably invaded the low-gradient drainages of Illinois from similar low-gradient streams on the former Mississippi Embayment. *C. diogenes* presumably moved from the Shawnee Hills and other southern areas into new drainages to the north.

P. gracilis, *O. immunis*, and *O. virilis* now occupy western drainages that were unglaciated, principally the upper Missouri, and they probably entered Illinois from the west. The eastward movement of other grassland and plains animals during the recent Xerothermic Period is discussed by Smith (1957).

O. propinquus now occurs only in glaciated areas of eastern North America but is most closely related to species living in streams in unglaciated southern Ohio, eastern Kentucky, West Virginia, and Pennsylvania (Fitzpatrick 1967). It and *C. robustus* probably invaded Illinois from the east. *C. robustus*, as discussed in the species account, has since retreated from Illinois.

O. stannardi does not now occur in areas considered to have been Pleistocene refugia, and it may be autochthonous to the Little Wabash River system of Illinois. Autochthonism would require it to have differentiated from its closest relatives since the Pleistocene.

The present decapod fauna of Illinois

Fig. 4.—Present drainages of Illinois.

Table 2.—Native species grouped according to their distributions among physiographic divisions of Illinois.

Coastal Plain	Shawnee Hills	Lowland	Glaciated Area	Statewide
C. puer	*O. illinoiensis*	*M. ohione*	*P. gracilis*	*P. acutus*
C. shufeldtii	*O. indianensis*	*P. kadiakensis*	*O. propinquus*	*O. immunis*
P. clarkii	*O. kentuckiensis*		*O. stannardi*	*F. fodiens*
P. viaeviridis	*O. placidus*		*O. virilis*[a]	*C. diogenes*
O. lancifer	*C. tenebrosus*[b]		*C. robustus*	

[a]Also found on the Coastal Plain.
[b]Also found in one locality in east-central Illinois.

may be divided into Coastal Plain, Shawnee Hills, Lowland, Glaciated-area, and Statewide species groups (Table 2). The Statewide species group includes two burrowers (*C. diogenes* and *F. fodiens*) and two sluggish-pool inhabitants (*P. acutus* and *O. immunis*).

Those species found on the Coastal Plain and in the Shawnee Hills presumably have been there for a long time and have undergone little or no post-glacial dispersal. Those in the glaciated regions must have invaded or re-invaded after glaciation (i.e., within the past 10,000–100,000 years) or must have speciated since then. Illinois' endemic decapods, *O. illinoiensis* and *O. stannardi*, and its near-endemics, *O. kentuckiensis* and *O. indianensis*, occur south of the boundary of the Wisconsinan glaciation. All except *O. stannardi*, which occurs on Illinoian glacial till, are occupants of the Shawnee Hills.

NATURAL HISTORY

Crayfish Life Cycle

During the mating season, form I males (males in which one or more of the terminal elements on the gonopods [first pleopods] are corneous) actively seek receptive females by grasping other crayfishes with their chelae. When a male or nonreceptive female is grasped, it resists, and the aggressive male releases his catch and continues searching. When a receptive female is grasped, it stretches the antennae, chelae, and walking legs forward, curves the end of the abdomen ventrally and anteriorly, and becomes motionless. The male turns the female on her back, holds her chelae in his, positions his abdomen over hers (still curved forward), inserts the ischial hooks on his pereiopods into the coxal membranes of the pereiopods of the female (which locks the two crayfish together), and inserts the tips of his gonopods in the annulus ventralis (seminal receptacle) of the female. Sperm travel from the reproductive openings on the bases of the fifth pereiopods along the gonopods to the annulus ventralis, and mating is completed. A waxy sperm plug projecting from the annulus indicates that the female has recently mated.

Frequencies of form I males among Illinois collections of crayfishes indicate that most matings occur between September and March, although considerable interspecific variation occurs. Species of *Cambarellus* have a high incidence of form I males throughout the year.

Sperm are carried by the female until oviposition (egg laying), which in Illinois occurs mostly in March, April, and May but may begin in some species as early as December or January. In preparation for oviposition the female cleans the underside of her abdomen, mostly through brushing motions of the fifth pereiopods. During oviposition the female turns on her back, curls the abdomen forward, and from glands on the abdomen secretes a clear, sticky substance (glair) which fills the area between the curled abdomen and the thorax. Sperm and eggs are released

Fig. 5.—Female *Orconectes immunis* with eggs attached ("in berry").

into the glair from the annulus ventralis and external openings of the oviducts, respectively. Following oviposition, the glair hardens and cements the fertilized eggs to the pleopods. With eggs attached to her abdomen, a female crayfish is said to be ovigerous or "in berry" (Fig. 5).

Eggs are carried by the female for 2–20 weeks, depending on the water temperature. When the eggs hatch, the young remain attached to the abdomen and are carried by the female through three instars. The first juvenile instar has extremely large eyes, a yolk-filled carapace, an incomplete abdomen, and hooked chelae. First instars attach to the female with the hooked chelae and by a stalk linking the telson of the instar to the abdomen of the mother. After 2–7 days first instars molt to second instars, which are more adultlike but still lack a fully developed abdomen and cling to the mother's abdomen by their chelae. After another 4–12 days, another molt results in the third instar, which closely resembles the adult and hangs onto the mother with its chelae and pereiopods. It may leave the protection of the mother for short periods. Subsequent instars are free living. Growth proceeds through a series of 6–10 molts during the summer, and sexual maturity may be attained by late summer or early fall. Sexual maturity in the male corresponds to a molt to form I. The first molt following the mating period returns the male to a nonreproductive state (form II) in which the gonopods are without corneous tips. Following copulation, females do not molt until after the young permanently have left. In Illinois, crayfishes appear to survive a maximum of two reproductive seasons.

In nonburrowing Illinois crayfishes, all aspects of their life history occur in surface waters. Burrowing species spend variable amounts of time in surface waters. Adults of *P. gracilis* and *P. viaeviridis* leave their burrows and enter temporary bodies of water to mate. *F. fodiens* leaves its burrows to mate, and females remain out of their burrows during the period in which they carry their eggs and young. Young of these three species remain above ground in temporary water as long as the water remains; as the water table recedes below the surface, they burrow. Adults of *P. viaeviridis* and *F. fodiens* may be found above ground in Illinois only during periods of late winter-to-spring flooding (January to May). Sexually mature *P. gracilis* leave burrows on warm rainy nights but otherwise seldom are found out of their burrows. Adults of *C. diogenes* leave their burrows on the banks

of streams more often than do the species just mentioned, perhaps to forage as well as to mate, but do so more frequently during the mating and egg- and young-carrying seasons.

Freshwater Shrimp Life Cycle

Females carry eggs attached to their pleopods between April and August in Illinois and between February and October farther south. The eggs hatch, and free-swimming larvae pass through six stages in about 3 weeks, described in detail for *Palaemonetes kadiakensis* by Broad & Hubschman (1963). Larvae and juveniles increase, and adults decrease, in abundance through the summer. Adults disappear in late summer-early fall, corresponding to a maximum life span of about 1 year in *Palaemonetes kadiakensis* and 2 years in *Macrobrachium ohione*. The largest adults mature and reproduce earliest in the year. Observations on copulation apparently are unrecorded.

KEY TO ILLINOIS SPECIES

Morphological characteristics used to describe and identify crayfishes and shrimps in keys and systematic accounts are illustrated in Fig. 6–9.

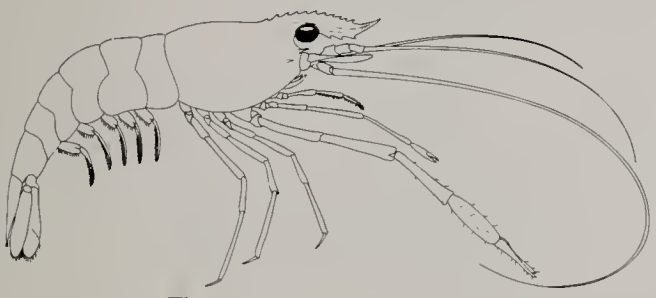

Fig. 6.—Lateral view of *Macrobrachium ohione* (after Holthuis 1952).

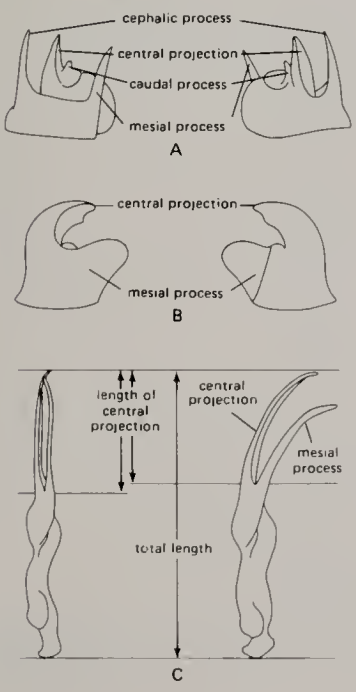

Fig. 7.—Morphology of crayfish gonopods (after Hobbs 1972a). (A) Mesial (left) and lateral views of terminal elements of generalized *Procambarus* gonopod. (B) Mesial (left) and lateral views of terminal elements of generalized *Cambarus* gonopod. (C) Generalized *Orconectes* gonopods.

Crayfishes are most easily and accurately identified by using characteristics of the gonopod (first pleopod) of form I (breeding) males, and in geographic areas having many similar species, accurate identifications of specimens other than form I males can be nearly impossible. In Illinois, with only 23 species of decapods, it is possible to identify most free-living specimens (including juveniles) to species. Following are two keys, the first is based on general morphology, the second on characteristics of form I male crayfishes. In both keys, references to crayfish gonopods are to those of form I males.

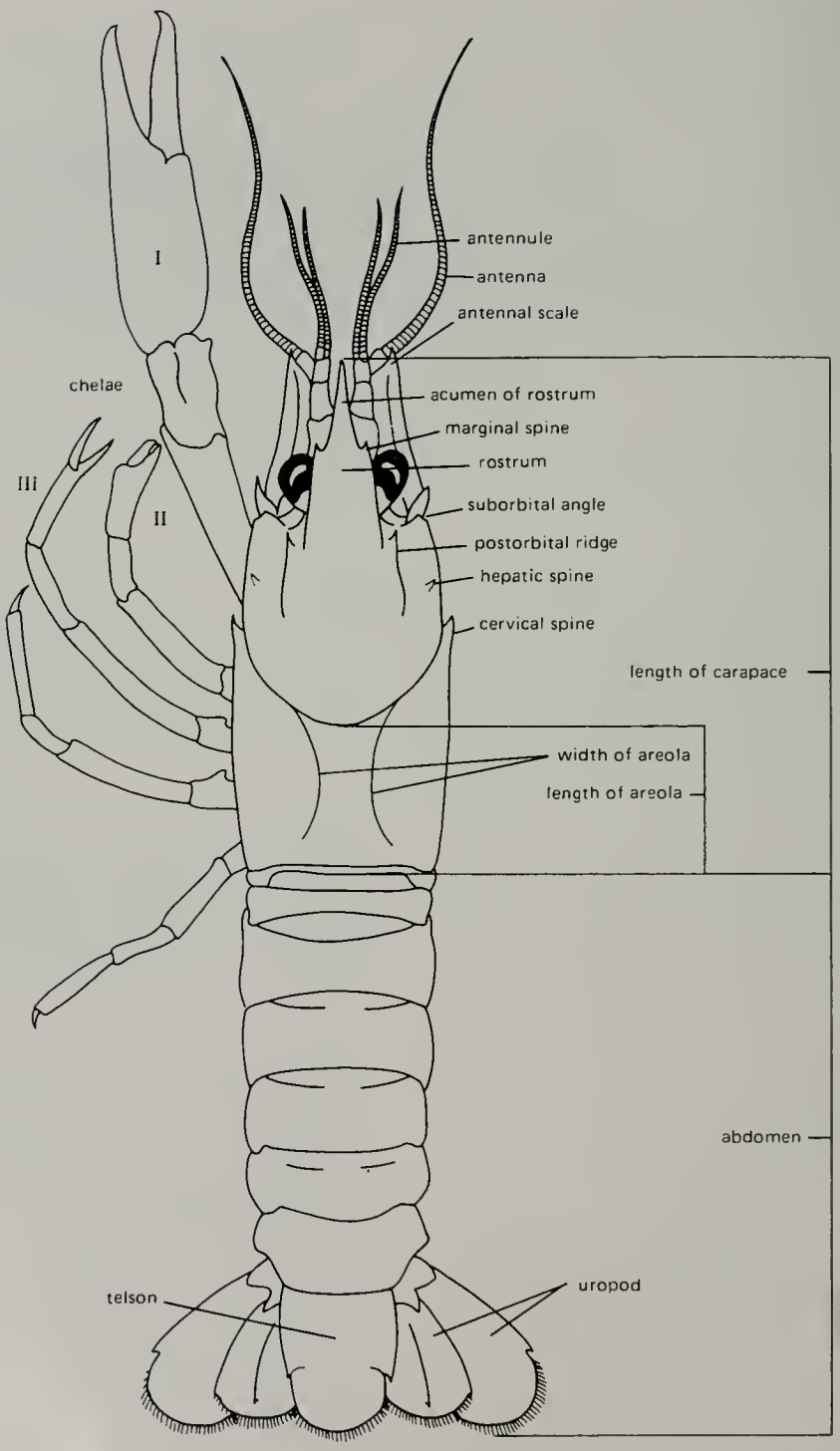

Fig. 8—Dorsal view of crayfish, illustrating features used in keys and descriptions (after Hobbs 1972a).

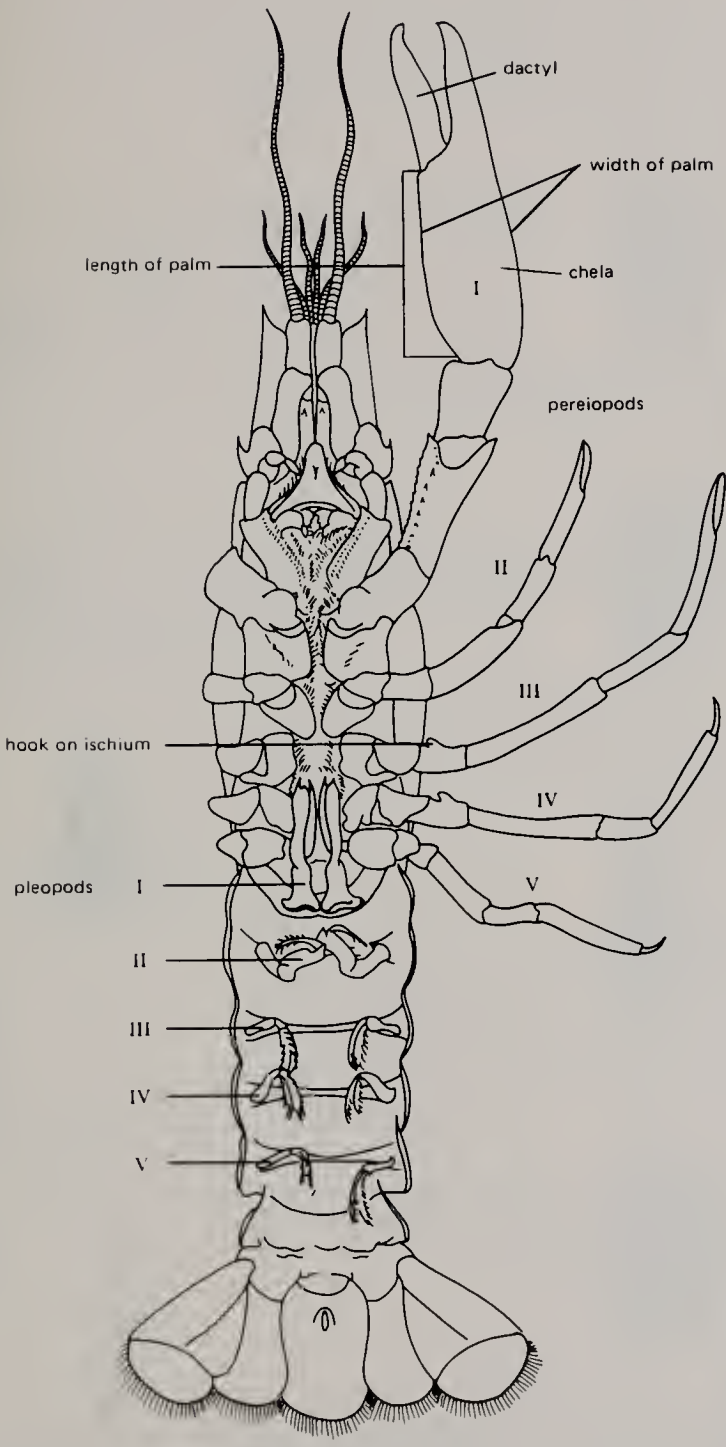

Fig. 9.—Ventral view of crayfish, illustrating features used in keys and descriptions (after Hobbs 1972a).

I. Key to Decapods of Illinois

(Key to form I male crayfishes on page 351)

1. First two pair of legs with chelae; abdomen compressed laterally (Fig. 6)...(Family Palaemonidae) 2

1. First three pairs of legs with chelae; abdomen flattened dorsoventrally (Fig. 8)...(Family Cambaridae) 3

Fig. 10.

2. Second pair of legs much longer than the first pair; 9–13 teeth along upper edge of rostrum (Fig. 10) ..... *Macrobrachium ohione* (p. 356)

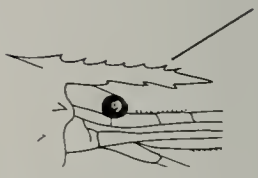

Fig. 11.

2. Second pair of legs only slightly longer than first pair; 6–8 teeth along upper edge of rostrum (Fig. 11) ..... *Palaemonetes kadiakensis* (p. 359)

Fig. 12.

3. Areola wide; narrowest width about 20–25 percent of length (Fig. 12); rostrum flat dorsally; small, adult carapace length never more than 16 mm (32 mm total length)...(Genus *Camcarellus*) 4

3. Areola obliterated to moderately wide but narrowest width never more than 20 percent of length (except in *Orconectes propinquus* and *O. stannardi*); rostrum concave dorsally; maximum carapace length much more than 16 mm 5

Fig. 13.

4. Terminal elements of gonopod curved (Fig. 13); margins of rostrum slightly convex, barely converging anteriorly; annulus ventralis extends anteroventrally (Fig. 14) ..... *Cambarellus puer* (p. 366)

Fig. 15.

Fig. 14.

4. Terminal elements of gonopod straight (Fig. 15); margins of rostrum straight, strongly converging anteriorly; annulus ventralis extends ventrally (Fig. 16)..... *Cambarellus shufeldtii* (p. 363)

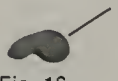

Fig. 16.

5. Areola linear to obliterated (Fig. 17) 6

5. Areola narrow to wide 10

Fig. 17.

6. Rostrum deeply excavated, with acumen longer than basal margin of rostrum (Fig. 18) ..... *Orconectes lancifer* (p. 400)

Fig. 18.

6. Rostrum shallowly excavated; acumen much shorter than margin of rostrum 7

Fig. 19.

7. Chela long and narrow, maximum width less than one-third of length (Fig. 19); acumen and marginal spines of rostrum well-developed (Fig. 20); a longitudinal blue stripe along underside of abdomen (fades in preservative) .....*Procambarus clarkii* (p. 381)

Fig. 20.

7. Chela wide, maximum width more than one-third of length; small acumen, no marginal spines on rostrum; no blue stripe on abdomen 8

Fig. 22.

Fig. 21.

8. Areola linear only at midlength (Fig. 21); gonopod terminates in small straight elements (Fig. 22); annulus ventralis subrectangular, elevated laterally ..... *Procambarus gracilis* (p. 370)

Fig. 23.

8. Areola linear through most of length (Fig. 23); gonopod terminates in two large curved elements (Fig. 24); annulus ventralis wider than long, elevated posteriorly 9

Fig. 24.

9. Suborbital margin of carapace smooth to slightly angular (Fig. 25); opposable margin of movable finger of chela with deep concavity (absent in regenerated chela) in proximal one-half (Fig. 26) ..... *Fallicambarus fodiens* (p. 422)

Fig. 25.

Fig. 26.

9. Suborbital margin of carapace angular (Fig. 27); opposable margin of dactyl of chela without deep concavity (Fig. 28) ..... *Cambarus diogenes* (p. 434)

Fig. 27.

Fig. 28.

10. Margins of rostrum without large spines (Fig. 29) 11

10. Margins of rostrum with large spines (Fig. 30) 15

Fig. 29.

11. Carapace laterally compressed; chela long and narrow, maximum width less than one-third of length 12

11. Carapace dorsoventrally flattened; chela wide, maximum width more than one-third of length 14

Fig. 30.

12. Gonopod terminates in large curved elements (Fig. 31); annulus ventralis wide, with fossa far to one side (Fig. 32)..... *Orconectes immunis* (p. 388)

Fig. 31.

12. Gonopod terminates in very short elements; annulus ventralis with fossa more centrally located 13

Fig. 32.

13. Margins of rostrum elevated, strongly converging to acumen (Fig. 33); narrow areola (Fig. 33) ..... *Procambarus acutus* (p. 376)

13. Margins of rostrum not elevated; rostrum more rounded anteriorly (Fig. 34); wide areola (Fig. 34) ..... *Procambarus viaeviridis* (p. 378)

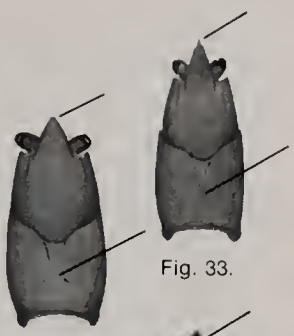

Fig. 33.

Fig. 34.

14. Base of fixed finger of chela with deep dorsal and ventral impressions (Fig. 35); margins of rostrum converge anteriorly (Fig. 36) ..... *Cambarus robustus* (p. 439)

14. Base of fixed finger of chela without deep impressions (Fig. 37); margins of rostrum nearly parallel, barely converging anteriorly (Fig. 38) ..... *Cambarus tenebrosus* (p. 428)

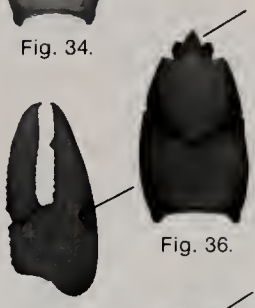

Fig. 36.

Fig. 35.

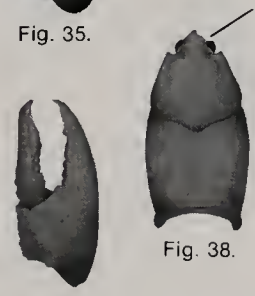

Fig. 38.

Fig. 37.

15. Margins of rostrum distinctly concave (Fig. 39) 16

15. Margins of rostrum straight (Fig. 40) 18

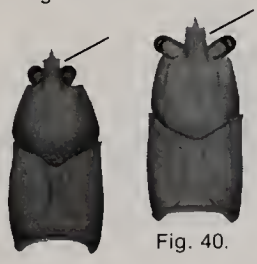

Fig. 40.

Fig. 39.

16. Central projection of gonopod large and bladelike, curved at right angle to shaft (Fig. 41); annulus ventralis with fossa to side ..... *Cambarus rusticiformis* (p. 432)

16. Central projection of gonopod not large and bladelike; annulus ventralis with fossa centrally located 17

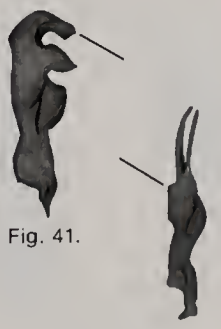

Fig. 41.

Fig. 42.

17. Dorsal (cephalic when lifted from body) surface of gonopod with prominent shoulder (Fig. 42) ..... *Orconectes rusticus* (p. 412)

17. Dorsal surface of gonopod without prominent shoulder (Fig. 43).....*Orconectes placidus* (p. 404)

18. Areola distinctly narrows just anterior to mid-length (Fig. 44); gonopod reaches coxa of cheliped with abdomen flexed; no black band on fingers of chela ..... *Orconectes virilis* (p. 417)

18. Areola remains fairly wide throughout (Fig. 40); gonopod does not reach coxa of first pair of walking legs; black band (fades in preservative) near tips of fingers of chela 19

19. Rostrum deeply excavated medially, with margins distinctly converging anteriorly (Fig. 45) .....*Orconectes illinoiensis* (p. 386)

19. Rostrum shallowly excavated, margins barely converging anteriorly 20

20. Rostrum without median carina (Fig. 46);..... *Orconectes kentuckiensis* (p. 396)

20. Rostrum with median carina (small in *O. indianensis*) (Fig. 47); 21

21. Mesial process of gonopod with spur on caudal surface (Fig. 48) .....*Orconectes stannardi* (p. 415)

21. Mesial process of gonopod without spur 22

22. Rostrum with large median carina (Fig. 49); gonopod with tips of elements barely diverging (Fig. 50);..... *Orconectes propinquus* (p. 406)

22. Rostrum with small median carina (Fig. 51); gonopod with tips of elements strongly diverging (Fig. 52).... *Orconectes indianensis* (p. 394)


Fig. 43.

Fig. 44.


Fig. 46.


Fig. 45.


Fig. 48.


Fig. 47.


Fig. 50.


Fig. 49.


Fig. 51.


Fig. 52.

II. Key to Illinois Crayfishes Based on Form I Males (i.e., males with corneous terminal elements on the gonopods)

1. Ischia of second and third pereiopods with hooks (Fig. 9)...*Genus Cambarellus* 2

1. Ischia of second pereiopods without hooks 3

2. Terminal elements of gonopod straight (Fig. 53) .....*Cambarellus shufeldtii* (p. 363)

2. Terminal elements of gonopod curved at about right angle to shaft (Fig. 54) ..... *Cambarellus puer* (p. 366)

Fig. 53.

Fig. 54.

3. Central projection of gonopod large and bladelike, curved at right angle to shaft (Fig. 55)... Genera *Fallicambarus* and *Cambarus* 4

2. Central projection of gonopod not bladelike... Genera *Orconectes* and *Procambarus* 8

Fig. 55.

Fig. 56.

4. Areola linear (Fig. 56).....5

4. Areola narrow to wide 6

Fig. 57.

5. Suborbital margin of carapace smooth to slightly angular (Fig. 57); opposable margin of movable finger of chela with deep concavity (absent in regenerated chela) in proximal one-half (Fig. 58) ..... *Fallicambarus fodiens* (p. 422)

Fig. 58.

Fig. 59.

5. Suborbital margin of carapace angular (Fig. 59); opposable margin of movable finger of chela without deep concavity (Fig. 60).....*Cambarus diogenes* (p. 434)

Fig. 60.

Fig. 61.

6. Base of fixed finger of chela with deep dorsal and ventral impressions (Fig. 61) .....*Cambarus robustus* (p. 439)

6. Base of fixed finger of chela without deep impressions.....7

Fig. 62.

7. Margins of rostrum concave, with spines (Fig. 62) ..... *Cambarus rusticiformis* (p. 432)

7. Margins of rostrum straight, without spines (Fig. 63) ..... *Cambarus tenebrosus* (p. 428)

Fig. 64.

Fig. 63.

8. Gonopod terminates in two elements (Fig. 64) ...Genus *Orconectes*.....9

8. Gonopod terminates in more than two, very short elements (Fig. 65)...Genus *Procambarus* 18

Fig. 65.

Fig. 66.

9. Areola obliterated (Fig. 66); rostrum deeply excavated, with acumen longer than basal margin of rostrum (Fig. 66)..... *Orconectes lancifer* (p. 400)

9. Areola narrow to wide; acumen much shorter than basal margin of rostrum 10

Fig. 67.

Fig. 68.

10. Both terminal elements of gonopod curved at right angle to shaft (Fig. 67); annulus ventralis with fossa far to one side (Fig. 68) ..... *Orconectes immunis* (p. 388)

10. One or both terminal elements of gonopod straight or only slightly curved; annulus ventralis with fossa more centrally located.....11

11. Central projection constitutes one-fourth or less of total length of gonopod (Fig. 7).....12

11. Central projection constitutes more than one-fourth of total length of gonopod (Fig. 7) 16

Fig. 69.

Fig. 70.

12. Terminal elements of gonopod distinctly divergent (Fig. 69 & 70) 13

12. Terminal elements of gonopod nearly parallel (Fig. 72 & 73).....14

13. Terminal elements of gonopod curved (Fig. 69) .....*Orconectes kentuckiensis* (p. 396)

13. Terminal elements of gonopod nearly straight (Fig. 70) ..... *Orconectes indianensis* (p. 394)

14. Rostrum with median carina (Fig. 71) 15

14. Rostrum without median carina..... *Orconectes illinoiensis* (p. 386)

Fig. 71.

Fig. 72.

15. Mesial process of gonopod with spur on caudal surface (Fig. 72) .....*Orconectes stannardi* (p. 415)

15. Mesial process of gonopod without spur (Fig. 73) ..... *Orconectes propinquus* (p. 406)

Fig. 73.

16. Both elements of gonopod curved (Fig. 74); areola distinctly narrows anteriorly (Fig. 75); no black bands on fingers of chela..... *Orconectes virilis* (p. 417)

16. Mesial process of gonopod not curved; areola remains fairly wide throughout; black band (fades in preservative) near tips of fingers of chela 17

Fig. 74.

Fig. 75.

17. Dorsal (cephalic when lifted from body) surface of gonopod with prominent shoulder (Fig. 76) .....*Orconectes rusticus* (p. 412)

17. Dorsal surface of gonopod without prominent shoulder (Fig. 77).....*Orconectes placidus* (p. 404)

Fig. 76.

Fig. 77.

18. Dorsal surface of gonopod with prominent shoulder (Fig. 78); cephalic process a large lobe (Fig. 78) ..... *Procambarus clarkii* (p. 381)

18. Dorsal surface of gonopod without shoulder; cephalic process small.....19

Fig. 78.

19. Areola linear at midlength (Fig. 79); hooks on ischia of third pereiopods only (Fig. 9)..... *Procambarus gracilis* (p. 370)

19. Areola narrow but not linear (Fig. 80 & 81); hooks on ischia of third and fourth pereiopods.....20

20. Margins of rostrum elevated, converging to acumen (Fig. 80); narrow areola (Fig. 80)..... *Procambarus acutus* (p. 376)

20. Margins of rostrum not elevated; rostrum more rounded anteriorly (Fig. 81); wide areola (Fig. 81) ..... *Procambarus viaeviridis* (p. 378)

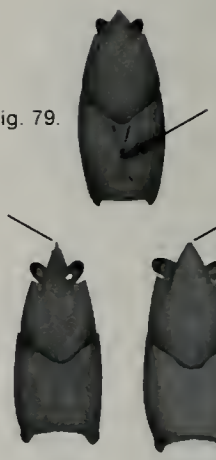

Fig. 79.

Fig. 80. Fig. 81.

SYSTEMATIC ACCOUNTS

FAMILY PALAEMONIDAE

Both shrimps native to Illinois are members of the family Palaemonidae, which is worldwide in distribution.

Macrobrachium ohione, with 9–13 teeth along the upper edge of the rostrum, is easily separable from *Palaemonetes kadiakensis*, which has only 6–8 (almost always 7) teeth. *M. ohione*, which reaches 100 mm in total length (tip of rostrum to tip of telson), also is much larger than *P. kadiakensis*, which reaches a maximum length of only about 50 mm.

Genus **Macrobrachium** Bate

Macrobrachium Bate 1868

Species of *Macrobrachium*, referred to as river shrimps, differ from species of *Palaemonetes* by possessing a hepatic spine, lacking a branchiostegal spine, and having the second pair of legs much longer than the first pair (in *Palaemonetes* the second pair is only slightly longer than the first pair).

Although *Macrobrachium* contains about 100 species worldwide (35 in the western hemisphere), only four (*M. ohione*, *M. acanthurus*, *M. carcinus*, and *M. olfersii*) are found in the freshwaters of the eastern United States (Hedgpeth 1949; Holthuis 1952). *M. ohione* is the only species of *Macrobrachium* found in the Mississippi River system.

Macrobrachium ohione (Smith) (Fig. 82)

Palaemon Ohionis Smith 1874
Palaemon sallei Kingsley 1882

Description.—Holthuis (1952) distinguished *M. ohione* from other American species of *Macrobrachium* by this combination of characteristics: carpus of second legs as long as or longer than merus; telson with a distinct posterior margin (rather than gradually tapering toward a slender tip); second chelae of adult male equal or nearly equal to one another in size (some species are bilaterally asymmetrical with the chela on one side much larger); no tubercles along cutting edges of fingers of second chela of adult male; cutting edges of fingers of large chela of adult male with one or two fairly large teeth proximally; eggs numerous and small (about 0.5 mm in diameter); second pair of legs of adult male with velvety pubescence on some or all joints; rostrum with styliform apex (and no teeth distally).

M. ohione is pale gray with light blue spots and a blue abdomen (Hedgpeth 1947, 1949). Adult females average larger than adult males and have much

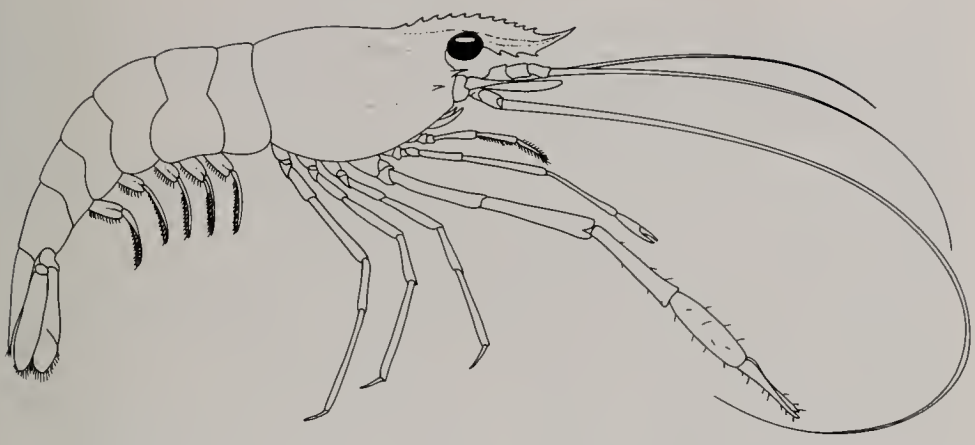

Fig. 82.—Lateral view of *Macrobrachium ohione* (after Holthuis 1952).

longer second legs (Holthuis 1952). Females reach about 100 mm in length, males about 70 mm (Hedgpeth 1949; Truesdale & Mermilliod 1979).

Distribution and Habitat.—*M. ohione* occupies freshwater habitats along the Atlantic coast from Virginia to Florida, along the Gulf Coast from Alabama to Texas, and north in the Mississippi and Ohio river systems to Oklahoma, Missouri, Illinois, Indiana, and Ohio (Fig. 83). Coastal populations move into estuaries in spring (Gunter 1937; Hedgpeth 1949; Reimer, Strawn, & Dixon 1974).

Fig. 83.—Total distribution of *Macrobrachium ohione.*

In Illinois, *M. ohione* has been recorded from Cairo, Alexander County (Forbes 1876); Grand Tower, Jackson County (Forbes 1876); Chester, Randolph County (McCormick 1934); and Shawneetown, Gallatin County (Hedgpeth 1949) (Fig. 84). Although Hedgpeth (1949) and Holthuis (1952) cite Luce (1933) as recording *M. ohione* from the lower Kaskaskia River, Illinois, the reference is actually to its use as fish bait.

Forbes (1876) described *M. ohione* as "abundant at Cairo, where it is frequently eaten" and reported second handedly its presence in the Mississippi River system from St. Louis to New Orleans. It apparently was common in the Mississippi River as recently as the 1930's, when McCormick (1934) described the successful use of "shrimp sets" at Chester. Shrimp sets were willow or cottonwood branches set along the river's edge and bent so that their leaves were under water. As shrimp fed on the leaves they were dipnetted by fishermen.

In the Illinois Natural History Survey collection are six series of *M. ohione* from Illinois, including one made by S. A. Forbes at Cairo (undated). The five collections with locality data,

(Mount Carmel, Wabash County, 1892; Mississippi River, Grand Tower, Jackson County, 1932 and 1944; Mississippi River, Missouri River Station, Madison County, 1944; and Mississippi River, 1 mi S Cairo, Alexander County, 1962) are represented on the distribution map (Fig. 84). No *M. ohione* were found during the present survey (1972–1982). Although perhaps still present in the state, the species obviously has undergone a tremendous reduction in population. Little information on the ecology of the species in Illinois is available, but its decline presumably is attributable to the loss of suitable habitats as a result of the excessive modifications (especially channelization, impoundment, and drainage of bottomland lakes) of Illinois' largest rivers.

Life History.—In the Mississippi River at Chester, McCormick (1934) counted 8,000 eggs on an 84-mm female and observed that ovigerous females ranged from 34 to 90 mm long. Among Illinois Natural History Survey collections of Illinois *M. ohione* (all made between May and October), ovigerous females are present only in a collection made 13–14 May 1932.

Fig. 84.—Distribution of *Macrobrachium ohione* in Illinois. Large circles = pre-1900 collections, small circles = 1932–1949 collections, black dot = collection made in 1962.

In Louisiana, Truesdale & Mermilliod (1979) found ovigerous females (50–93 mm in total length) from March through September. Five females, ranging from 54 to 80 mm, were carrying 6,273–24,800 eggs. Eggs were about 0.5 mm across, bright orange when first laid, and brown at later stages. Huner (1977) found *M. ohione* at Port Allen, Louisiana, to range from 17 to 92 mm long, to average 30.6 mm (N = 7,058), and to live a maximum of 2 years. Ovigerous females (N = 88) ranged from 27 to 92 mm and averaged 66 mm.

In the springs of 1969–1971, Reimer, Strawn, & Dixon (1974) studied movements of *M. ohione* into Galveston Bay, Texas. Increased movement was associated with rainfall, and salinities as high as 15 percent seemed to prevent further movement. The first individuals to appear in the bay were males and females without eggs. Females carrying eggs first appeared in late March. Females averaged larger than males, and only the largest females (52–82 mm) bore eggs.

M. ohione feeds on both plant and animal material (McCormick 1934; Gunter 1937; Darnell 1958; Truesdale & Mermilliod 1979) and in turn is fed upon by several predators, including flathead catfish (*Pylodictis olivaris*) and white bass (*Morone chrysops*) (Bryan, Truesdale, & Sabins 1975).

Genus **Palaemonetes** Heller

Palaemonetes Heller 1869

Of the approximately 17 species of *Palaemonetes* (referred to as prawns, glass shrimp, and freshwater shrimp) in the western hemisphere, only *P. kadiakensis* occurs in Illinois. *P. paludosus* is widespread in the eastern United States and along the Gulf Coast

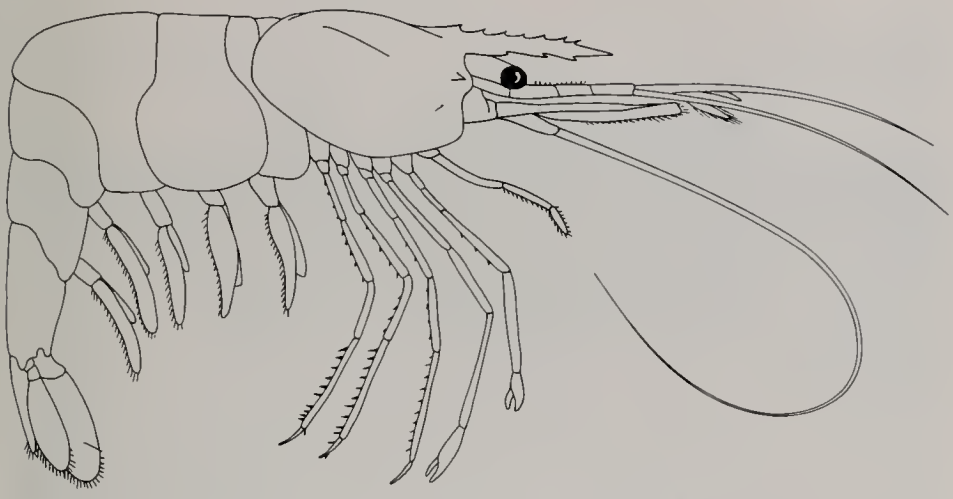

Fig. 85.—Lateral view of *Palaemonetes kadiakensis*.

as far west as eastern Texas, but it does not enter the Mississippi River system. In addition to *P. kadiakensis* and *P. paludosus*, the only freshwater species in the United States are highly localized spring- and cave-inhabiting forms in Texas (*P. antrorum*, *P. holthuisi*, and *P. texanus*) and Florida (*P. cummingi*) (Strenth 1976).

Palaemonetes kadiakensis Rathbun
(Fig. 85)

Palaemonetes kadiakensis Rathbun 1902

Description.—*P. kadiakensis* is the only species of *Palaemonetes* with three apical setae on the appendix masculina (Fig. 86) occurring in the freshwaters of the United States (Fleming 1969). Rostrum straight; upper margin convex with 6–8, usually 7, teeth; lower margin with 2–3 teeth. Carapace with antennal and branchiostegal spines; branchiostegal spine below branchiostegal groove. Abdomen humped at third segment; sixth abdominal slightly less than twice as long as fifth segment, slightly shorter than telson. Anterior pair of dorsal spines on telson usually distinctly behind middle of length, posterior pair near distal margin. Eyes large, pigmented. Lateral antennular flagellum with rami fused for 11–23 articles; free portion of shorter ramus with 3–8 articles. Scaphocerite about three times as long as wide, lamella overreaching distolateral tooth.

Living specimens are transparent with green eyes, red-brown antennae, and many very small red-brown specks on the body. The internal organs are readily visible, and a bright green vegetation-filled intestine is often a prominent feature. The species reaches a

Fig. 86.—Appendices masculina and interna (left) and entire second pleopod (right) of male *Palaemonetes kadiakensis* (after Meehean 1936).

maximum length of about 53 mm total length (Meehen 1936).

Distribution and Habitat.—*P. kadiakensis* occupies sluggish freshwater habitats from Minnesota and the shores of Lakes Ontario, Erie, and Michigan south in the Mississippi River system to the Gulf of Mexico, and Gulf Coast drainages from northeastern Mexico (Nuevo Leon) to northern Florida (Holthuis 1952) (Fig. 87). Although the

Fig. 87.—Total distribution of *Palaemonetes kadiakensis.*

locality given on the label accompanying the type specimen is Kodiak Island, Alaska, it is doubtful that the species ever occurred in Alaska (Holthuis 1952).

P. kadiakensis now occurs throughout the southern one-fourth of Illinois, in backwaters along the Mississippi River, in backwaters of the Illinois River at least as far north as Bureau County, and in Wolf Lake (Lake Michigan drainage) in Cook County (Fig. 88). It abounds in swamps (Fig. 89) and swamplike streams on the Coastal Plain of Illinois and is common in standing- and sluggish-water habitats as far north as Salem. It is uncommon in the Illinois River and in Wolf Lake.

Fig. 88.—Distribution of *Palaemonetes kadiakensis* in Illinois. Open circle = pre-1898 record for the Kankakee River; black dots = 1972–1982 collections.

Forbes (1876) recorded *P. kadiakensis* (as *P. exilipes*) only from the Illinois River but described it as being very common. A specimen in the U.S. National Museum of Natural History documents its former occurrence at Kankakee, Kankakee County (pre-1898, exact date unknown), a locality well outside the present range.

P. kadiakensis almost always is associated with, and is most abundant in, living aquatic vegetation. Its reduction in distribution and abundance in Illinois probably is attributable to increased turbidity and sedimentation and the resultant loss of vegetation. Beds of emergent and submerged vegetation once were common throughout Illinois but now are rarely encountered. The loss of vegetation is also one of the

Fig. 89.—Mermet Swamp, Massac County, Illinois (8 October 1984). Large populations of *Palaemonetes kadiakensis* and *P. clarkii* occur here.

main causes of reductions in populations of Illinois fishes (Smith 1979).

Life History.—Reproduction in Illinois, as indicated by the presence of ovigerous females, occurs from April to August (Table 3). In Louisiana the reproductive period extends from February to October (Meehean 1936; White 1949), and in central Missouri (where the species is introduced) from mid-May to August (Nielsen & Reynolds 1977).

In Illinois collections, ovigerous females range in total length from 30 to 39 mm. Eggs (embryos) on 15 females numbered 22–137 (mean, 86.6) (Table 4). The relationship (Model II regression) between the number of eggs (N) and total length (L) was $N = -230.16 + 9.19L$, $r = 0.674$, and between the number of eggs and the weight of the female (W) was $N = 10.78 + 318.21W$, $r = 0.694$. Nielsen & Reynolds (1977) found that the number of eggs varied from 20 to 76 on females 25–36 mm in length and equalled $-111.43 + 5.29$ L, $r^2 = 0.64$. Meehean (1936) found as many as 154 eggs (on a 49-mm female).

Eggs are spherical, orange, and about 1.0 mm in diameter. The egg mass constituted an average of 11.2 percent of the weight of the female (without the eggs) in 15 Illinois females (Table 4). Females may produce more than one brood per season (Broad & Hubschman 1963; Nielsen & Reynolds 1977). The incubation period lasts 24–28 days at 18.5°–24° C. Detailed accounts of lar-

Table 3.—Illinois collections of *Palaemonetes kadiakensis*.

Month	No. of Collections	No. of Collections with Ovigerous Females	Percentage of Collections with Ovigerous Females
January	2	0	0
February	3	0	0
March	2	0	0
April	8	2	20
May	8	6	75
June	11	5	45
July	8	5	63
August	3	1	33
September	16	0	0
October	11	0	0
November	1	0	0
December	1	0	0

Table 4.—Relationship between size of female and the number and weight of eggs (embryos) in Illinois-collected *Palaemonetes kadiakensis*.

Date of Collection	Total Length of Female, mm	Weight of Female[a] w o Eggs, g	Total Weight of Eggs[a], g	Number of Eggs
28 April 1976	38	0.334	0.037	125
"	39	0.369	0.052	137
18 May 1973	31	0.162	0.023	61
"	30	0.129	0.027	77
"	31	0.103	0.017	64
29 May 1974	31	0.174	0.027	97
"	33	0.153	0.021	91
"	37	0.210	0.021	97
20 June 1973	37	0.361	0.032	113
"	38	0.345	0.040	112
"	35	0.281	0.020	85
25 July 1973	32	0.234	0.018	73
"	36	0.272	0.013	69
"	37	0.296	0.013	76
10 August 1973	32	0.151	0.012	22

[a]Air dried.

val development and postembryonic growth are given by Broad & Hubschman (1963) and Hubschman & Rose (1969).

In Missouri, Nielsen and Reynolds (1977) found growth to be rapid from hatching through fall, slow in winter, and rapid in spring as shrimp matured. Females reached a larger size (to 36 mm) than males. Most individuals of both sexes reproduced at 1 year of age and then died. Sex ratios varied among study areas and among monthly samples, although females usually constituted about 55–60 percent of the sample.

P. kadiakensis feeds mainly on living plants but also may feed on dead plants and living or dead animals (Creaser 1933; Meehean 1936; Nielsen & Reynolds 1975).

FAMILY CAMBARIDAE

Except for species of the genus *Pacifasticus* (which is restricted to Pacific drainages and the headwaters of the Missouri River in Wyoming and Montana), all North American crayfishes are members of the family Cambaridae. Elsewhere the family occurs only in Japan, Korea, and the Amur Basin of eastern Asia (Hobbs 1974a). Included among North American cambarids are about 300 described and several undescribed species in two subfamilies. Cambarellinae contains only the genus *Cambarellus;* Cambarinae contains 10 genera: *Barbicambarus, Bouchardina, Cambarus, Distocambarus, Fallicambarus, Faxonella, Hobbseus, Orconectes, Procambarus,* and *Troglocambarus* (Hobbs 1974a, 1977; Hobbs & Carlson 1983).

Cambarid crayfishes differ from crayfishes of the family Astacidae (which occur in Europe and western North America) by possessing cyclic dimorphism in the male (i.e., the alternation between forms I and II) and hooks on the ischia of one or more of the second through fourth pereiopods of the male. Astacids lack cyclic dimorphism and ischial hooks. Cambarids have a variety of complex terminal elements on the gonopod, but in astacids the gonopod has a simple cylindrical termination. Astacids lack an annulus ventralis; female cambarids usually have one. In crayfishes of the family Parastacidae (occurring in Australia, New Guinea, New Zealand, Madagascar, and South America), the first pleopod is absent in both sexes, and the telson is never completely divided by a transverse

suture; except in some species of *Fallicambarus*, the telson always is divided in North American cambarids.

Genus Cambarellus Ortmann

Cambarellus Ortmann 1905

Gonopod with three terminal elements; central projection not large and bladelike. Ischia of second and third pereiopods of male with hooks.

Species of *Cambarellus* are distributed throughout the southern United States and Mexico, generally in swamps and other standing- or sluggish-water habitats. They are "dwarf" crayfishes, reaching a maximum total length of about 30 mm. Two of the 17 recognized species of *Cambarellus* occur in southern Illinois. Fitzpatrick (1983) revised *Cambarellus*, proposing the recognition of three subgenera.

Cambarellus shufeldtii (Faxon) (Fig. 90)

Cambarus Shufeldtii Faxon 1884

Description.—Rostrum broad, flat, often deflecting downward anteriorly; margins straight, strongly converging anteriorly, ending in large spines; acumen moderately large. Carapace compressed, with cervical spines; suborbital margin angular. Areola wide, narrowest part about 19–24 percent of length. Chela narrow and long, smooth; palm without tubercles. Form I gonopod terminates in three elements, all distally directed (not curved): sclerotized central projection, nonsclerotized mesial process, and nonsclerotized caudal process. Dorsal color variable, from rust red to light brown with two dark brown stripes or rows of spots on either side of the areola extending down the abdomen.

C. shufeldtii appears to have no obviously close relatives, being the only species in the genus with straight terminal elements on the gonopod and the only member of the subgenus *Dirigicambarus* (Fitzpatrick 1983).

Distribution and Habitat.—*C. shufeldtii* occupies bodies of sluggish water, mostly on the Coastal Plain, from southern Illinois to southwestern Alabama and eastern Texas (Fig. 91). In Illinois, *C. shufeldtii* is known only from Alexander, Jackson, Massac, Pulaski, and Union counties in both the Mississippi and Ohio basins. Most localities are on the former Mississippi Embayment, but the species also ascends the lower Mississippi River Valley and the lower Big Muddy River to about Sand Ridge in Jackson County (Fig. 92).

C. shufeldtii was first collected in Illinois at Cairo by Robert Kennicott (Faxon 1914). Brown (1955) found the species in five sloughs and ditches in Alexander and Massac counties. The 28 collections made in the present survey were from cypress swamps, sloughs, and backwaters. *C. shufeldtii* is especially common in the heavily vegetated LaRue Swamp-Wolf Lake complex in Union County. *C. shufeldtii* and *C. puer* have not been found together in Illinois and apparently compete for suitable habitats. In Gulf Coast streams *C. shufeldtii* is supplanting *C. puer* (see *C. puer* account).

C. shufeldtii was probably more common and widespread in extreme southern Illinois prior to the extensive clearing of swamps and river floodplains. Brown (1955) mentioned an earlier collection of a "dwarf crayfish" near Shawneetown (Gallatin County) but was unable to document the occurrence of *Cambarellus* that far northeast. In view of the occurrence, or former occurrence, of several swamp-inhabiting fishes (*Fundulus dispar*, *Elassoma zonatum*, *Lepomis punctatus*, and *L. symmetricus* [Smith 1979]) that far northeast, or even into the lowlands of the lower Wabash River drainage, the presence of *C. shufeldtii* or *C. puer* in the same area is possible.

In Louisiana, *C. shufeldtii* lives in clear, shallow (less than 40 cm deep), permanent, sun-exposed, mud-bottomed, vegetated bodies of water (Penn 1950). *C. shufeldtii* characteristically does not burrow but may survive periods of drought in subterranean cells (Penn 1950). Apparently the crayfish

Fig. 90.—*Cambarellus shufeldtii*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 91.—Total distribution of *Cambarellus shufeldtii*.

Fig. 92.—Distribution of *Cambarellus shufeldtii* in Illinois; black dots = 1972–1982 collections.

excavates a chamber in the mud bottom of the slough or swamp as drying occurs and then seals the top of the chamber to prevent desiccation.

Life History.—Form I males are present in Illinois collections (Table 5) during most months and peak in occurrence in December, February, and March. In Louisiana, Penn (1942, 1950) found form I males in all months except September, with peaks in January, February, and July. Presumably, mating in *C. shufeldtii* may occur at anytime but peaks in winter in Illinois and in winter and summer in Louisiana.

Females carrying eggs were found in Illinois from February to May, and peaked in occurrence in March (Table 5); females carrying young have been found in Illinois in April, June (Table 5), and July (Brown 1955). In Louisiana, females with eggs or young are present in every month, with strong peaks in January–March and June–July (Penn 1942, 1950; Lowe 1961), again suggesting two peaks of reproductive activity in the southern part of the range.

Nine Illinois females, 11.6–14.2 mm CL, collected in February and March were carrying 47–99 (mean, 80.1) eggs averaging 1.1 mm in diameter. The relationship between numbers of eggs (N) and carapace length (CL) is $N = -539.0 + 558.9 \log CL$, $r = 0.86$. Four females, 12.4–13.5 mm CL, collected in April 1974 were carrying 15–74 (mean, 44.8) young. The decline from an average of 80.1 eggs to an average of 44.8 young suggests a 44 percent mortality during egg and early instar stages. Penn (1942) found the number of eggs or young on a female to increase with the carapace length of the female, with females 8.5 mm averaging 27 offspring and those 11 mm averaging 54 offspring. An overall average of 34 offspring per female ($N = 100$) in Louisiana (Penn 1942) is about one-half the average number of offspring (69.2) per female ($N = 13$) in Illinois; however, the comparison is

Table 5.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Cambarellus shufeldtii*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	2	0	0	0	0	0	0
February	2	2	100	1	50	0	0
March	3	3	100	2	67	0	0
April	2	1	50	1	50	1	50
May	4	2	50	1	25	0	0
June	7	3	43	0	0	1	13
July	2	1	50	0	0	0	0
August	2	0	0	0	0	0	0
September	2	0	0	0	0	0	0
October	4	1	25	0	0	0	0
November	4	1	25	0	0	0	0
December	2	2	100	0	0	0	0

marred by the fact that females tend to carry fewer young than eggs, and the proportion of females with young to females with eggs is unknown for the Louisiana sample.

Of 95 individuals collected in LaRue Swamp-Wolf Lake in February and March 1974, 47 were females and 48 were males. The unimodal size-frequency distribution of the 95 individuals (Fig. 93) suggests that all were from the same year class. Longevity probably seldom exceeds 1 year (Lowe 1961), although an occasional individual may live part of a second year. The largest *C. shufeldtii* from Illinois, a 15.2-mm female collected in Kincaid Creek, Jackson County, 29 November 1973, is larger than any specimen recorded for Louisiana (Lowe 1961) and probably was in its second year of life.

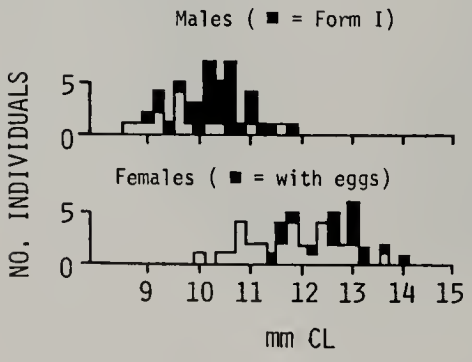

Fig. 93.—Size-frequency distribution of *Cambarellus shufeldtii* collected in LaRue Swamp-Wolf Lake, February, March 1974.

Females ($N = 47$, mean = 12.2 mm CL) were significantly (t cal = 11.27, $P < 0.001$) longer than males ($N = 48$, mean = 10.3). In *C. shufeldtii* populations, and in mixed populations of *C. shufeldtii* and *C. puer*, the largest individuals are dominant (Lowe 1956; Penn & Fitzpatrick 1963).

Sixteen (34 percent) of the 47 females were ovigerous and ranged from 11.6 to 14.2 (mean, 12.8) mm CL; non-ovigerous females were generally smaller, ranging from 10.2 to 13.7 (mean, 11.9) mm CL. Of the 48 males, 34 (71 percent) were form I and ranged from 9.1 to 11.9 (mean, 10.5) mm CL; other males were generally smaller and ranged from 8.8 to 11.8 (mean, 9.9) mm CL. In Louisiana, form I *C. shufeldtii* measure 6.7–11.5 mm CL and weigh 64.0–339.4 mg (Black 1966).

Growth is rapid, and sexual maturity may be reached in 2 months in Louisiana (Penn 1950), where 12–13 molts are required to reach sexual maturity and the mean growth increment is 0.45 mm/molt (Black 1966).

Cambarellus puer Hobbs
(Fig. 94)

Cambarellus puer Hobbs 1942

Description.—Rostrum broad, flat, often deflecting downward anteriorly;

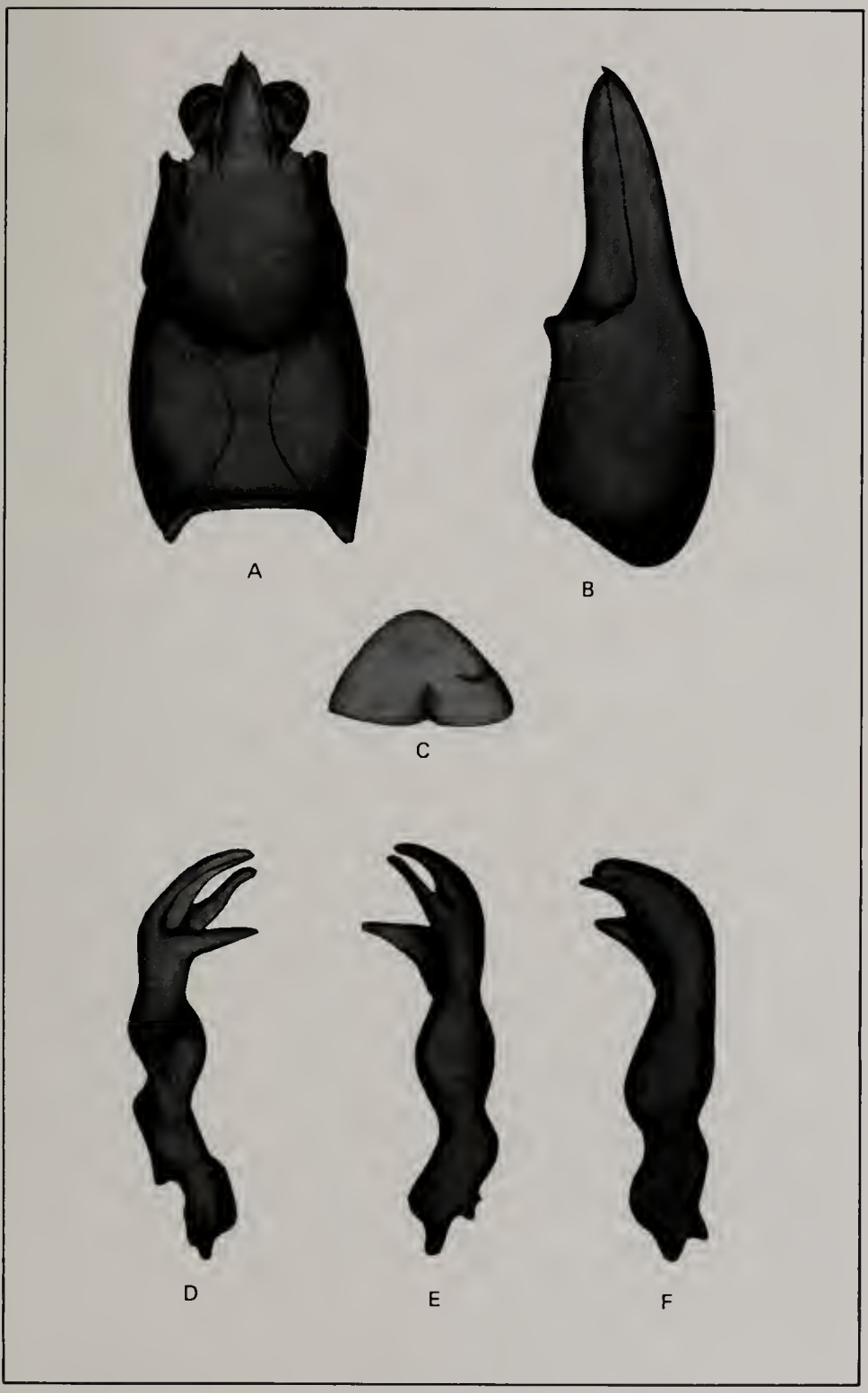

Fig. 94.—*Cambarellus puer*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

margins convex, barely converging anteriorly, ending in large spines; acumen moderately large. Carapace compressed, with cervical spines; suborbital margin angular. Areola wide, narrowest part about 25 percent of length. Chela narrow and long, smooth; palm without tubercles. Form I gonopod terminates in three elements: sclerotized central projection, nonsclerotized mesial process, and nonsclerotized caudal process, all curved at sharp angle (about 45°–90°) to principal axis of gonopod. Color as in *C. shufeldtii*.

The closest relatives of *C. puer* are *C. schmitti* and *C. lesliei* (see Fitzpatrick & Laning 1976), two occupants of the Gulf Coastal Plain from Mississippi to Florida. *C. puer*, *C. schmitti*, *C. lesliei*, *C. diminutus*, *C. blacki*, *C. ninae*, and *C. texanus* all are members of the subgenus *Pandicambarus* (Fitzpatrick 1983).

Variation in morphological characteristics of *C. puer* was studied by Chambers, Payne, & Kennedy (1979). Three populations were separable from one another but not given taxonomic status. Illinois populations are part of a larger population extending along the Mississippi River and across southern Louisiana. In general, individuals in the east are larger than those in the west; females are larger and have shorter, broader chelae and shorter rostra than do males.

Distribution and Habitat.—*C. puer* ranges from southern Illinois and southeastern Missouri to the Gulf Coast of Louisiana and the lower Colorado River drainage of Texas (Fig. 95). All populations are on the Coastal Plain. In Louisiana, *C. puer* occurs most frequently in shallow (less than 40 cm deep), clear, permanent, sun-exposed, mud-bottomed, vegetated water bodies (Penn 1950).

C. puer was first found in Illinois in 1973 (Page & Burr 1973) and now is known from seven sites in the Mississippi and Ohio basins in Union, Johnson, and Alexander counties (Fig. 96). In Illinois, it occupies cypress swamps (Fig. 97), effluent streams, and lowland areas which probably were swamps prior to being cleared. All but one collection from a roadside ditch were made in permanent water bodies, and most specimens were found among living or dead vegetation. *C. puer* may be more widespread on the Coastal Plain of Illinois than present records indicate and almost certainly was more widespread and common prior to the drainage of swamps and lowlands.

C. puer and *C. shufeldtii* were collected at 23 sites in Illinois, mostly in Coastal Plain swamps, but never were collected together. Competitive exclusion among species of *Cambarellus* has been documented in Gulf Coast areas (Penn & Fitzpatrick 1962, 1963) and apparently is operating in Illinois. *C. puer* and *C. shufeldtii* seem unable to coexist and, at least along the Gulf Coast, *C. shufeldtii* has supplanted *C. puer* at several localities within historic times (Penn & Fitzpatrick 1962, 1963). *C. shufeldtii* was found experimentally to be dominant over *C. puer* (i.e., *C. puer* retreats following contact with *C. shufeldtii*) (Penn & Fitzpatrick 1963), suggesting that in nature *C. shufeldtii* agressively displaces *C. puer* from certain habitats.

Life History.—Louisiana data suggest two reproductive periods (winter and summer) (Penn 1950; Black 1966), although form I males can be found in all months (Black 1966). Illinois data are seasonally incomplete (Table 6), but two reproductive periods, somewhat later (i.e., late winter–spring and fall) than in Louisiana, may also occur in Illinois. In Louisiana, form I males peak in occurrence from December to March (about 60–95 percent of all males) and from July to August (about 45–75 percent) (Penn 1950; Black 1966). In the available Illinois collections (Table 6), form I males are present February–May and in October. In Louisiana, form I *C. puer* males measure 7.2–12.0 mm CL and weigh 75.4–412.1 mg (Black 1966). Thirteen or 14 molts are required to reach sexual maturity, with a mean

Fig. 95.—Total distribution of *Cambarellus puer*.

Fig. 96.—Distribution of *Cambarellus puer* in Illinois; black dots = 1972-1982 collections.

growth increment of 0.45 mm/molt (Black 1966). Sixteen form I males collected in Illinois ranged from 7.7 to 12.8 and averaged 10.4 mm CL.

In Louisiana, females carrying eggs or young occur January–April, and August–September (Penn 1950). In Illinois, females carrying eggs were collected March–May, and females carrying young have been collected in May (Table 6). Ten Illinois females carrying eggs (collected March–May) ranged from 11.0 to 14.6 mm and averaged 12.2 mm; five females carrying young (in May) ranged from 10.6 to 11.5, and averaged 10.9 mm CL.

Six Illinois females, 11.0–14.6 mm CL, had 52–98 (mean, 82.3) eggs averaging 1.1 mm in diameter. Five females, 10.6–11.5 mm CL, had 15–48 (mean, 30.8) young attached; the young on the female with 48 young were first instars, the 15–36 young on the other females were later instars, suggesting a high mortality while they are carried by the mother.

Of the 60 *C. puer* collected in Illinois, 30 were males (16 were form I), and 30 were females. Longevity is 15–18 months (Black 1966).

Genus **Procambarus** Ortmann

Procambarus Ortmann 1905
Paracambarus Ortmann 1906
Ortmannicus Fowler 1912

Gonopod terminates in three or four (sometimes two in species occurring outside of Illinois) very short elements. Ischia of third, or third and fourth, pereiopods of male with hooks.

Illinois harbors four species of *Procambarus*, a genus of 148 species (Hobbs 1981) reaching its greatest diversity in the southern United States and extending as far south as Cuba and Honduras. The four species in Illinois are sluggish-water inhabitants, as are most species of the genus. Illinois species are in the subgenera *Girardiella* (*gracilis*), *Ortmannicus* (*acutus* and *viaeviridis*), and *Scapulicambarus* (*clarkii*).

Procambarus gracilis (Bundy)
(Fig. 98)

Cambarus gracilis Bundy 1876

Description.—Rostrum broad, deeply excavated, with short acumen, no median carina; margins barely converge anteriorly, without tubercles or spines. Carapace compressed, lacking cervical spines; suborbital margin angular. Areola extremely narrow, almost linear. Chela large, heavily punctate; palm with one row or large tubercles on mesial margin; dactyl with shallow concavity on basal half of opposable margin. Form 1 gonopod terminates in four short elements: a sclerotized, curved central projection; a curved mesial process; a straight cephalic process;

Fig. 97.—Bell Pond, east of Grantsburg, Johnson County, Illinois (8 October 1984), supports large populations of *C. puer* and *P. clarkii*.

Table 6.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Cambarellus puer*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
February	1	1	100	0	0	0	0
March	3	2	67	1	33	0	0
April	1	1	100	1	100	0	0
May	1	1	100	1	100	1	100
August	1	0	0	0	0	0	0
October	1	1	100	0	0	0	0

and a large sclerotized caudal process. Adults have a bright red thorax and abdomen, are red brown elsewhere; young are red brown overall.

Bundy (in Forbes 1876) described *Cambarus gracilis* (= *P. gracilis*) from Normal, McLean County, Illinois, and Racine, Racine County, Wisconsin. Hobb (1974b) restricted the type locality to Normal. *P. gracilis* is a member of the subgenus *Girardiella* (see Hobbs 1972b) and has its closest relationships to *P. liberorum* and *P. reimeri* (Fitzpatrick 1978a; Hobbs 1979).

Distribution and Habitat.—*P. gracilis* is a burrower occupying grasslands and former grasslands from eastern Indiana and southeastern Wisconsin to southeastern Nebraska, eastern Kansas, Oklahoma, and northeastern Texas (Fig. 99). It is generally distributed throughout the glaciated area of Illinois, i.e., north of the Shawnee Hills, although it appears to be absent in the Big Muddy-Lower Kaskaskia drainage area and is uncommon in northern Illinois and in the Kankakee River basin (Fig. 100).

P. gracilis is found in low, poorly drained areas usually with a silt or clay substrate and covered with grasses or other prairie plants. Where tracts of prairie remain in Illinois, *P. gracilis* often is present in large populations. Unfortunately, few large tracts of prairie remain, and populations of *P. gracilis* more typically are small and isolated in such habitats as roadside ditches (Fig. 101) and field drainage ditches. Although appearing to retain little of the original characteristics of prairies, when flooded these ditches will be found to harbor *P. gracilis*.

P. gracilis spends most of the year underground in burrows (Fig. 102) that may reach 2 m in depth (Creaser 1932) and end in an enlarged resting chamber beneath the water table (Creaser & Ortenburger 1933; Phillips 1980). During periods of heavy rainfall, usually late winter and spring, the ditches and prairies flood, and *P. gracilis* can be found above ground. Usually only small individuals are found. During the present survey, few adult *P. gracilis* were encountered; in fact, judging from the individuals collected, most populations seemed to consist only of juveniles. Apparently even during periods of flooding, large individuals stay underground. Large individuals are more likely to leave the burrows on warm rainy summer nights and walk above ground.

Life History.—Because so few adult *P. gracilis* were collected during the present survey, little new life history information can be added. Of the 101 collections of Illinois *P. gracilis* procured during the present study, only five contained form I males, and none contained females with eggs or young attached. Form I males ($N = 7$) were present in June, July, and October collections (Table 7) and ranged from 30.2 to 34.4 mm CL (mean, 32.7 mm CL). The largest female (from Bugaboo Creek, Lawrence County, 12 April 1979) was 34.8 mm CL.

Rietz (1912) found form I males in

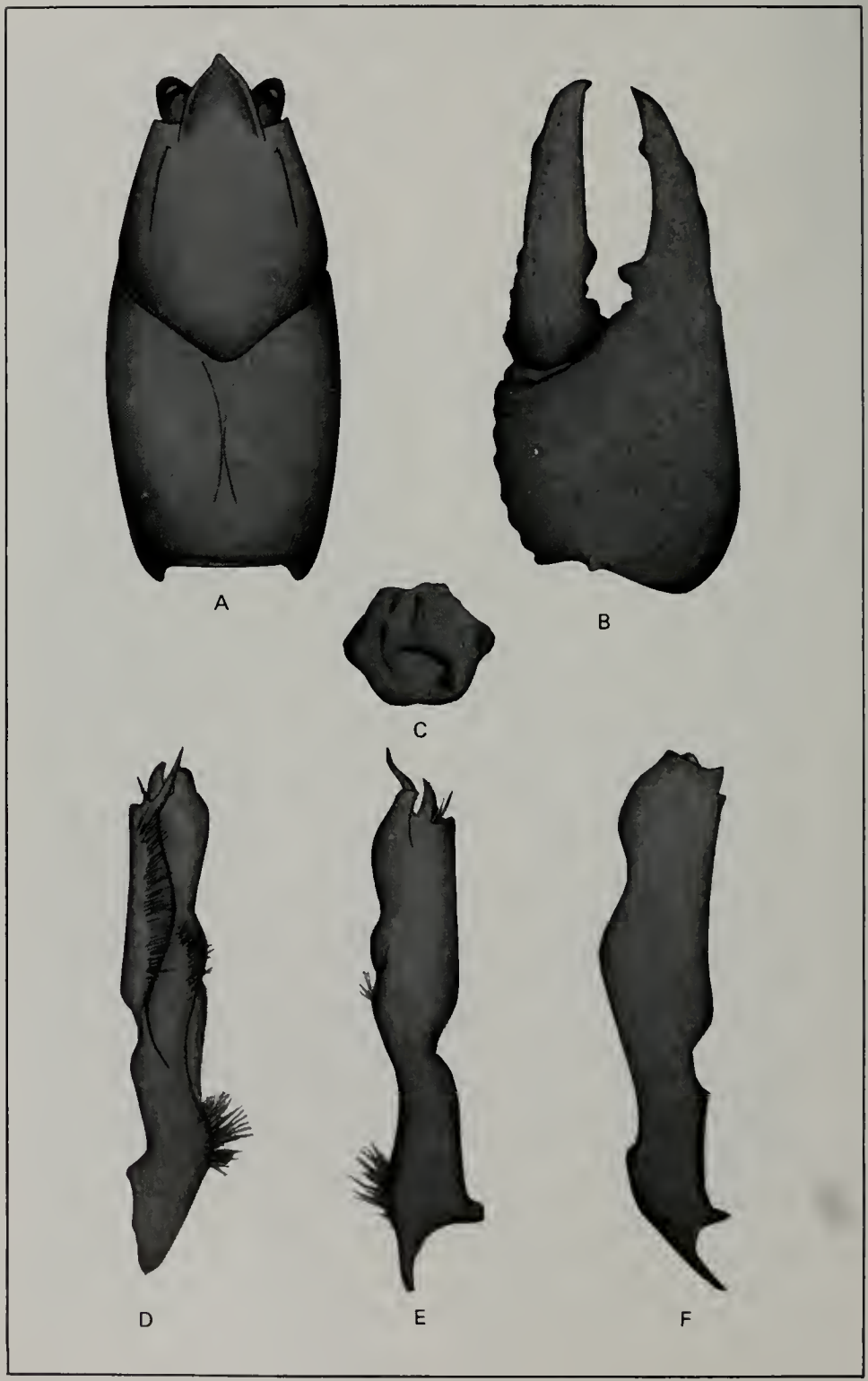

Fig. 98.—*Procambarus gracilis*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 99.—Total distribution of *Procambarus gracilis*. The eastern limit of its range is unknown.

Fig. 100.—Distribution of *Procambarus gracilis* in Illinois. Open circle = 1922 record for the Kankakee River; black dots = 1972–1982 collections.

Illinois in February, March, April, and May. Brown (1955) found form I males in Illinois in August and October and females with young attached in March, April, and October. Brown's largest form I male was 39 mm CL, and his largest female was 47 mm CL. Williams & Leonard (1952) found young attached to many of the females collected in early spring in Kansas. Creaser (1932) noted that "females with young attached are taken in Missouri as late as October."

Among all specimens collected in the present study, males outnumbered

Table 7.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Procambarus gracilis*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
February	3	0	0	0	0	0	0
March	13	0	0	0	0	0	0
April	17	0	0	0	0	0	0
May	16	0	0	0	0	0	0
June	12	3	25	0	0	0	0
July	6	1	17	0	0	0	0
August	2	0	0	0	0	0	0
September	16	0	0	0	0	0	0
October	13	1	8	0	0	0	0
November	3	0	0	0	0	0	0

Fig. 101.—Roadside ditch, ½ mi. W Winterrowd, Effingham County, Illinois, 3 May 1977; typical habitat for *Procambarus gracilis*.

Fig. 102.—Capped entrance to burrow of *Procambarus gracilis* in a field in Des Plaines, Cook County, Illinois, 15 June 1972.

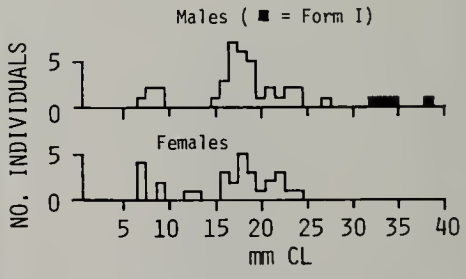

Fig. 103.—Size-frequency distribution of *Procambarus gracilis* collected in northeastern Illinois, June 1972.

females 182 to 157 (1.16:1). Very small specimens (< 10 mm CL) were collected as early as February 28 and as late as October 7. Length-frequency data on June-collected samples from northeastern Illinois suggest that males live to a third year (i.e., are 2+ years old); form I males were the largest males in the collection (Fig. 103). The lengths of larger females collected elsewhere in Illinois suggest that they also live to a third summer (i.e., to 35 mm CL) and maybe even to a fourth (to 47 mm CL).

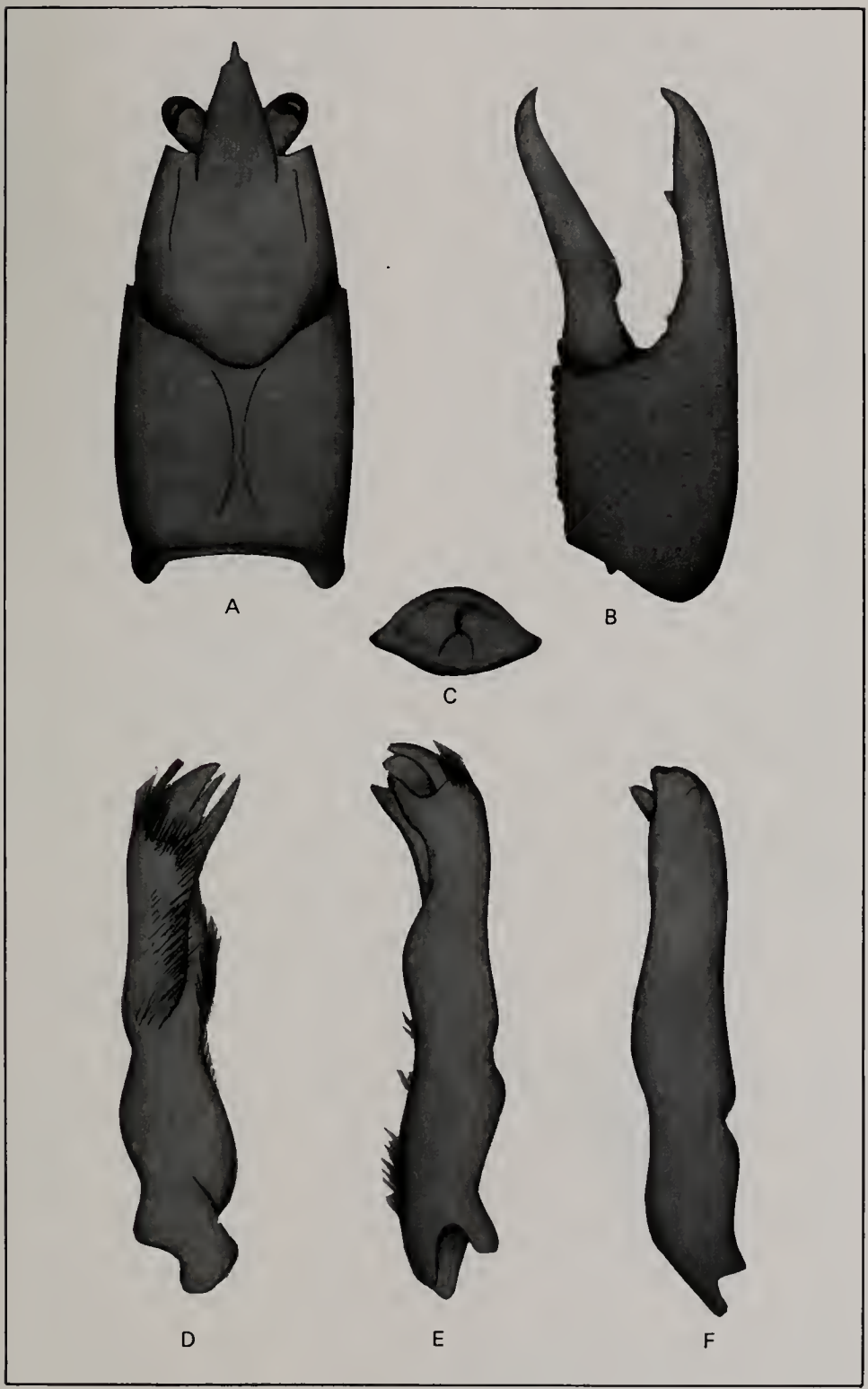

Fig. 104.—*Procambarus acutus*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Procambarus acutus (Girard)
(Fig. 104)

Cambarus acutus Girard 1852
Cambarus stygius Bundy 1876

Description.—Rostrum broad posteriorly, strongly converges anteriorly, excavated, no median carina, marginal spines or tubercles small to absent (largest on small individuals). Carapace compressed, cervical spines present; suborbital margin angular. Areola narrow, narrowest part about 5–8 percent of length. Chela long and narrow, heavily punctate; palm with row of large tubercles on mesial margin, one or two adjacent rows on dorsal and ventral surfaces. Form I gonopod terminates in four elements, all more or less directed caudodistally and variously obscured by a mass of setae originating on the caudal knob: a relatively large sclerotized central projection, an unsclerotized slender mesial process, a sclerotized cephalic process, and a sclerotized caudal process. Dorsal color pinkish brown to dark red; largest individuals dark red with a black rectangle on each abdominal segment.

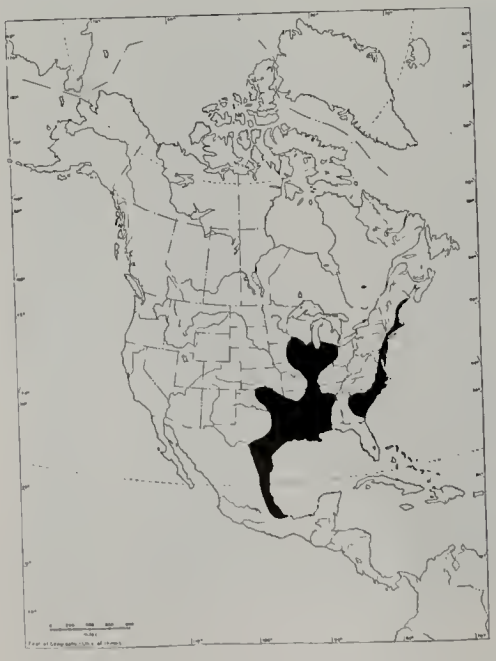

Fig. 105.—Total distribution of *Procambarus acutus*.

P. acutus is a member of the *P. blandingii* species group of the subgenus *Ortmannicus* (Hobbs 1962, 1972b). Two subspecies of *P. acutus* are recognized. *P. a. cuevachicae* occupies San Luis Potosi and Puebla and intergrades with *P. a. acutus* in northern Mexico and Texas. *P. a. acutus* occupies the rest of the range of the species (Hobbs 1972a), as described below. Hobbs (1981) noted the existence of several regionally restricted "variants" of *P. a. acutus* and suggested that some may deserve taxonomic recognition.

Cambarus stygius was described by Bundy (in Forbes 1876) from specimens found, following a storm, on the shore of Lake Michigan at Racine, Wisconsin, (Bundy 1882) and listed by Forbes (1876) as an Illinois species. Creaser (1932) declared *Cambarus stygius* to be a synonym of *Cambarus blandingii acutus* (= *Cambarus acutus* Girard).

Distribution and Habitat.—*P. acutus* has a disjunct range. In the east it occurs along the Atlantic Slope from Maine to central Georgia (Altamaha River system) and to the west (Great Lakes and Mississippi River basins) it ranges from southern Michigan and western Indiana west to southeastern Minnesota and south to Alabama, western Oklahoma, and along the Gulf slope into Mexico (Fig. 105).

P. acutus has been counted among the Illinois fauna since 1870 (Hagen 1870), and Forbes (1876) stated that it was very common in central Illinois. Rietz (1912) found the species (as *Cambarus blandingii*) to be widely distributed and generally abundant and documented its occurrence in 32 Illinois counties. Brown (1955) found it in 36 counties drained by the Sangamon, Wabash, and Ohio river systems and reported it especially common in the Sangamon system. Populations in Illinois were generally referred to as *P. blandingii* until Hobbs (1962) restricted the range of *P. a. blandingii*) to North and South Carolina.

Presently *P. acutus* occupies most, perhaps all, drainages of the state, but

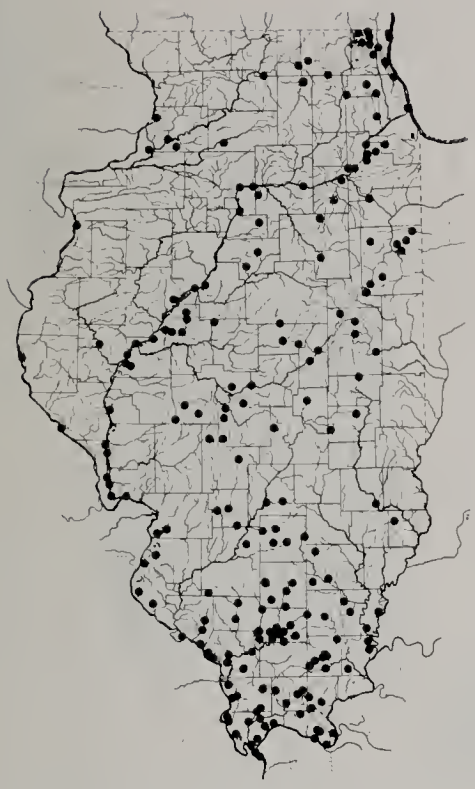

Fig. 106.—Distribution of *Procambarus acutus* in Illinois; black dots = 1972–1982 collections.

records are absent from the Spoon and other small rivers in western Illinois and from the Pecatonica and other streams in northwestern Illinois (Fig. 106). It is most common in the sluggish streams of southern Illinois, especially in the Big Muddy drainage and in streams on the Coastal Plain. Being a relatively deep water species, *P. acutus* is somewhat more difficult to capture than are shallow water crayfishes, and it may be more common in Illinois than present records suggest.

In Illinois, the species is most common in permanent standing water bodies, especially those with luxuriant vegetation, and also is found in stream pools and slowly flowing runs with mud or sand bottoms. Elsewhere, the species occupies similar habitats but also may rarely be found in swiftly flowing streams (e.g., Williams 1954; Brown 1959; Hobbs 1981).

A burrow may be constructed and inhabited when water bodies reach below-normal levels (Cralley 1932; Creaser & Ortenburger 1933), adults may burrow during cold weather, and females sometimes sequester themselves in burrows when carrying eggs and young (Cralley 1932; Penn 1956; Hobbs 1981). The sequestering behavior could explain the extremely small number of ovigerous females found in Illinois and elsewhere (see below). In the Reelfoot Lake area, Hobbs & Marchand (1943) found burrows of *P. acutus* to be shallow excavations, usually under logs and consisting of a single passageway extending only a few inches under-

Table 8.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Procambarus acutus*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	7	2	29	0	0	0	0
February	6	1	17	0	0	0	0
March	13	2	15	0	0	0	0
April	28	4	14	0	0	0	0
May	37	2	5	0	0	0	0
June	33	10	30	0	0	0	0
July	17	8	47	0	0	0	0
August	13	3	23	0	0	0	0
September	18	5	28	0	0	0	0
October	23	0	0	0	0	0	0
November	11	0	0	0	0	0	0
December	6	1	17	0	0	1	17

ground. A burrow 60 cm deep was found along the margin of a drainage ditch in Iowa (Phillips 1980).

Life History.—In the present survey of Illinois, 212 collections of *P. acutus* were made. Form I males were found every month except October and November (Table 8). They peaked in relative abundance in June–September and, secondarily, in January. Cralley (1932) found form I males in Illinois in June and July, and Brown (1955) from April to July and in September. Form I males have been found in June and July in western Tennessee (Hobbs & Marchand 1943); in August and September in the Ozark-Quachita region (Williams 1954); from February to July and in September in Texas (Penn & Hobbs 1958); from May to August in Iowa (Phillips 1980); in April, August, and "the fall" in Georgia; in March, April, June, July, and September in Alabama; in April and May in Florida; and in all months except May in South Carolina (Hobbs 1981).

No females were found carrying eggs, and only one (49.3 mm CL), collected in December, was carrying young (N = 30). In other Illinois surveys, Rietz (1912) reported a female collected with young in April, Cralley (1932) reported ovigerous females collected in July, and Brown (1955) found a female with eggs in August and one with young attached in April. All females with eggs and young found by Cralley and Brown were taken from burrows.

Few females with eggs or young have been collected elsewhere, probably because of their sequestering behavior (Penn 1956; Hobbs 1981). In the southeastern United States, no females with eggs and only one female with young (from Alabama in September) have been collected (Hobbs 1981). Turner (1926) reported eggs and young on *P. acutus* in Ohio and Indiana in March, July, and September, and Penn (1956) found females with young attached in October and January in Louisiana.

In the present survey males slightly outnumbered females, 523 to 513. The largest Illinois specimen is a 54.1-mm CL female collected on 20 February 1974 in the Maeystown Creek system, Monroe County. The largest male is a 54.0 mm-CL form I collected in 1974 in the Mississippi River, Whiteside County. Hobbs (1981) recorded a 58.9-mm CL form I male from Georgia. The smallest form I male from Illinois is 30.8 mm CL and was collected in the Mississippi River, Randolph County, on 24 March 1975.

Procambarus viaeviridis (Faxon) (Fig. 107)

Cambarus viae-viridis Faxon 1914

Description.—Rostrum flat, deflecting downward anteriorly; margins converge anteriorly to short acumen, without spines or tubercles; no median carina. Carapace compressed, lacking cervical spines; suborbital margin barely angular. Areola narrow, narrowest part about 4–7 percent of length. Chela long and narrow, heavily punctate; palm with row of 7–9 long tubercles on mesial margin, 2–3 adjacent rows of smaller tubercles. Form I gonopod terminates in four short elements: a sclerotized mesial process, a sclerotized central projection, a cephalic process, and a large setae-covered caudal knob on cephalic surface. Adults are deep rust red dorsally with the abdomen somewhat lighter in color than the carapace.

P. viaeviridis is a member of the *P. blandingii* species group of the subgenus *Ortmannicus* (Hobbs 1962, 1972b).

Distribution and Habitat.—*P. viaeviridis* occupies standing water bodies and sluggish streams on the former Mississippi Embayment and Gulf Coastal Plain from southern Illinois south to northern Louisiana and central Alabama (Fig. 108).

P. viaeviridis is restricted in Illinois to cypress swamps and floodplains along sluggish streams in the extreme southern part of the state (Fig. 109). First reported for Illinois by Page and Burr (1973), the species now is known

Fig. 107.—*Procambarus viaeviridis*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 108.—Total distribution of *Procambarus viaeviridis*.

Fig. 109.—Distribution of *Procambarus viaeviridis* in Illinois; black dots = 1972–1982 collections.

from localities in the Ohio River drainage in Alexander, Johnson, Massac, Pope, and Pulaski counties. The largest populations are in cypress swamps (especially Heron Pond–Little Black Slough and Bell Pond) in Johnson County.

Life History.—Other than brief comments on its affinity for sluggish and standing bodies of water, nothing appears to have been published on the ecological characteristics of *P. viaeviridis*. During the present study, 16 collections of the species were made, all from December through May (Table 9). During this period, water levels in southern Illinois are generally high, and *P. viaeviridis* can be found on flooded floodplains, in some roadside ditches, and in swamps. Periodically flooded areas appear to be the preferred habitat of *P. viaeviridis*, and when they dry, the crayfish burrows underground. In April, specimens were dug from burrows 15–30 cm deep on the floodplain

Table 9.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Procambarus viaeviridis*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	1	1	100	0	0	0	0
February	2	0	0	0	0	0	0
March	2	0	0	0	0	0	0
April	5	0	0	0	0	0	0
May	5	2	40	0	0	0	0
December	1	0	0	0	0	0	0

Fig. 110.—Floodplain of Max Creek at the Route 147 bridge, Johnson County, Illinois, 8 October 1984. *Procambarus viaeviridis* can be found here above ground during flooding and can be dug from burrows during periods of low water. *P. viaeviridis* persists here even though the formerly forested floodplain now is covered with grasses.

of Max Creek, Johnson County (Fig. 110). In December and January, 1975–76, crayfish were active in water 1°C under a cover of ice. The usual absence of floodwater in southern Illinois from June through November accounts for the lack of Illinois collections during this period (Table 9); however, more extensive effort presumably would reveal that the species may be found in permanent swamps even during this period.

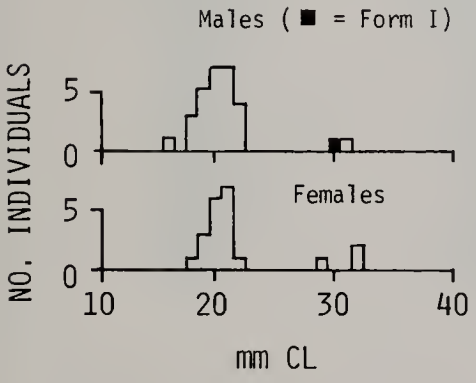

Fig. 111.—Size-frequency distribution of *Procambarus viaeviridis* collected in Bell Pond, Johnson County, Illinois, 19 May 1973.

Form I males were present in collections made in January and May (Table 9). Among the four form I males collected, the smallest was 24.1 mm CL, and the largest was 29.9 mm CL. The largest Illinois specimen of *P. viaeviridis* is a 32.3-mm CL female collected in Heron Pond on 30 March 1973. No females with eggs or young attached were collected. The smallest individuals (about 5–10 mm CL) were collected in January and February.

The length-frequency distribution of individuals collected in Bell Pond in May (N = 50) suggests that the species, at least in Illinois, lives 2 years (Fig. 111). The sex ratio in this collection was 1.4 males: 1 female.

Procambarus clarkii (Girard)
(Fig. 112)

Cambarus Clarkii Girard 1852

Description.—Rostrum deeply ex-

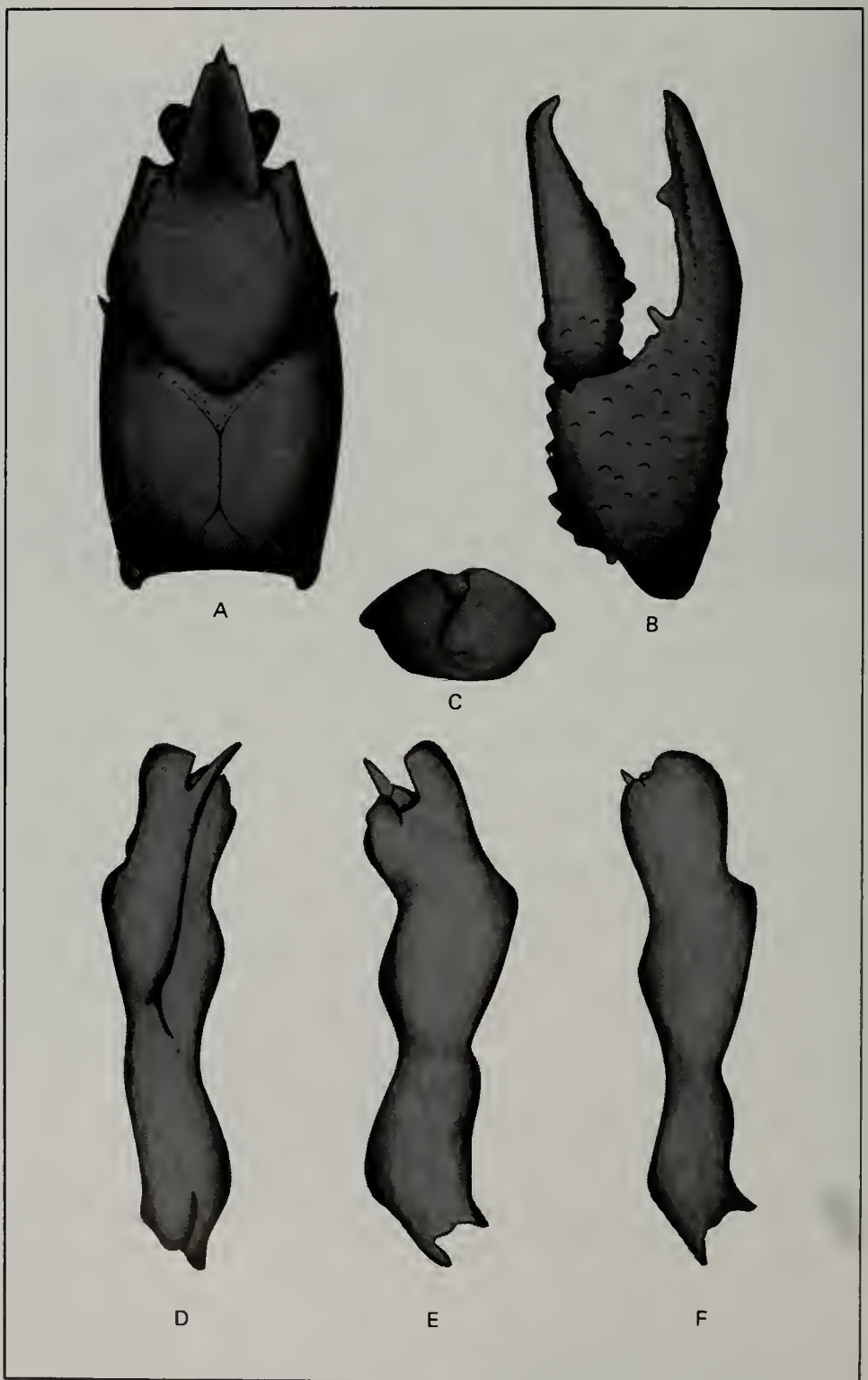

Fig. 112.—*Procambarus clarkii.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

cavated; margins converge anteriorly, terminating in small to large spines; acumen long; no median carina. Carapace compressed, with cervical spines; suborbital margin angular. Areola extremely narrow, sometimes obliterated at midlength. Chela long and narrow, punctate; palm with row of 6–8 tubercles on mesial margin, 2–3 adjacent rows of smaller tubercles. Form I gonopod with a large angular shoulder on cephalic surface, a large lobiform sclerotized cephalic process, small mesial process, and small sclerotized central projection. Light to dark red dorsally and laterally; white ventrally with blue stripe along middle of abdomen.

P. clarkii is a member of the subgenus *Scapulicambarus* (Hobbs 1972b), an assemblage of six species confined to the Atlantic and Gulf Coastal Plain of the United States and Mexico (Hobbs & Grubbs 1982).

Distribution and Habitat.—*P. clarkii* is an abundant inhabitant of standing water bodies and slowly flowing streams on the Gulf Coastal Plain from the Florida panhandle to northern Mexico and up the former Mississippi Embayment to southern Illinois (Fig. 113). It is the crayfish commonly harvested for human consumption in the eastern United States.

In Illinois, *P. clarkii* occurs in swamps, vegetated ponds, and stream pools in the extreme southern part of the state (Pope, Johnson, Massac, Union, Pulaski, and Alexander counties) (Fig. 114). Most localities are in the Ohio River drainage, although some are in the Mississippi River drainage. It remains common, especially in Mermet Swamp (Fig. 89), Bell Pond (Fig. 97), LaRue Swamp, Horseshoe Lake, and parts of the Cache River system but undoubtedly was more common prior to the drainage of much of the southern Illinois wetlands. *P. clarkii* is taken often with *P. acutus* but is more common than *P. acutus* in the cypress-

Fig. 113.—Total distribution of *Procambarus clarkii*. The southwestern limit of its range is unknown.

Fig. 114.—Distribution of *Procambarus clarkii* in Illinois; black dots = 1972–1982 collections.

Table 10.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Procambarus clarkii*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
February	3	0	0	0	0	1	33
March	2	0	0	0	0	0	0
April	3	1	33	0	0	0	0
May	10	1	10	0	0	0	0
June	3	1	33	0	0	0	0
August	1	0	0	0	0	0	0
September	1	1	100	0	0	0	0
October	4	0	0	0	0	0	0
November	2	0	0	0	0	0	0
December	1	0	0	0	0	0	0

tupelo swamps in which it reaches its greatest abundance.

Brown (1959) compared the habitat characteristics of *P. clarkii* and *P. acutus* in Illinois and Louisiana and concluded that *P. clarkii* is found more often in standing turbid water over mud; *P. acutus* is found more often in running water over a variety of substrates, but also usually over mud.

In Louisiana, Penn (1956) estimated that most collections of *P. clarkii* were made in marshes, then swamps, lakes and ponds, ditches, and, finally, slow streams (especially bayous). The species prefers shallow (less then 40 cm), permanent, static water exposed to full sunlight and usually is collected in mud-bottomed habitats with abundant vegetation (Penn 1956). *P. clarkii* feeds on vegetation (Viosca 1931).

Life History.—The life history of *P. clarkii* in Louisiana has been studied by Viosca (1939, 1953) and Penn (1943). Females carry eggs and young from June through early September. Juveniles leave the females and live in open water, grow slowly through fall and winter, grow rapidly in spring, and reach sexual maturity by May. Most 1-year-old males are form I during the summer, and copulation apparently occurs through September. The smallest form I male recorded in Louisiana was 24 mm CL. The smallest ovigerous female was 29 mm CL. Adults spend the winter in shallow burrows in marshes and swamp bottoms. Burrows, usually shallow but sometimes reaching 60 cm deep, also may be constructed to escape the drying of the habitat. In the Reelfoot Lake region of western Tennessee, Hobbs & Marchand (1943) found many individuals in burrows in June and July.

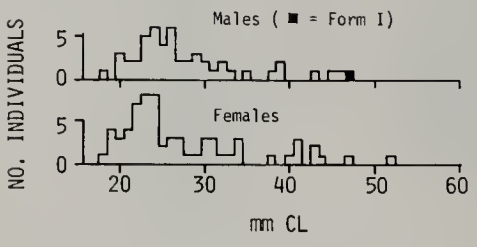

Fig. 115.—Size-frequency distribution of *Procambarus clarkii* collected in Bay Creek, Pope and Johnson counties, Illinois, 19 May 1973.

Among the 30 collections and 267 individuals (125 males: 142 females) of *P. clarkii* collected in the present survey, form I males were found from April to June and in September (Table 10). The smallest was 34.7 mm CL and was collected in the Cache River, Pulaski County, on 27 April 1976. Brown (1955) found form I males in Illinois in July, August, and September.

In the present survey, the only female with eggs or young attached was a female ca. 47 mm CL (the rostrum was damaged) collected on 18 February 1981 with 43 young attached. Brown (1955)

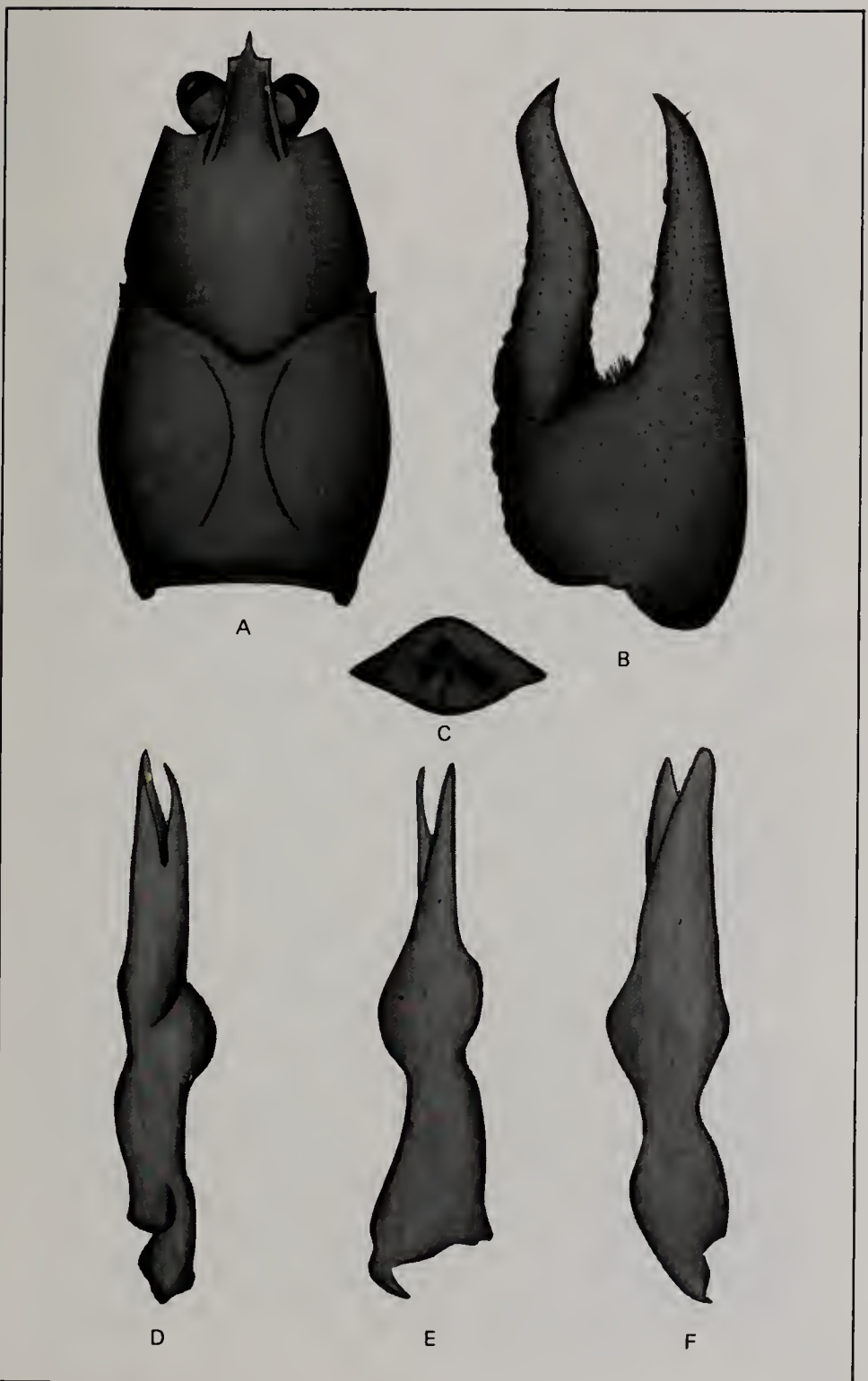

Fig. 116.—*Orconectes illinoiensis.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

found two females with eggs and three with young attached in Illinois on 6 September 1954; all were dug from burrows. Penn (1943) found a female only 30.5 mm CL carrying young in Louisiana.

The largest Illinois specimen is a 60.7-mm CL female collected in Horseshoe Lake, Alexander County, on 20 June 1973; the largest male, from the same collection, is a 51.7 mm CL form I. Brown (1955) recorded a 54-mm CL form I male from Illinois.

The size-frequency distribution of 116 individuals collected in the Bay Creek system on 19 May 1973 suggests that individuals of both sexes live a maximum of about 2 years (Fig. 115), although the largest female mentioned above, at 60.7 mm, may have been 3 years old.

Genus **Orconectes** Cope

Orconectes Cope 1872
Faxonius Ortmann 1905

Gonopod with two terminal elements; central projection not large and bladelike. Ischium of third pereiopod with hook.

Ten of the 65 recognized species of *Orconectes* (Hobbs 1981) occur in Illinois. Species of *Orconectes* are, with few exceptions, open stream inhabitants and they, more than other crayfishes, have found Illinois suitable for occupation.

Orconectes illinoiensis Brown (Fig. 116)

Orconectes illinoiensis Brown 1956

Description.—Rostrum deeply excavated, deflecting downward anteriorly; long acumen; margins thick, converging anteriorly, straight to slightly concave, terminating in spines; no median carina. Carapace flattened dorsoventrally, with large cervical spines; suborbital margin smooth to slightly angular. Areola moderately wide, narrowest part about 13–15 percent of length. Chelae large, heavily punctate; fingers often very long; palm with row of 8–9 tubercles on mesial margin; 1–2 adjacent rows of tubercles on dorsal surface. Form I gonopod terminates in two short, straight elements: a sclerotized central projection and an unsclerotized mesial process. Dorsally light to dull red brown; fingers of chelae with red tips, subdistal black bands.

O. illinoiensis is a member of the *Propinquus* group of *Orconectes* (Fitzpatrick 1967). The closest relative in Illinois is *O. propinquus*.

Distribution and Habitat.—*O. illinoiensis* is endemic to southern Illinois. It was recognized first by Brown (1955) as a distinct species and formally described by him in 1956. During the present survey it was found to occupy rocky riffles and pools of streams in the Ohio and Big Muddy (Mississippi River drainage) systems of Hardin, Pope, Johnson, Massac, Pulaski, Alexander, Union, Williamson, and Jackson counties (Fig. 117). Most of the known

Fig. 117.—Distribution of *Orconectes illinoiensis;* black dots = 1972–1982 collections.

localities (Fig. 118) are in the Shawnee Hills, but a few populations occupy rocky streams on the Coastal Plain and in the region just north of the Shawnee Hills. Some populations may have been eliminated or reduced in recent decades through stream desiccation or other recent perturbations, but the distribution of the species today probably approximates its prehistoric distribution. Many populations are large, especially in upland streams in Pope County.

Brown (1956) recorded a collection of *O. illinoiensis* from Cypress Ditch near Junction in Gallatin County. This is in the Saline River drainage, from

Fig. 118.—Gibbons Creek, Herod, Pope County, Illinois, (8 October 1984) provides habitat for *Orconectes illinoiensis.*

Table 11.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Orconectes illinoiensis*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
March	2	1	50	1	50	0	0
April	2	1	50	1	50	1	50
May	7	0	0	0	0	1	14
June	4	0	0	0	0	0	0
July	4	1	25	0	0	0	0
August	12	0	0	0	0	0	0
October	7	4	57	0	0	0	0
November	4	3	75	0	0	0	0

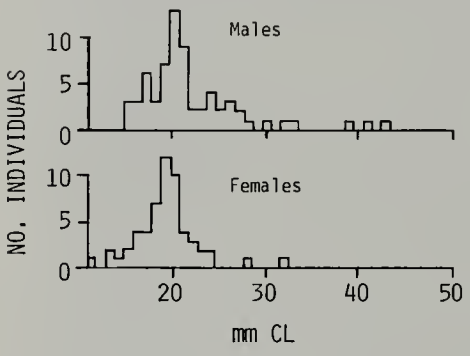

Fig. 119.—Size-frequency distribution of Orconectes illinoiensis collected in April and May.

which no other collections of *O. illinoiensis* have been made. Although the specimens cannot now be located and re-examined, it seems likely that they were misidentified *O. indianensis*. Attempts to collect in Cypress Ditch during this survey produced no *Orconectes*.

Life History.—Among the 263 specimens in the INHS collection, 132 are males and 131 are females. The largest specimen is a 42.6-mm CL form II male collected in Gibbons Creek, Pope County, on 2 May 1972. The largest female, 41.6 mm CL, is from Dutchman Creek, Pope County, collected on 14 October 1974.

Form I males collected during the present survey ranged from 18.5 to 42.4 mm CL (the largest has a right chela 55.5 mm in length) and were collected in March, April, July, October, and November (Table 11). Brown (1955) collected form I males from July to November.

Three females in two collections (Table 11) were ovigerous: a 26.1-mm CL female collected on 26 March 1975 with 175 eggs, a 21.5-mm CL female collected on 8 April 1978 with 84 eggs, and a 31.3-mm CL female collected on the latter date with 110 eggs. Eggs are spherical and average 2.0 mm in diameter. Two females, a 20.0-mm CL female collected on 28 April 1976 and a 27.1-mm CL female collected on 19 May 1973, had 57 and 34 young attached, respectively.

April- and May-collected specimens (N = 122) were modally 19–20 mm CL (Fig. 119), and most of these specimens were presumably 1 year old. The few especially large males (39–43 mm CL) were probably 3 years old and represent the maximum longevity of the species.

Orconectes immunis (Hagen)
(Fig. 120)

Cambarus immunis Hagen 1870
Cambarus signifer Herrick 1882
Cambarus immunis spinirostris Faxon 1884
Faxonius (Faxonius) immunis pedianus Creaser 1933

Description.—Rostrum excavated; acumen moderately long; margins convex, converging anteriorly, without terminal spines, sometimes with small terminal tubercles; no median carina. Carapace compressed, with cervical

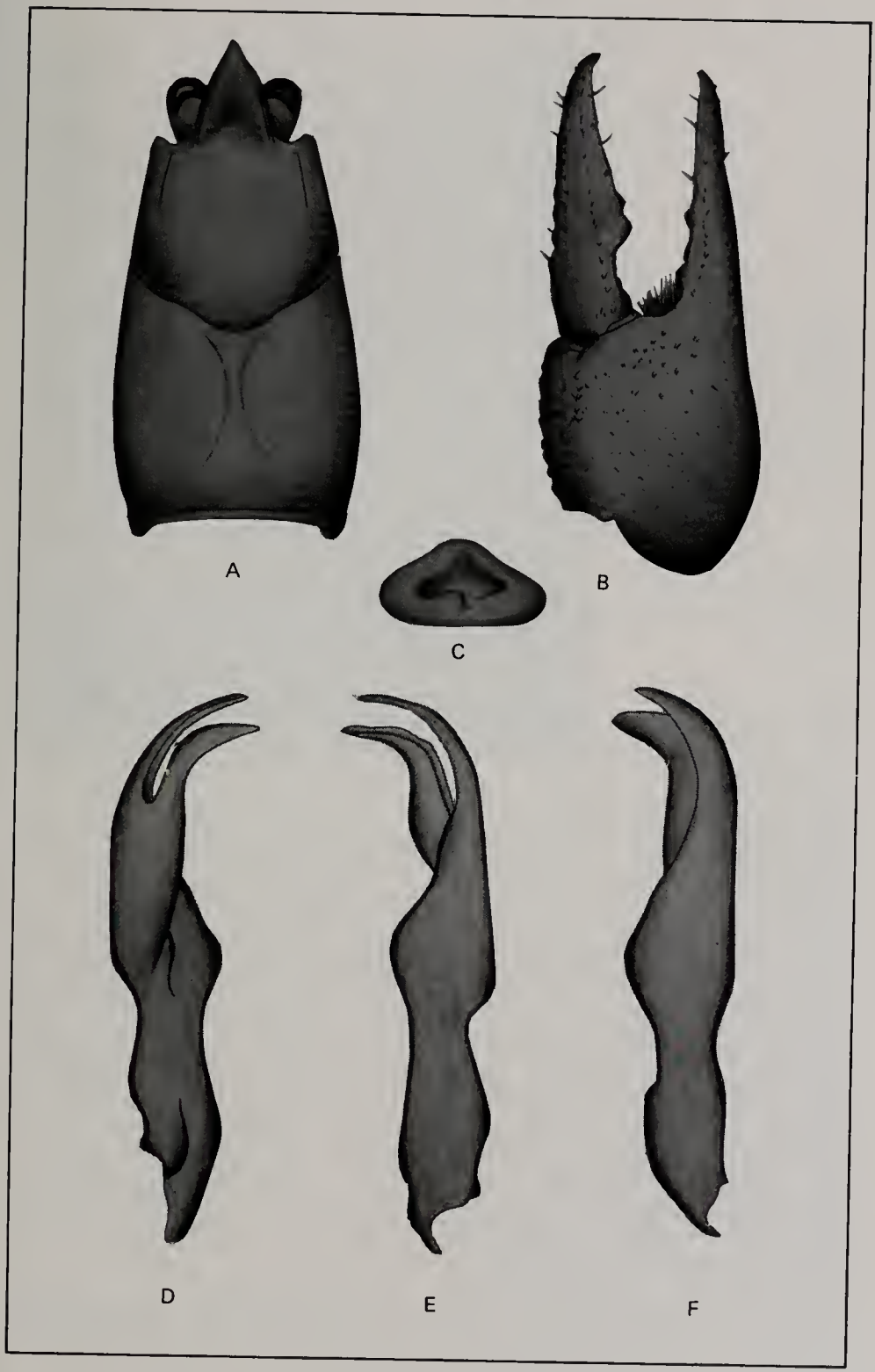

Fig. 120.—*Orconectes immunis*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 121.—Total distribution of *Orconectes immunis*.

spines; suborbital margin bluntly angular. Areola narrow, constricted anteriorly, narrowest part about 10 percent of length. Chelae moderate in size, heavily punctate; palm with 2–3 rows of small tubercles on dorsomesial margin. Form I gonopod terminates in two fairly short (central projection about 23 percent of total length of gonopod) elements curved at 90° angle to main axis: a sclerotized central projection and an unsclerotized mesial process. Annulus ventralis distinctive, with fossa far to one side. Dorsal color highly variable, from uniformly red brown to light green with dark brown mottling; fingers of chelae without bright red tips and subdistal black bands.

O. immunis is a member of the *Virilis* group of *Orconectes* and is most similar to *O. alabamensis*, *O. rhoadesi*, and *O. validus*, species inhabiting the Cumberland, Tennessee, and Mobile Bay drainages. Some populations of the wide-ranging *O. immunis* have been considered sufficiently distinct to warrant taxonomic recognition (see synonymy above), and Bovbjerg (1952) referred to northeastern Illinois populations as "*O. immunis* x *pedianus*." However, Williams & Leonard (1952) found that the characteristics which had been used to distinguish subspecies varied clinally and could not be used to diagnose geographically limited populations. No subspecies were recognized by Hobbs (1974b).

Distribution and Habitat.—*O. immunis* ranges from southern Quebec, Maine, and Connecticut west through the Great Lakes (except Lake Superior), to eastern Wyoming and eastern Colorado (Fig. 121). The southern edge of the range approximates the southern limit of Pleistocene glaciation but extends farther south into western Kentucky and Tennessee and farther west into the Great Plains. An isolated population in Muddy Creek (Canadian-Arkansas River drainage), Okfuskee

Fig. 122.—Distribution of *Orconectes immunis* in Illinois; black dots = 1972–1982 collections.

Fig. 123.—Little Wabash River, 2 mi. WSW Mattoon, Coles County, Illinois, 25 October 1983. This and other sluggish weedy streams in Illinois often contain large populations of *Orconectes immunis*.

County, Oklahoma, (Creaser & Ortenburger 1933) is far south of other populations and may have been introducted.

The species occurs throughout Illinois except in the unglaciated northwest (Fig. 122). It appears to be rare in extreme western Illinois, although Rietz (1912) found it in several western counties (Fulton, Hancock, Henderson, and Mercer) for which recent records are unavailable. Elsewhere in the state it is generally common, and local populations sometimes consist of thousands of individuals. It undoubtedly was even more common and widespread when Illinois had large expanses of undrained prairies. In fact, Forbes (1876) referred to *O. immunis* as "the commonest species of central Illinois," and "especially frequent in the muddy ponds of the prairies, where it may be drawn by the hundreds with a small seine."

O. immunis lives in slowly flowing pools, usually with soft bottoms, of headwaters, creeks, and small to large rivers (Fig. 123). It also is found in standing-water bodies but, at least in Illinois (and in the Reelfoot Lake region of Tennessee, Hobbs & Marchand 1943), is primarily a stream species. It frequents intermittent streams and temporary ponds, burrowing down to the water table as drying occurs. *O. immunis* can be found under rocks in drying streams, and burrows are constructed as a means of escaping desiccation. Burrows usually are simple structures, although they may have chimneys and occasionally are relatively elaborate. Brown (1955) described the burrows as up to 2 feet deep and ending in an enlarged pocket below the water table.

Tack (1941) made observations on the

Table 12.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Orconectes immunis*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	5	1	20	2	40	0	0
February	4	3	75	2	50	0	0
March	13	7	54	4	31	0	0
April	28	6	21	4	14	4	14
May	26	5	19	0	0	1	4
June	39	5	13	0	0	1	3
July	51	14	27	0	0	0	0
August	36	5	14	0	0	0	0
September	20	3	15	0	0	0	0
October	15	7	47	0	0	0	0
November	5	1	20	0	0	0	0

habits and activities of a pond population of *O. immunis*. On bright sunny days some individuals could be seen moving about and others were partially buried in the mud, but most were hidden under stones or in burrows and came out only at dusk. Most activities occurred at night, including overland movements on rainy nights.

Because *O. immunis* often is found in turbid, sluggish-water bodies, it sometimes is considered more pollution-tolerant than are other crayfishes. It probably is more tolerant of low oxygen conditions associated with certain types of pollution, channelization, and impoundments, which so drastically alter the biotic characteristics of streams, than are inhabitants of clear-water streams. Thus, these conditions have a less detrimental effect on populations of *O. immunis* than they have on clear-water stream inhabitants. However, no data exist to show a greater tolerance to toxic chemicals than that found in other species.

Life History.—In ponds near Ithaca, New York, mating occurred from mid-June to mid-October and peaked in August (Tack 1941). After mating, females retreated to burrows and laid their eggs in October and November. First-year females (N = 31) laid from 4 to 170 eggs (mean, 84), and second-year females (N = 6) laid 38–289 eggs (mean, 195), with the number increasing with the length of the female (r = 0.642). Eggs hatched in May, and young grew to 13–29 mm CL by late September. Females reaching at least 23 mm CL produced eggs in their first fall, and males were sexually mature at about 20 mm CL; however, most individuals did not reach these lengths until their second summer. Little or no growth occurred during winter. Most individuals die during their second year; a few (mostly females) may live to 3 years.

In northeastern Iowa, Caldwell & Bovbjerg (1969) found that copulation could occur anytime from June through April except during winter, when crayfish were torpid; that eggs were laid in October in burrows or in April and hatch in April, May, and June; that young remain attached to the female for 7–19 days; and that some individuals mature in their first year and die the next but that others do not mature until their second year and live 2 full years. In Iowa, Phillips (1980) found females in berry and with young attached in April and May.

In Illinois, form I males have been found from January through November (Rietz 1912; Cralley 1932; Brown 1955; Table 12). Elsewhere form I males have been found in June and July in Tennessee (Hobbs & Marchand 1943) and from April through September in New York (Crocker 1957). The smallest Illinois form I male recorded was 40 mm

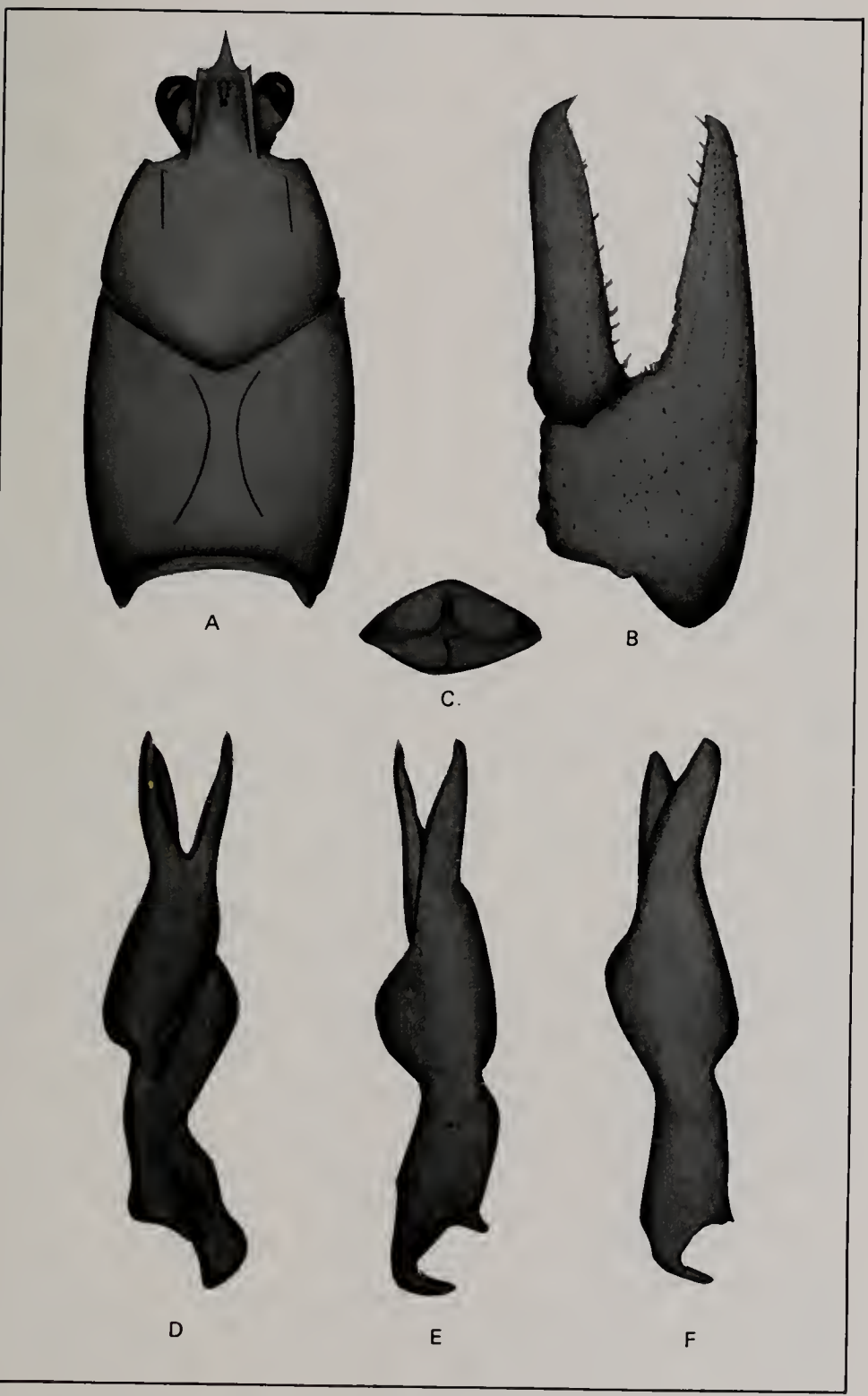

Fig. 124.—*Orconectes indianensis.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

total length (about 20 mm CL) (Rietz 1912).

Females carry eggs in Illinois from January through April and carry young from April through June (Rietz 1912; Brown 1955; Table 12). The smallest ovigerous Illinois female is 22 mm CL (collected in Richland County, 12 April 1979), the same length as that reported by Tack (1941) in New York.

Elsewhere, eggs have been noted in April and November in Michigan (Herrick 1896; Pearse 1910); April, May, and October in Iowa (Caldwell & Bovbjerg 1969; Phillips 1980); March and April in Indiana (Williamson 1907); April in Kansas (Harris 1902); April and October in Nebraska (Engle 1926); June in North Dakota (Creaser & Ortenburger 1933); and October–November and April–May in New York (Tack 1941; Crocker 1957). Young are carried in May in New York and Ontario (Tack 1941; Crocker 1957; Crocker & Barr 1968) and from April through June in Iowa (Caldwell & Bovbjerg 1969; Phillips 1980).

Seven Illinois females collected during the present study (21.8–35.9 mm CL) were carrying 102–285 (mean, 168.9) eggs. Eggs averaged about 1.7 mm in diameter. Three females (26.6–35.5 mm CL) carried 58–184 (mean, 120.3) young.

The largest individual encountered during the present survey was a 41.9-mm CL form II male collected in Bennett Creek, Crawford County, on 30 April 1973. Brown (1955) collected a 46-mm CL female from Illinois, and Crocker (1957) recorded a 49-mm CL female from New York. The ratio among all Illinois specimens collected was 505 males: 513 females.

Orconectes indianensis (Hay)
(Fig. 124)

Cambarus indianensis Hay 1896

Description.—Rostrum excavated, slightly deflected downward anteriorly, with long acumen; margins converge slightly anteriorly, ending in small spines; small median carina. Carapace flattened dorsoventrally, with large cervical spines; suborbital margin barely angular. Areola moderately wide, narrowest part 15–20 percent of length. Chela large, heavily punctate; palm with row of 7–9 tubercles on mesial margin, 2–3 adjacent rows of smaller tubercles on dorsal surface. Form I gonopod terminates in two short, distally tapering and strongly diverging elements: a sclerotized central projection and an unsclerotized mesial process. Overall dark brown dorsally, except thorax yellow brown; fingers of chelae with red tips and subdistal black bands.

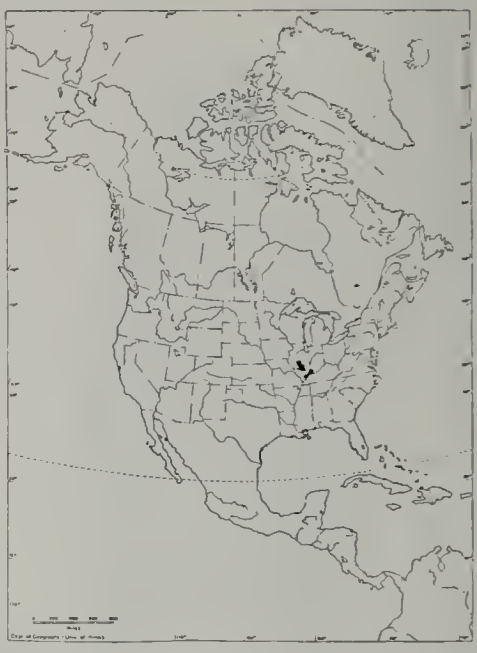

Fig. 125.—Total distribution of *Orconectes indianensis*.

O. indianensis is most similar, and perhaps most closely related, to *O. wrighti*, a species known only from Hardin County, Tennessee (Hobbs 1974b).

Distribution and Habitat.—*O. indianensis* lives in rocky riffles and pools of small to medium-sized streams in the Wabash River drainage of southwestern Indiana and in the Saline River and Honey Creek systems (both tributary to

the Ohio River) in southeastern Illinois (Fig. 125). This species uses stones as cover and often constructs a short tunnel with a terminal pocket under a stone as a resting place (Brown 1955).

Recent Illinois collections of *O. indianensis* are available from the Saline drainage of Gallatin, Saline, Williamson, Pope, and Johnson counties, and from Honey Creek in Hardin County (Fig. 126). Most collections in the Saline system are from that part of the system draining the Shawnee Hills. The northern part of the system, draining the Mount Vernon Hill Country (Central Lowland Province) seems to be devoid of *O. indianensis*. Honey Creek, also in the Shawnee Hills, is the first large stream south of the Saline River.

Brown (1955) documented essentially the same distribution in Illinois as did the present survey, but his record for *O. illinoiensis* in Cypress Ditch, near Junction, Gallatin County was probably based on *O. indianensis*. Rietz (1912) had more widespread records, but some of them probably (because of the localities) were based on misidentifications of the then undescribed *O. illinoiensis* and *O. stanndardi*. Rietz's record for Grand Pierre Creek, Pope County, and two records for Bay Creek, Pope and Johnson counties were surely based on *O. illinoiensis*. Her record for Skillet Fork, Wayne County, was probably based on *O. stannardi*. The Little Fox River, White County, record may have been based on *O. propinquus*. However, her records for South Fork Saline River and, more interestingly, for the North Fork Saline River must have been for *O. indianensis*. No similar species occurs or ever has been recorded for the Saline system. The North Fork records are interesting because *O. indianensis* no longer is found there. The North and Middle forks of the

Fig. 126.—Distribution of *Orconectes indianensis* in Illinois. Open circles = pre-1912 records (Rietz 1912); black dots = 1972–1982 collections.

Table 13.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Orconectes indianensis*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
March	1	1	100	1	100	0	0
April	2	0	0	2	100	0	0
May	2	0	0	0	0	1	50
July	1	0	0	0	0	0	0
August	2	1	50	0	0	0	0
September	2	2	100	0	0	0	0
October	3	3	100	0	0	0	0

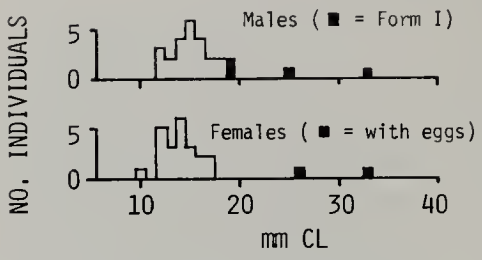

Fig. 127.—Size-frequency distribution of *Orconectes indianensis* collected in Honey Creek, Hardin County, on 23 March 1973.

Saline are badly polluted. They suffer from strip-mine and oil-field pollution, siltation, and desiccation (Smith 1971) and are among the most damaged and abused streams in Illinois. In many areas of these streams little aquatic life of any kind can be found.

Life History.—Apparently the only ecological information on *O. indianensis* is that presented by Brown (1955) and that from the present survey.

Brown (1955) found no ovigerous females and collected form I males only in September and November. In the present study, collections were made from March through October (except June), and form I males were present in March, August, September, and October (Table 13). The smallest form I male was 17.7 mm CL, and the largest was 33.4 mm CL.

Ovigerous females were found in March and April (Table 13). One hundred twenty-one eggs were counted on a 26.3-mm CL female, 148 eggs on a 27.7-mm CL female, and 178 eggs on a 32.2-mm CL female. Eggs averaged about 1.8 mm in diameter. The only female with young attached was 35.0 mm CL and was collected on 19 May 1973. Attached to her were 132 young and 21 unhatched eggs.

The largest Illinois specimens examined were the above-mentioned 35.0-mm female and 33.4-mm form I male. The size-frequency distribution of 51 specimens collected in Honey Creek, Hardin County, on 23 March 1973 (Fig. 127) suggests a 2-year life span, with 1-year-old males averaging 15.2 mm (N = 25), 1-year-old females averaging 13.4 mm (N = 22), and 2-year-olds (N = 4) ranging from 25 to 33 mm CL. Of the 219 specimens of *O. indianensis* collected during the present survey, 104 were males and 115 were females.

Orconectes kentuckiensis Rhoades (Fig. 128)

Orconectes kentuckiensis Rhoades 1944

Description.—Rostrum excavated, deflected downward anteriorly, with long acumen; margins barely converge anteriorly, ending in tubercles or small spines; lacks median carina. Carapace flattened dorsoventrally, with large cervical spines; suborbital margin barely angular. Areola wide, narrowest part about 18 percent of length. Chela large, heavily punctate; palm with row of 7–9 tubercles on mesial margin; 1–2 adjacent rows of smaller tubercles on dorsal surface. Form I gonopod terminates in a short, thick, distally directed, sclerotized central projection, and a short, caudodistally directed, unsclerotized mesial process. Dorsally dark brown (with yellow brown thorax) to red brown; fingers of chelae with red tips, subdistal black bands.

The gonopod of *O. kentuckiensis* most closely resembles that of *O. sloanii* in southern Indiana and Ohio and *O. harrisonii* in southeastern Missouri. Although the relationships of these species have not been investigated, *O. sloanii* and *O. harrisonii* probably are the closest relatives of *O. kentuckiensis*.

Distribution and Habitat.—*O. kentuckiensis* occurs only in small streams in a small area of southeastern Illinois and northwestern (Crittenden, Livingston, and Union counties) Kentucky (Fig. 129). In Illinois, it occurs only in Big, Hosick, and Peters creeks, three spring-fed, rocky, direct tributaries of the Ohio River in Hardin County (Fig. 130). Its distribution in the headwaters of Big Creek (Fig. 131), by far the largest of the three streams, complements the downstream distribution of *O. placidus*

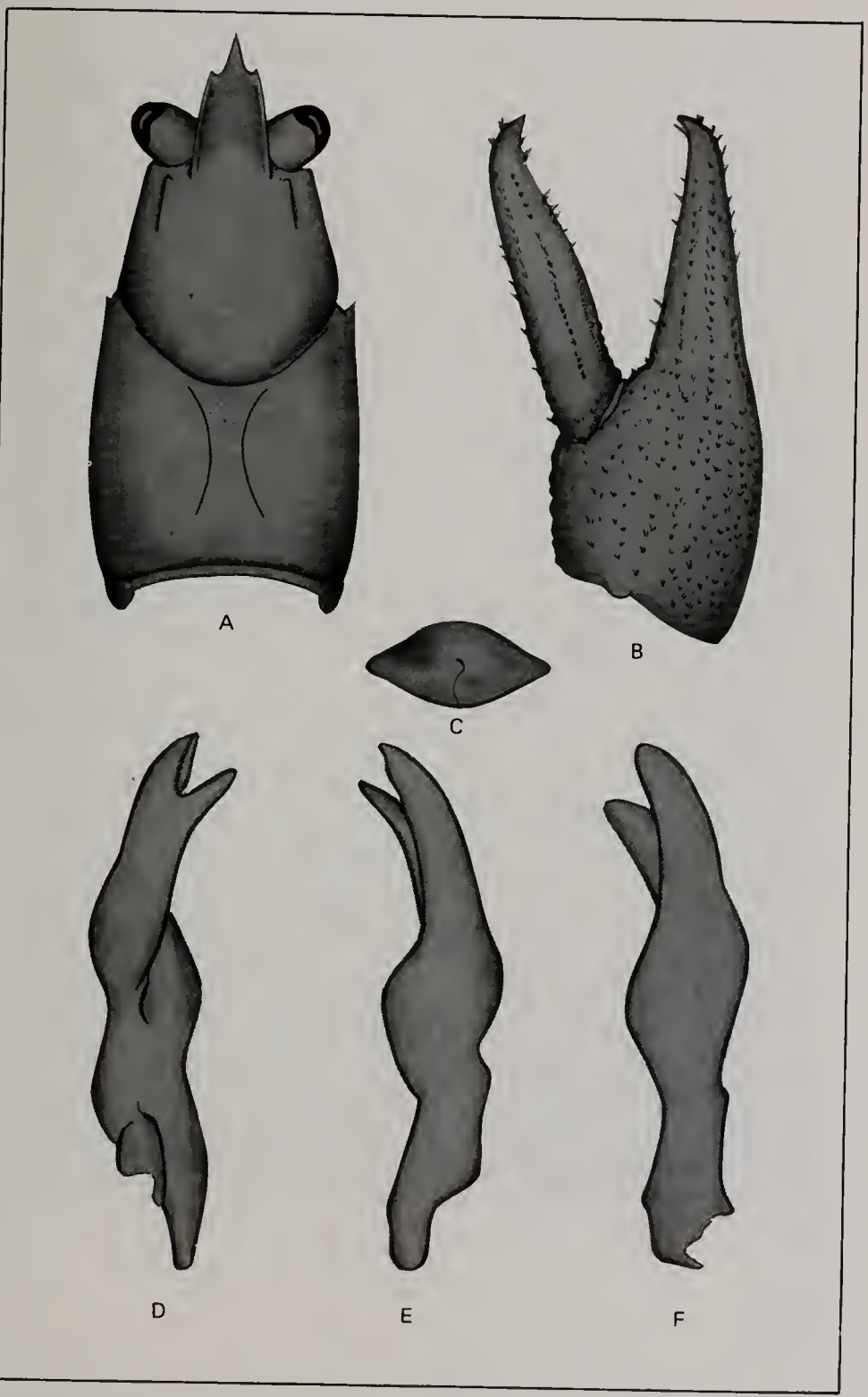

Fig. 128.—*Orconectes kentuckiensis.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male, F, lateral view of gonopod of form II male.

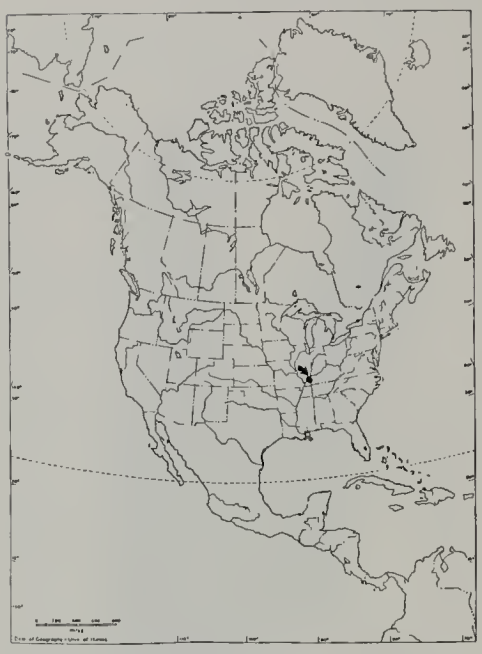

Fig. 129.—Total distribution of *Orconectes kentuckiensis.*

Fig. 130.—Distribution of *Orconectes kentuckiensis* in Illinois; black dots = 1972–1982 collections.

(Boyd & Page 1978). No record of its occurrence in Illinois predates those of Brown (1955). *O. kentuckiensis* probably was never more widespread in Illinois than it is today.

O. kentuckiensis is most common in shallow, rocky pools of small streams (Boyd & Page 1978), where large rocks are used as cover, although Rhoades (1944a) collected specimens in accumulations of brush over mud. This species does not burrow but may bury itself in loose gravel 2–4 cm below the surface of a dry stream bed (Boyd & Page 1978).

Life History.—The life history of *O.*

Table 14.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Orconectes kentuckiensis.*

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	5	4	80	0	0	0	0
February	1	1	100	0	0	0	0
March	10	7	70	3	33	0	0
April	5	2	40	3	60	0	0
May	9	0	0	1	11	0	0
June	16	0	0	0	0	0	0
July	5	2	40	0	0	1	20
August	4	1	25	0	0	0	0
September	9	7	78	0	0	0	0
October	11	6	55	0	0	0	0
November	4	4	100	0	0	0	0
December	3	3	100	0	0	0	0

Fig. 131.—Headwaters of Big Creek, 2 mi E Karbers Ridge, Hardin County, Illinois, support large populations of *Orconectes kentuckiensis*.

kentuckiensis in Big Creek was studied by Boyd & Page (1978). The species was active at temperatures of 6°–32° C and dissolved oxygen levels of 3.5–14.4 ppm. Most individuals were found in water 5–61 cm deep. The species lived a maximum of 2+ years, had a 1:1 sex ratio, fed on vascular plants and arthropods (amphipods, isopods, crayfishes, caddisflies, and midges), and was preyed upon by fishes.

Form I males (15.9–37.5 mm CL) were present from July through April and peaked in occurrence in November, December, and February; females carrying eggs or young were present in March, April, May, and July (Table 14) and measured 14.8–32.8 mm CL. Fifteen females were carrying 49–248 (mean, 110) eggs. Eggs were spherical and averaged 1.9 mm in diameter. The relationship between the number of eggs (N) and the female's weight in grams (W) was $N = 49.809 + 25.310\ W$, $r = 0.807$, and that between N and the female's carapace length (L) was $N = -0.43611 + 1.8516 \log L$, $r = 0.859$. Counts of ovarian eggs in 15 females were 59–249 and averaged 109. Numbers of eggs, ovarian and abdominal, increased significantly with carapace length. The growth of first-year crayfish occurred during a period of 4.5 months, of adult males during spring and summer molts, and of adult females during a summer molt.

The largest *O. kentuckiensis* from Illinois is a 37.5-mm CL form I male collected on 25 April 1975; the largest female is 36.2 mm CL, collected on 30 September 1975. Both are from Big Creek.

Orconectes lancifer (Hagen)
(Fig. 132)

Cambarus lancifer Hagen 1870
Cambarus faxonii Meek 1894

Description.—Rostrum deeply excavated; acumen longer than basal margin of rostrum, turning upward anteriorly; no median carina; margins convex, diverging anteriorly, terminating in spines. Carapace slightly flattened dorsoventrally, with large cervical spines; suborbital margin angular. Areola narrow, obliterated anteriorly. Chela long and narrow, setose, without tubercles. Form I gonopod terminates in two short, spatulate elements: a sclerotized central projection and an unsclerotized mesial process. Mottled overall in shades of red, brown, and green; fingers of chelae without bright red tips and without black bands subdistally.

O. lancifer is a highly distinctive crayfish with no obviously close relatives.

Distribution and Habitat.—*O. lancifer* is an inhabitant of the Gulf Coastal Plain and is known to occur in Louisiana, Mississippi, Tennessee, eastern Texas, Arkansas, and extreme southern Illinois (Fig. 133). It lives in deep water of oxbows, bayous, and large streams (Black 1972) and, as a result is rather poorly represented in collections.

O. lancifer has been found at only two localities in Illinois. Robert Kennicott, an early naturalist, collected a female at Cairo in the middle 1800's (Faxon 1914), and Page & Burr (1973) recorded a collection of eight individuals from Horseshoe Lake. Both localities are in the Mississippi River drainage of Alexander County (Fig. 134). Four additional collections of *O. lancifer* recently have been made at Horseshoe Lake, where the species probably is common but difficult to collect. Horseshoe Lake (Fig. 135) is an old, relatively deep oxbow of the Mississippi River supporting stands of bald cypress and many species of Coastal Plain animals that are rare in Illinois (Evers & Page 1977). Few oxbows of the Mississippi River exist in southern Illinois, and *O. lancifer* is unlikely to be found elsewhere in the state. Wolf Lake in Union County appears to offer suitable habitat for *O. lancifer*, but several searches there have failed to document its presence.

In Louisiana, *O. lancifer* lives in deep (more than 40 cm), clear, permanent

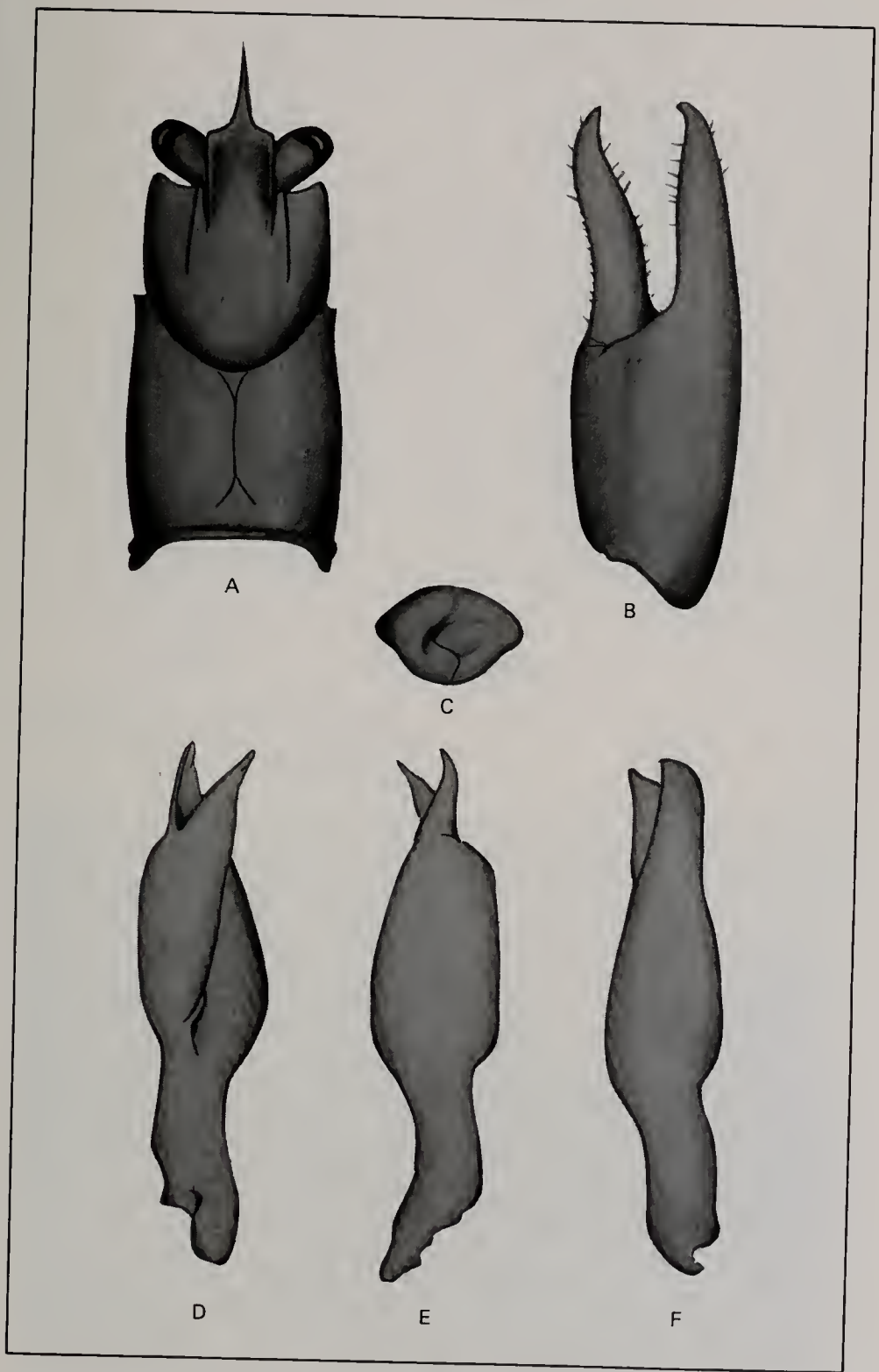

Fig. 132.—*Orconectes lancifer.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 133.—Total distribution of *Orconectes lancifer*.

Fig. 134.—Distribution of *Orconectes lancifer* in Illinois. Open circle = collection made in the mid-1800's (Faxon 1914); black dots = 1972–1982 collections.

Fig. 135.—Horseshoe Lake in Alexander County is the only known locality in Illinois still supporting a population of *Orconectes lancifer*.

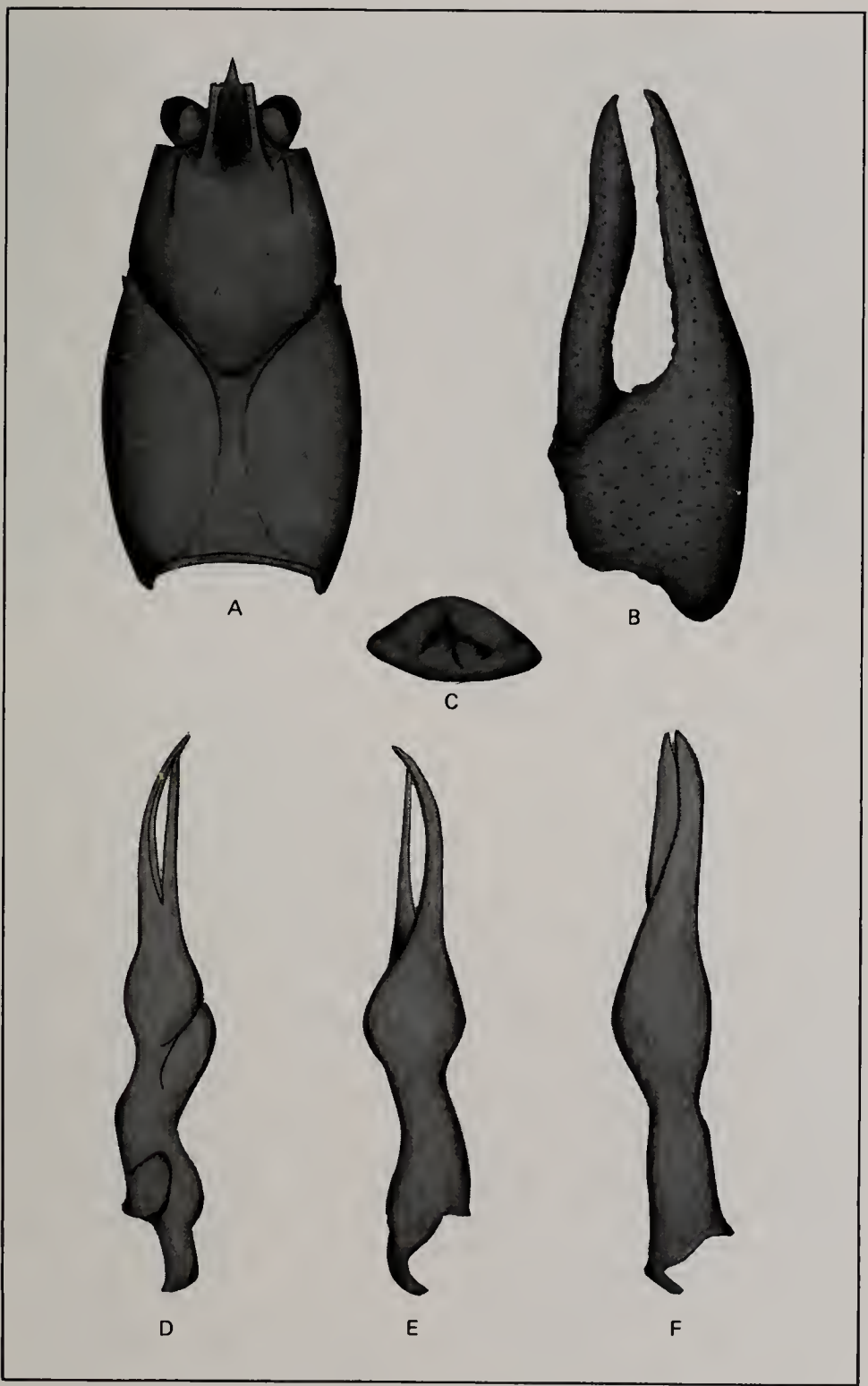

Fig. 136.—*Orconectes placidus*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

water over mud or mixed mud and sand with little aquatic vegetation present (Penn 1952). This description fits Horseshoe Lake fairly well except that the lake is heavily vegetated.

Life History.—Black (1972) summarized the scant life history data available on *O. lancifer:* form I males have been collected from August through November; females carrying eggs or young have been found only in February; juveniles predominate in May, June, and July.

Among the collections made in Illinois are two made in June and one each in July, September, and October. The September and October collections contain a total of three form I males (30–32 mm CL). Also in the Illinois Natural History Survey collection is a 40-mm female from Cheniere Lake, Ouachita Parish, Louisiana, collected on 18 February 1977, with 570 eggs attached. The eggs average 1.5 mm in diameter. These additional observations agree with Black's (1972) description of an autumnal breeding season and winter egg-laying season.

Fig. 137.—Total distribution of *Orconectes placidus.*

Orconectes placidus (Hagen)
(Fig. 136)

Cambarus placidus Hagen 1870

Description.—Rostrum excavated, no (or low) median carina, long acumen; margins thick, straight to slightly concave, barely converging anteriorly, terminating in spines. Carapace flattened dorsoventrally, with large cervical spines; suborbital margin smooth. Areola moderate, narrowest part about 11–15 percent of length. Chelae large, heavily punctate; palm with 2–3 rows of tubercles along mesial margin. Form I gonopod terminates in a long sclerotized central projection curved at tip and a slightly shorter unsclerotized mesial process; cephalic surface smooth or with broadly rounded (not angular) shoulder. Dorsally red brown; fingers of chelae with red tips, subdistal black bands.

Fig. 138.—Distribution of *Orconectes placidus* in Illinois; black dots = 1972–1982 collections.

Fig. 139.—Gravel riffles in the lower portion of Big Creek, Hardin County, Illinois (10 March 1976) provide the best habitat in Illinois for *Orconectes placidus*.

Among the crayfishes of Illinois, populations herein assigned to *O. placidus* are the most troublesome taxonomically. The only large population is that in Big Creek in Hardin County; other populations are small, highly localized ones inhabiting rocky areas along the banks of the Ohio and Mississippi rivers. Although all are assigned to *O. placidus,* these populations show variations usually indicative of specific distinctiveness in *Orconectes.* The gonopod of the form I male lacks any hint of a shoulder on its dorsal surface in Big Creek specimens but has a definite shoulder (although not as pronounced and angular as in *O. rusticus*) in Mississippi River specimens (no form I males from the Ohio River are available). Big Creek specimens always lack a carina on the rostrum; those from the Ohio and Mississippi rivers may or may not have one. In general, western populations differ the most from typical *O. placidus* occupying the Cumberland and Tennessee river systems in Kentucky and Tennessee (Hobbs 1974b). Variation in *O. placidus* and its relatives is badly in need of study.

Distribution and Habitat.—*O. placidus* occupies streams of the Cumberland, Tennessee, and lower Ohio rivers in Kentucky, Tennessee, and Illinois (Fig. 137). It lives in rocky riffles and pools, using cavities and interstices as hiding places.

Recent Illinois records exist for Big Creek, Hardin County, the Ohio River, Massac and Pulaski counties, and the Mississippi River, Randolph and Jackson counties (Fig. 138). Most of the large-river collections were made along rocky banks or in rocky backwater areas. In the Big Creek system, *O. placidus* is found mainly in downstream gravel and rubble riffles (Fig. 139), and *O. kentuckiensis* is found mainly in upstream shallow rocky pools (Boyd & Page 1978). As discussed below for *O. rusticus,* Hagen's (1870) and Forbes' (1876) reference to "*C. placidus*" at Quincy is thought to refer to a waif of the Missouri populations of *O.* cf. *rusticus.* Brown's (1955) discussion of "*O.*

Table 15.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Orconectes placidus*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	3	2	67	0	0	0	0
February	1	0	0	0	0	0	0
March	6	5	83	1	17	0	0
April	2	0	0	1	50	0	0
May	6	0	0	0	0	0	0
June	19	0	0	0	0	0	0
July	3	0	0	0	0	0	0
August	1	0	0	0	0	0	0
September	7	5	71	0	0	0	0
October	8	7	88	0	0	0	0
November	4	3	75	0	0	0	0
December	1	1	100	0	0	0	0

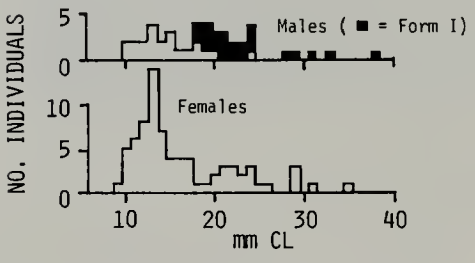

Fig. 140.—Size-frequency distribution of *Orconectes placidus* collected in October in Big Creek, Hardin County.

rusticus" refers to the Big Creek population of *O. placidus*.

Life History.—During the life-history study of *O. kentuckiensis* (Boyd & Page 1978), a large number (61) of collections of *O. placidus* were made. The following observations are based on those collections.

Form I males were present in collections from September through January and in March (only one collection was made in February) (Table 15). Brown (1955) found form I males in Big Creek in November.

Ovigerous females ($N = 3$) were found only in March and April (Table 15); they were 15.7, 20.5, and 27.2 mm CL, with 12, 88, and 134 eggs attached, respectively. Eggs were spherical and averaged 2.1 mm in diameter. No females with young attached were found.

The largest preserved Illinois male is a 45.6-mm form II; the largest female is 41.7 mm CL. Both were collected in May and, compared with the size-frequency distribution of October-collected specimens (the largest sample), were probably 2 or 3 years old (Fig. 140). The largest form I male (39.6 mm) has extremely large chelae (right chela = 46.1 mm long). Among the Big Creek specimens were 344 males and 387 females (a ratio of 1:1.13).

Among a combined total of 506 stripetail and spottail darters (*Etheostoma kennicotti* and *E. squamiceps*) examined, the ingested remains of crayfishes were found in the stomachs of 4 *E. squamiceps* (Page 1974a, 1975). Considering the relative abundances of crayfishes in Big Creek, these were almost certainly *O. placidus* or *O. kentuckiensis* (Boyd & Page 1978).

Orconectes propinquus (Girard) (Fig. 141)

Cambarus propinquus Girard 1852
Orconectes iowaensis Fitzpatrick 1968

Description.—Rostrum excavated, deflecting downward anteriorly; well-developed median carina; long acumen; margins thick, straight or slightly concave, barely converging anteriorly, terminating in spines or lage tubercles. Carapace flattened dorsoventrally, with

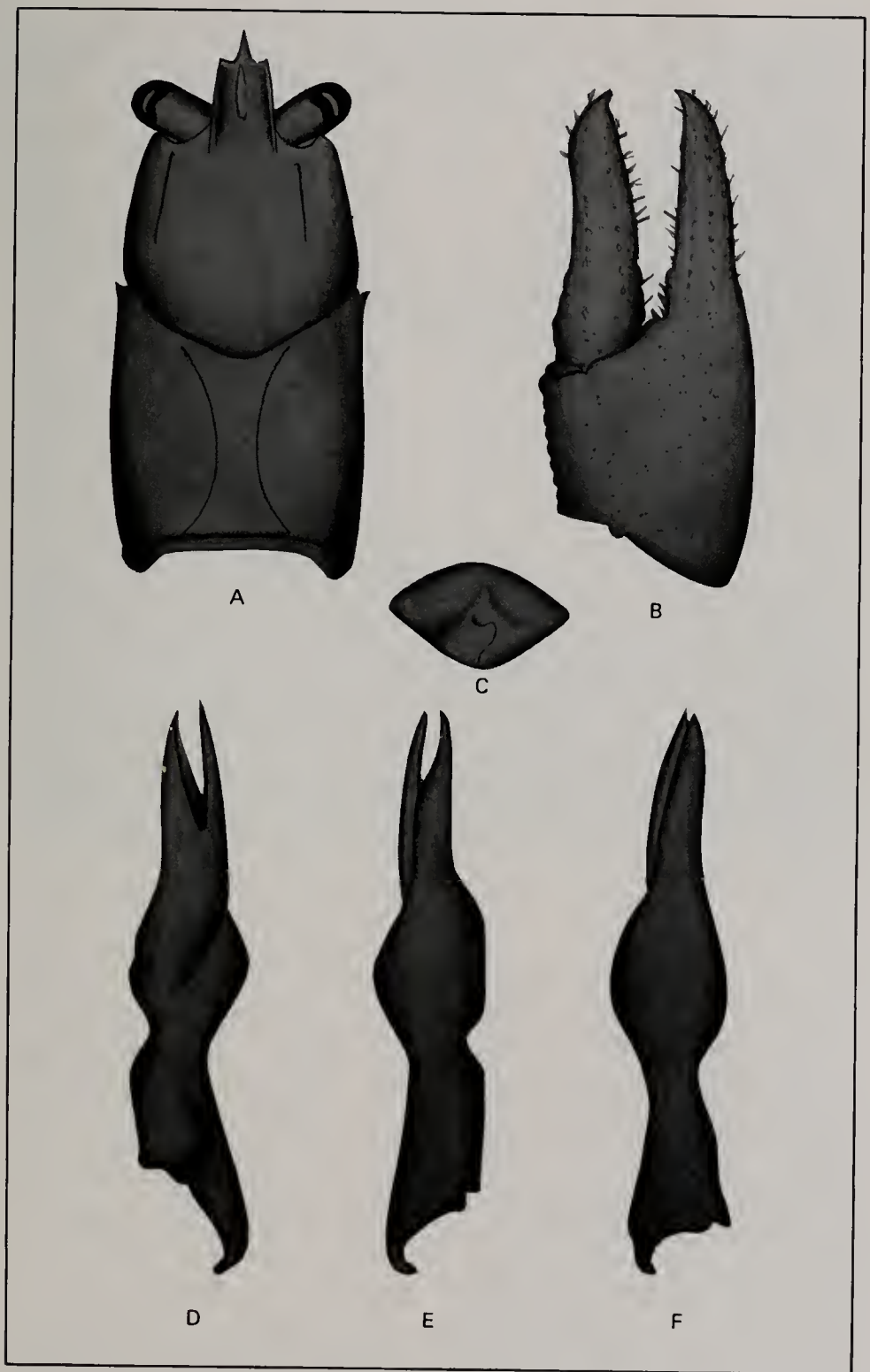

Fig. 141.—*Orconectes propinquus.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

cervical spines; suborbital margin smooth. Areola wide, narrowest part about 19–25 percent of length. Chelae large, heavily punctate; palm with 2–3 rows of tubercles on mesial margin. Form I gonopod terminates in two short, straight elements: a sclerotized central projection and an unsclerotized mesial process. Dorsally green to red brown; fingers of chelae with red tips, subdistal black bands.

Fitzpatrick (1967) found *O. propinquus* to be the most variable species among the *Propinquus* group of species but also to lack taxonomically recognizable subspecies. "*O. iowaensis*," previously thought to be a parapatric relative of *O. propinquus* occupying areas of Iowa adjacent to Illinois (Fitzpatrick 1968), has been relegated to the synonymy of *O. propinquus* by Page (1985).

Distribution and Habitat.—*O. propinquus* ranges from southern Ontario and Quebec south to Illinois, Indiana, Ohio, northern Pennsylvania, New York, and Massachusetts. To the west, its range extends into eastern Iowa and southeastern Minnesota (Fig. 142).

In Illinois, *O. propinquus* occurs in Lake Michigan and in the Wabash, Illinois, Rock, Mississippi, and extreme upper Kaskaskia drainages (Fig. 143). In the Wabash drainage, it extends as far south as White County, is widespread in the Embarras River, but is absent in the Little Wabash River system. In the Illinois and Mississippi rivers, it occurs as far south as Calhoun and Rock Island counties, respectively.

Throughout its range in Illinois, *O. propinquus* is the most common crayfish in clean rocky riffles (Fig. 144). In the fast, rubble and gravel riffles characteristic of the Vermilion, Kankakee, and upper Rock drainages, *O. propinquus* often is abundant. Its absence in most of western and central Illinois presumably is due to the absence of suitable habitat; its absence in southern Illinois apparently is due to the presence there of other species of

Fig. 142.—Total distribution of *Orconectes propinquus*. The northeastern limit of its range is unknown.

Fig. 143.—Distribution of *Orconectes propinquus* in Illinois; black dots = 1972–1982.

Fig. 144.—Middle Fork Vermilion River, near Collison, Vermilion County, Illinois, provides abundant habitat for *Orconectes propinquus*.

rocky stream-inhabiting species of *Orconectes*.

O. propinquus may dig under stones on the stream bed to escape desiccation (Bovbjerg 1952; Brown 1955) or occasionally into stream banks (Hay 1896; Cralley 1932). Young often are found in vegetation along the margins of a stream. Although primarily an inhabitant of rocky streams, it can become established in lakes (Bovbjerg 1952).

O. propinquus remains widespread and locally common, even abundant, in some areas but probably was more widespread and common prior to the extensive modification of the Illinois landscape. It does best in clean, clear streams and presumably has suffered population declines as stream siltation has progressed during the last few decades. Among the widespread crayfishes of Illinois, it is probably the best indicator of environmentally healthy streams.

All earlier records of *O. propinquus* in Illinois fall within, or almost within, the present distribution. The record for the Kaskaskia drainage, near Humboldt, Coles County (Rietz 1912), is one county to the south of recent records. This record is significant in documenting the fact that the presence of the

Table 16.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Orconectes propinquus*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	1	1	100	0	0	0	0
February	1	0	0	0	0	0	0
March	6	5	83	0	0	0	0
April	2	0	0	2	100	0	0
May	4	1	25	2	50	0	0
June	14	0	0	0	0	0	0
July	14	3	21	0	0	0	0
August	37	8	22	0	0	0	0
September	31	12	39	0	0	0	0
October	14	9	64	0	0	0	0
November	2	1	50	0	0	0	0

species in the Kaskaskia is not an especially recent event, even a recent introduction, as the restricted distribution in the upper portion of the drainage might otherwise suggest. The record for the Mississippi River at Quincy, Adams County (Rietz 1912), also is south of the present range.

Rietz's (1912) record for "*O. propinquus*" in Big Muddy Creek at the Richland-Clay county line and Brown's (1955) records for Clay, Effingham, Marion, Shelby, and White counties (all Little Wabash drainage) are probably based on misidentifications of *O. stannardi*, as discussed below.

Life History.—The following information is from a life-history study of *O. propinquus* conducted at Urbana, Illinois, 1932–1934 (Van Deventer 1937). Free-swimming young (about 5 mm CL) appear in May and June. They reach 12–27 mm CL during the first growing season and most become sexually mature at about 20 mm. Most individuals reach maturity by fall, and copulation takes place in late fall or early spring. Growth ceases during winter. Eggs are laid in March and April and are carried 4–6 weeks. Those individuals which reach maturity in the fall of their first year and produce young in the following spring die as yearlings. Those which do not mature until their second growing season usually live 2 years, and a very few individuals live to a third year.

Cralley (1932) found form I males in Champaign County from June through August and recorded seeing copulations in September and October. Van Deventer (1937) found form I males (as small as 12.6 mm CL) in Illinois in September, October, November, and March. Brown (1955) found form I males June–September. During the present survey, form I males (14.6–31.5 mm CL) were found in every month except December, February, and April, when too few collections were made to be meaningful, and June. The data suggest a peak of activity from fall to early spring (Table 16). Form I males have been recorded in August in New England (Crocker 1979) and April–October in New York (Crocker 1957).

In Illinois, females carry eggs in April and May and carry young in May and June (Rietz 1912; Cralley 1932; Van Deventer 1937; Bovbjerg 1952; Brown 1955; Table 16). Van Deventer (1937) found 4–250 eggs on females 16–36 mm CL, with larger females carrying more eggs. Counts of eggs on recently collected females (N = 5; 27–32 mm CL) were 175, 192, 228, 229, and 277.

Females carry eggs in April–July in Ontario (Crocker & Barr 1968), eggs in April and May and young in June in New York (Crocker 1957), eggs in April

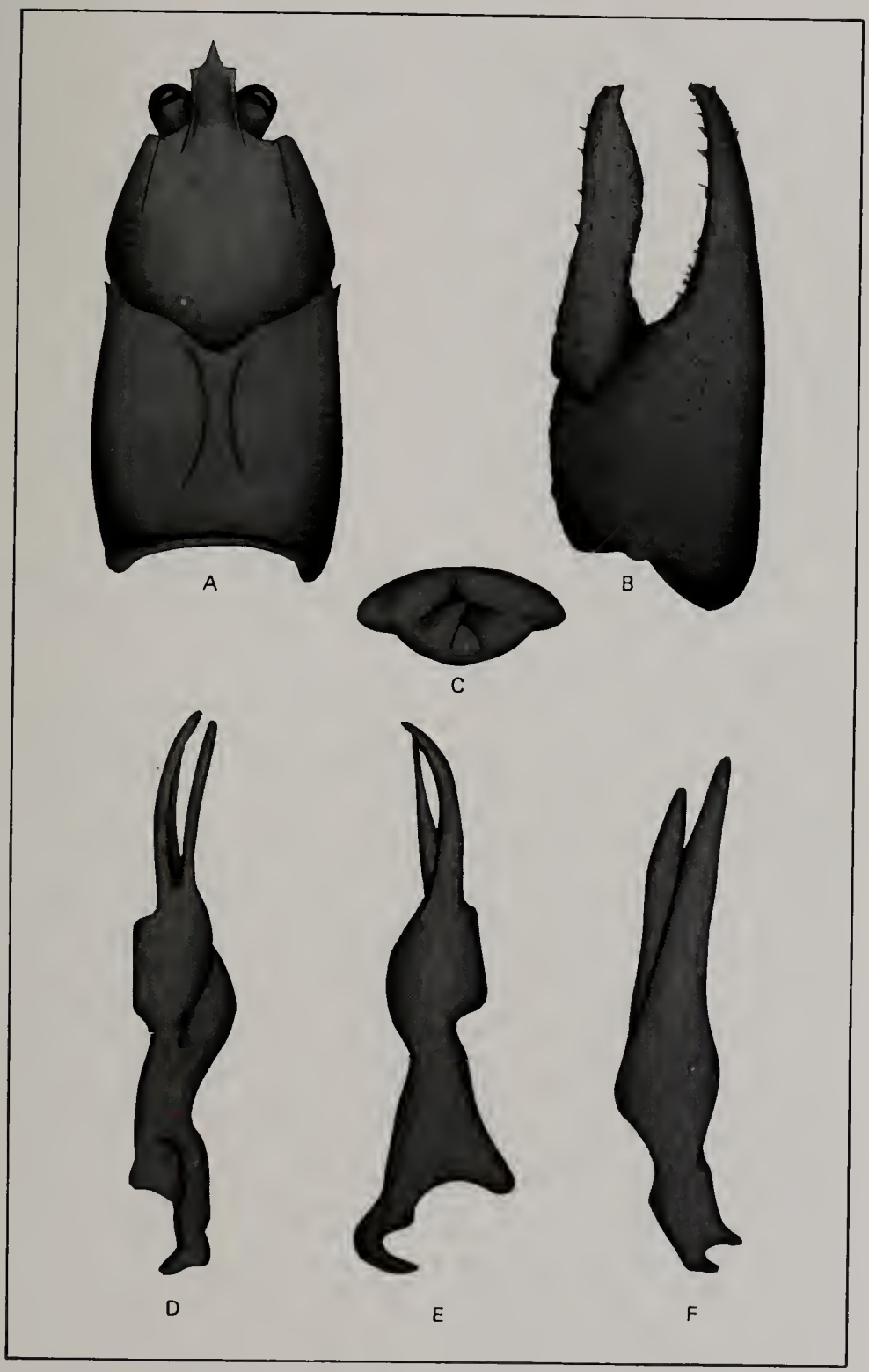

Fig. 145.—*Orconectes rusticus.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

and May in Iowa (as *O. iowaensis*, Phillips 1980), and eggs and young in April–June in Michigan (Pearse 1910; Creaser 1931). Females with eggs and young may be as small as 16 mm CL (Crocker 1957; Berrill 1978). Eggs are spherical and average about 1.9 mm in diameter.

The ratio of males to females among recent Illinois collections is 334:335. The largest specimen collected during the present survey is a 39.3-mm CL female; the largest male is a 31.5-mm form I. Van Deventer (1937) and Brown (1955) each recorded a 40-mm male; Cralley (1932) recorded a 90-mm TL (about 45-mm CL) male and a 90-mm TL female from Champaign County.

O. propinquus is omnivorous, feeding on plant materials and insect larvae (Bovbjerg 1952).

Fig. 146.—Presumed native distribution of *Orconectes rusticus*.

Orconectes rusticus (Girard)
(Fig. 145)

Cambarus rusticus Girard 1852
Cambarus juvenilis Hagen 1870

Description.—Rostrum excavated; no median carina; long acumen; margins thick, concave, terminating in spines. Carapace flattened dorsoventrally, with cervical spines; suborbital margin smooth. Areola moderate, narrowest part about 10–15 percent of length. Chelae large, heavily punctate; palm with two rows of tubercles on mesial margin. Form I gonopod with an angular (90° to axis of gonopod) shoulder on dorsal surface, terminating in two long elements: a sclerotized central projection curved at its tip, and a slightly shorter unsclerotized mesial process. Dorsally green brown to rust red; often a large red spot surrounded by light brown on side of carapace; fingers of chelae with red tips, subdistal black bands.

Close relationships to *O. rusticus* are not readily apparent. Species often confused with, and at times considered related to, *O. rusticus* include *O. forceps*, *O. placidus*, *O. putnami*, *O. spinosus*, and until synonymized with *O. rusticus* by Bouchard (1977), *O. juvenilis*.

Distribution and Habitat.—*O. rusticus* now occurs in New England, Ontario, Michigan, Ohio, Indiana, Kentucky, Tennessee, Illinois, Wisconsin, Minnesota, Iowa, Missouri, and New Mexico. It has been widely introduced, presumably through use as fishing bait, and the boundaries of its native range (Fig. 146) now are difficult to determine. However, at least its occurrences in New England (Crocker 1979), Ontario (Crocker & Barr 1968), Wisconsin (Capelli & Munjal 1982), New Mexico (Bouchard 1977), and Illinois are certainly the results of introductions. Once introduced, *O. rusticus* successfully displaces native species and expands its range, apparently because it is a large and aggressive species able to thrive in impoundments and other disturbed habitats (Berrill 1978; Capelli 1982; Capelli & Munjal 1982; Capelli & Magnuson 1983). Its continued use as a live bait species is therefore unwise.

Taxonomic confusion about *O. rus-*

Fig. 147.—Distribution of *Orconectes rusticus* in Illinois. Open circle = Adams County locality given by Hagen (1870) for "*Cambarus placidus*;" black dots = 1972–1984 collections.

ticus and its relatives has reigned since their descriptions. "*Cambarus wisconsinensis* Bundy," found at Normal (Forbes 1876), is a synonym of *O. virilis* (Hobbs 1972a) and is not a reference to *O. rusticus*, as thought by Rietz (1912) and Page (1974b). Brown's (1955) records for "*O. rusticus*" all were for Big Creek in Hardin County and are treated herein as *O. placidus*.

"*Cambarus placidus* Hagen" was recorded from Quincy by Hagen (1870) and Forbes (1876) and considered by Rietz (1912) to represent a record of *O. rusticus*. Quincy is directly across the Mississippi River from the Fabius River system of Missouri which supports a population of *O. rusticus* or a closely related undescribed species. The Quincy record probably represents a waif from the Fabius River population of *Orconectes* and is plotted on the *O. rusticus* map (Fig. 147).

In Illinois, *O. rusticus* has been found recently in Peoria Lake, Tazewell County (in 1973 and 1974), Powder Horn Lake, Cook County (1975), Wolf Lake, Cook County (1975, 1978, 1980), Eagle Creek, Lake County (1975), Kent Creek, Winnebago County (1977), Nippersink Creek, McHenry County (1979), in a backwater of Fox River at Oak Point State Park, Lake County (1982), and in Lake Michigan, 1 mile east of Burnham Harbor, Cook County (1984). All of these localities are heavily used by fishermen or are near such areas, and the presence of *O. rusticus* in Illinois is surely the result of bait-bucket introductions. Except for Lake Michigan and Wolf and Powder Horn lakes, which are in the Lake Michigan drainage, and Kent Creek, which is a tributary of the Rock River, all localities are in the Fox-Illinois River system (Fig. 147).

O. rusticus is reproducing in Illinois (at least in Wolf Lake, where specimens as small as 16 mm CL have been found) and probably is supplanting native species, as it is in southern Ontario (Berrill 1978) and Wisconsin (Capelli & Munjal 1982). Hybridization between *O. rusticus* and *O. propinquus* and between *O. rusticus* and *O. limosus* has been recorded in Wisconsin and Massachusetts (Capelli & Capelli 1980; Smith 1981) and appears to represent an intermediate step in the displacement by *O. rusticus* of these native species. In Illinois, it appears to be hybridizing with *O. virilis* in Wolf Lake. *O rusticus* lives in rocky riffles, pools, and along wave-swept lake margins.

Life History.—In fish ponds in Ohio, Langlois (1935) found mating to occur in September and October; following copulation, the females burrow into banks. Oviposition occurs in a few females in October, but mostly in April and May, when females are 1 year old. Eggs hatch in about 20 days and remain attached to the female for about 5 days. Sexual maturity is reached in the fall

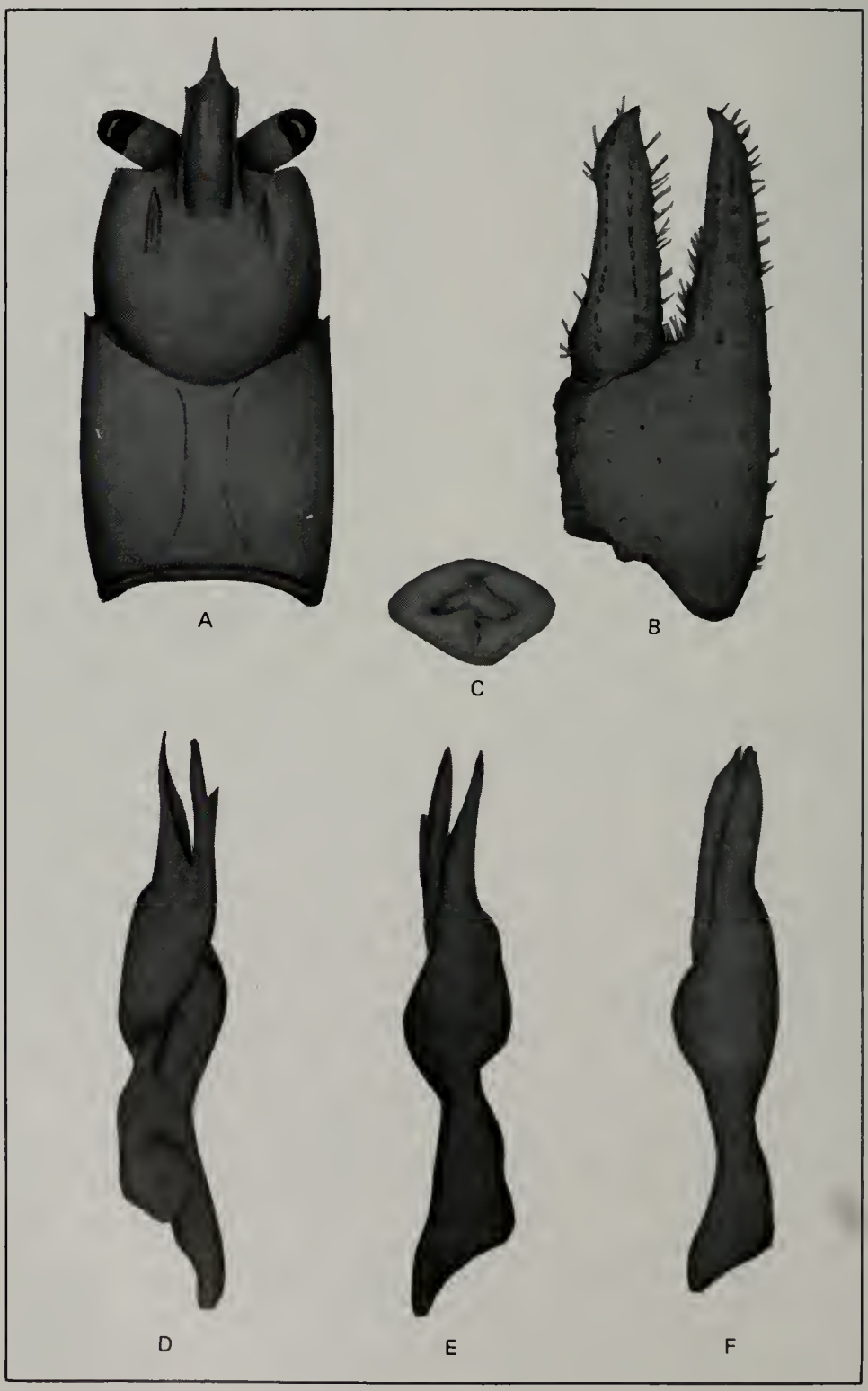

Fig. 148.—*Orconectes stannardi.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

following one summer's growth.

Prins (1968) studied *O. rusticus* in a stream in Kentucky and found that mating peaks in September and October, females oviposit from February through June at about 22–24 months, eggs hatch in May after being carried by the female for 4–6 weeks, young remain attached to the mother for 3 weeks (through April and May), sexual maturity is reached at about 15 months (about 18 mm CL), the sex ratio among juveniles is 1:1, and the species reaches a maximum longevity of about 3 years and a maximum CL of 45 mm. Counts of ovarian eggs in 43 females ranged from 54 to 357. The smallest female with eggs attached (55 eggs) was 17 mm CL; the largest, with 231 eggs, was 38 mm CL. The relationship between the number of eggs (N) and carapace length (L) of 49 females was $N = -91.49 + 8.31L$, with $r = 0.86$. The species feeds mainly on plants and detritus and has been observed feeding out of water along the banks. During winter, *O. rusticus* typically burrows into stream banks and into interstices in the substrate.

Form I males have been found in July and August in Ontario (Crocker & Barr 1968), in June in Maine (Crocker 1979), and in July and September in Iowa (Phillips 1980). Females in berry were collected in April in Iowa (Phillips 1980). Busch (1940) found that it took 20 days for eggs to hatch at 20°–22° C.

Among the nine Illinois collections (made from May through September), form I males (20.5–34.0 mm CL) are present in August and September. No ovigerous females were found. Some Illinois specimens approach the maximum size recorded for the species; the largest Illinois male (form II) is 40.5 mm, and the largest female is 41.5 mm CL.

Orconectes stannardi Page
(Fig. 148)

Orconectes stannardi Page 1985

Description.—Rostrum excavated; well-developed median carina; long acumen; margins moderately thick, subparallel, slightly converging medially, terminating in spines. Carapace flattened dorsoventrally, with cervical spines; suborbital margin weakly angular. Areola moderately wide, narrowest part about 15–25 percent of length. Chela large, heavily punctate; palm with two rows of tubercles on mesial margin. Form I gonopod terminates in two short, straight elements: a sclerotized central projection and an unsclerotized mesial process with spur about middle of caudal surface; shoulder on cephalic surface at base of central projection. Olive green to light brown and usually heavily speckled with dark brown dorsally; fingers of chelae with red tips, subdistal black bands.

Distribution and Habitat.—*O. stannardi* is a member of the *O. propinquus* species group that is endemic, and

Fig. 149.—Distribution of *Orconectes stannardi*. Open circles = localities given by Rietz (1912) and Brown (1955) for "*O. propinquus*" and "*O. indianensis*;" black dots = 1972–1984 collections.

Fig. 150.—*Orconectes stannardi* is most common along rocky stream margins such as this one on the Little Wabash River, 3.5 mi NNW Louisville, Clay County, Illinois (8 October 1984).

possibly autochthonous, to the Little Wabash River system of Illinois. The region drained by the Little Wabash was glaciated during the Illinoian (about 100,000 y.b.p.) but not the Wisconsinan (about 10,000 y.b.p.) advances, suggesting that the species originated sometime within the past 100,000 years (Page 1985). All collections made since 1972 are from the Little Wabash River proper (Fig. 149).

Rietz (1912) and Brown (1955) re-

corded localities for *O. propinquus* and *O. indianensis* in the Little Wabash River system that almost certainly were based on misidentified *O. stannardi* (Page 1985). Data collected during the present survey suggest that *O. propinquus*, *O. indianensis*, and *O. stannardi* occur allopatrically and that neither *O. propinquus* nor *O. indianensis* occurs in the Little Wabash River system. Unfortunately, the collections made by Rietz and Brown cannot be located and re-examined.

Although all collections of *O. stannardi* that have been made since 1972 are from the Little Wabash River proper, some of the collections of Rietz (1912) and Brown (1955) were from tributaries. Collections of Rietz (1912) were made in Big Muddy Creek between Richland and Clay counties and in Skillet Fork at Wayne City, Wayne County; the former was identified by Rietz as *O. propinquus* and the latter as *O. indianensis*. Collections cited by Brown (all as *O. propinquus* but which must have been of *O. stannardi*) were made in Dismal Creek, 2¼ mi N Iola, Clay County; Salt Creek, 1 mi SE Effingham, Effingham County; Blue Point Creek, 2½ mi S Shumway, Effingham County; Lost Fork, 1½ mi E Omega, Marion County; branch of Little Wabash River, 1¼ mi SW Trowbridge, Shelby County; and Little Wabash River, 4 mi NE Shumway, Effingham County.

Most individuals were found in shallow riffles composed of large flat stones (Fig. 150). A few were found in deeper water but always in association with stones or accumulations of sticks and other debris. The preference of *O. stannardi* for rocky riffles is typical of the *Propinquus* group of *Orconectes*, the members of which typically hide under stones and among debris. *O. stannardi* is locally common in the Little Wabash River.

Life History.—All seven collections of *O. stannardi* presently available (from November 1973, November 1983, May 1984, and August 1984) contain form I males, and one (May 1984) contains two ovigerous females. All 20 males collected in November, 5 of 11 collected in August, and 1 of 25 collected in May are form I. The two ovigerous females collected in May 1984 were 20.7 mm and 28.9 mm CL and carried 124 and 184 eggs, respectively. Eggs average 1.9 mm in diameter. The largest specimen is a 38.3-mm CL female collected on 22 August 1984; the largest male, from the same collection, is a 30.5-mm form I.

Orconectes virilis (Hagen)
(Fig. 151)

Cambarus virilis Hagen 1870
Cambarus debilis Bundy 1876
Cambarus wisconsinensis Bundy 1876
Cambarus couesi Streets 1877

Description.—Rostrum excavated; moderately long acumen; no median carina; margins thick, straight, barely converging anteriorly, with terminal spines. Carapace flattened dorsoventrally, with cervical spines; suborbital margin bluntly angular. Areola narrow, constricted anteriorly, narrowest part about 6–7 percent of length. Chelae large, heavily punctate; palm with two rows of tubercles on dorsomesial margin. Form I gonopod terminates in two long, caudodistally directed elements: a sclerotized central projection and a shorter unsclerotized mesial process. Dorsally light brown to dark green-brown; fingers of chelae without bright red tips and subdistal black bands.

O. virilis occasionally occurs as a blue color morph in Illinois and elsewhere. Sugar Creek, a tributary of the Sangamon River in McLean County, contains a large number of blue *O. virilis*. The upper reaches of Sugar Creek are highly modified and receive a large amount of pollution from Bloomington-Normal, and the large number of blue crayfish may somehow be related to the degradation of the stream. Anderson (1975) described a 41-mm CL female *O. virilis* from the Kishwaukee River at De Kalb, Illinois, that was "chalky white" overall except

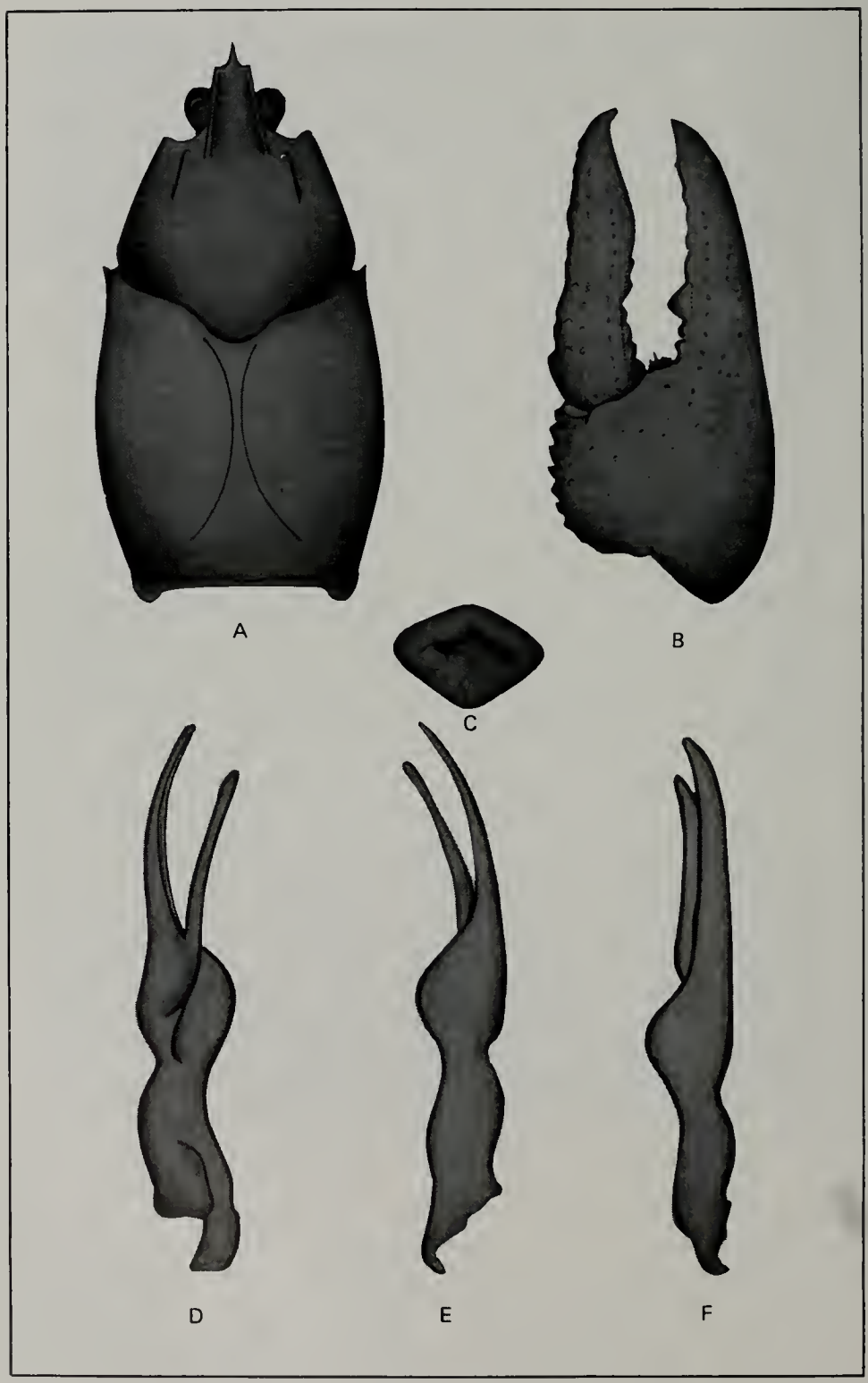

Fig. 151.—*Orconectes virilis*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 152.—Total distribution of *Orconectes virilis*. The northern limits of the range are unknown.

for darkly pigmented eyes.

The closest relatives of *O. virilis* are *O. causeyi*, which may be conspecific with *O. virilis* (Hobbs 1974b), and *O. nais*. *O. nais* is very similar to *O. virilis* morphologically but is distinct serologically (Pryor & Leone 1952). An area of intergradation between *O. virilis* and *O. nais* may be present in southwestern Iowa (Phillips 1980).

Distribution and Habitat.—*O. virilis* ranges from New England across southern Canada to the Continental Divide in Montana, southeastern Wyoming, and northeastern Colorado, and south to the Ohio River in Ohio, Indiana, and Illinois, the Missouri River in Missouri, and the Platte River in Nebraska (Fig. 152). The northern limits of its range are unknown (Crocker & Barr 1968), but it occurs farther north than does any other North American crayfish.

O. virilis is the most common crayfish in Illinois and, in some streams, exists in huge populations. It occurs naturally throughout the state except in the Saline River system and in streams draining the Shawnee Hills and the eastern Coastal Plain (Fig. 153). It is common to abundant over much of its Illinois range, but less so in the lower-gradient streams characteristic of much of western and southeastern Illinois. In the past, its abundance led to its large-scale consumption by humans (e.g., Creaser 1932), but this no longer appears to be true, at least in Illinois.

Although absent from the Shawnee Hills, *O. virilis* occupies Clear Creek and Mill Creek, both of which drain the Ozark Plateaus Province in Union and Alexander counties. Habitats in the "Illinois Ozarks" appear similar to those in the Shawnee Hills, but several animals occupy the Ozark Uplift and not the Shawnee Hills, e.g., the snow scorpionfly, *Boreus brumalis;* the

Fig. 153.—Distribution of *Orconectes virilis* in Illinois; black dots = 1972–1982 collections.

Fig. 154.—*Orconectes virilis* lives in a variety of habitats but usually is found in rocky areas or accumulations of logs and debris such as this logjam on the Little Wabash River, 2.5 mi W Watson, Effingham County, Illinois (8 October 1984).

slender madtom, *Noturus exilis;* the fantail darter, *Etheostoma flabellare;* and the green water snake, *Nerodia cyclopion* (Webb, Penny, & Marlin 1975; Smith 1961, 1979).

A recent record for *O. virilis* in an impoundment in the Saline River system (Berkel Lake, Saline County, 9 October 1977) is almost certainly the result of a recent introduction. The record is based on two individuals, one of which is small (16.3 mm CL), suggesting that the species is reproducing in the lake.

In Illinois, *O. virilis* occupies rocky streams (Fig. 154) and lake margins. It usually occurs in moderate current but is less common in swift riffles (where, throughout much of Illinois, it is replaced by *O. propinquus)* and in sluggish pools (where *O. immunis* predominates). The largest populations are found in areas where large flat stones provide a preponderance of hiding places. In lakes, *O. virilis* may occur as deep as 9 m (Crocker & Barr 1968).

Cralley (1932) found numerous burrows belonging to *O. virilis* opening just above the water line along the banks of the Kaskaskia River in Champaign County. Brown (1955) found a few burrows of *O. virilis* in Illinois and described them as being simple, with an enlarged pocket at the lower end and only one surface opening. Phillips (1980) found a burrow in Iowa about 30 cm deep with two terminal chambers and a chimney about 5 cm tall. Hazlett et al. (1974) found *O. virilis* burrowing extensively along a stream and pond in Michigan; burrows frequently had two entrances, often one above the water level. Rarely during the present survey was *O. virilis* found in burrows, and it appears to be much more common for *O. virilis* to hide under rocks, even in winter, than to burrow; however, as discussed below, ovigerous females may habitually burrow.

Life History.—The wide-ranging and often abundant *O. virilis* has been the subject of numerous studies. In both

Table 17.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Orconectes virilis*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	5	1	20	0	0	0	0
February	4	0	0	0	0	0	0
March	5	3	60	0	0	0	0
April	13	1	8	3	23	0	0
May	27	5	19	2	7	0	0
June	90	6	7	0	0	0	0
July	99	9	9	0	0	0	0
August	101	11	11	0	0	0	0
September	86	28	33	0	0	0	0
October	52	22	42	0	0	0	0
November	21	10	48	0	0	0	0

sexes maturity is usually reached in summer and fall of the third year (Momot 1967), although some females bear eggs during their second year (Momot 1978), and some males become form I in their second year (Weagle & Ozburn 1972). Photoperiod and temperature control ovarian maturation, and increased water temperature triggers egg laying in the spring (Aiken 1969). Form I males may be present during any month but usually peak in abundance in fall. Egg laying occurs from mid-March through July. Threinen (1958a, 1958b) believed that most adult males die after mating, and most adult females die after producing young. Momot (1967) found the maximum longevity to be 3+ years. *O. virilis* feeds on algae and "aufwuchs" in marl lakes (Momot 1967) and probably on a variety of plants and animals, both dead and alive, elsewhere (Caldwell & Bovbjerg 1969).

In Michigan, males at 1 year of age average 31.2 mm CL, at 2 years average 36.5 mm, and at 3 years average 40.8 mm; females average 29.5 mm at 1 year and 36.4 mm at 2 years (Momot 1967).

In Illinois, form I males have been found in all months except February and December (Rietz 1912; Cralley 1932; Brown 1955; Table 17). In the present study, they predominated in March and September–November (no collections were made in December). Females carrying eggs have been found in March, April, and May, and females with young attached have been found in May and June (Rietz 1912; Brown 1955; Table 17).

Among the 1,182 female *O. virilis* collected in the present survey, only 5 had eggs, and none had young attached. This extremely small number of ovigerous females suggests that they sequester themselves, probably in burrows, when carrying offspring. Although no direct evidence was gathered during the present survey, Cralley (1932) found a female with eggs attached in a burrow in Champaign County, and Hazlett, et al. (1974) noted that, along a stream in southeastern Michigan, ovigerous females tended to stay in burrows.

Egg counts on the five ovigerous females (35.5–49.7 mm CL) collected during the present survey ranged from 385 to 490 (mean, 449), with the largest female carrying the most and the smallest the fewest eggs. The other three females, all 40.0 mm CL, carried 452, 452, and 466 eggs. Weagle & Ozburn (1972) found a mean number of 214 eggs per female (N = 16; 26–36 mm CL) in northwestern Ontario, and egg count averages ranged from 98.9 (N = 22 females, size range not given) to 150.3 (N = 46 females) on females collected

in several Ontario lakes (Momot 1978). Momot & Gowing (1977) found much lower egg counts among high-density populations of *O. virilis* in Michigan lakes. The number of attached eggs on 402 females (22–35 mm CL) averaged only 91.9. These females were smaller than those found in Illinois. Also, fecundity in these lakes was thought to be related to density- dependent processes, i.e., as the density increased the number of eggs carried by females decreased (Momot & Gowing 1977).

Elsewhere, form I males have been found in April and June–October in New England (Crocker 1979), May and August in New York (Crocker 1957), June–August in Ontario (Crocker & Barr 1968), and July–April in Iowa (Caldwell & Bovbjerg 1969). Form I males may be as small as 25 mm CL (Berrill 1978; Weagle & Ozburn 1972).

Females carrying eggs have been found in April and May in Iowa (Caldwell & Bovbjerg 1969; Phillips 1980), April and May in Michigan (Pearse 1910; Momot & Gowing 1977) and New Hampshire (Crocker (1979), May in Rhode Island (Crocker 1979), and May–July in Ontario (Crocker & Barr 1968). Females with young attached have been collected in May in Iowa (Phillips 1980) and in June in Maine (Crocker 1979).

Some Illinois specimens appear to be among the largest recorded, although Creaser (1932) noted that in Wisconsin the species "frequently attains a size of over eight inches" (about 100 mm CL). The largest Illinois specimens are from reservoirs: a 59.5-mm CL female from Dawson Lake, McLean County, collected on 25 September 1972, and a 59.2-mm CL form I male from Baldwin Lake, Randolph County collected on 2 November 1972. *O. virilis* is an agressive crayfish and, with its large size giving it an advantage, actively excludes the often syntopic *O. immunis* from desirable hiding places (Bovbjerg 1970). Intraspecific dominance was examined by Bovbjerg (1953). The sex ratio among specimens collected during the present survey was 1,243 males:1,182 females.

Genus Fallicambarus Hobbs

Fallicambarus Hobbs 1969

Gonopod with two large terminal elements curved at about 90° angle to shaft; central projection large and bladelike. Ischium of third pereiopod of male with hook. Opposable margin of dactyl of chela with deep concavity.

Only *F. fodiens* of the 14 recognized species of *Fallicambarus* (Hobbs 1981) occurs in Illinois. *F. fodiens* is assigned to the subgenus *Creaserinus* and is most closely related to *F. hedgepethi* (see comment below) and *F. uhleri* (Hobbs 1973).

Fallicambarus fodiens (Cottle) (Fig. 155)

Astacus fodiens Cottle 1863
Cambarus argillicola Faxon 1884

Description.—Rostrum broad, excavated, with short acumen, lacking marginal spines and tubercles, lacking median carina. Carapace compressed, lacking cervical spines; suborbital margin smooth (not angular). Areola obliterated. Chela large, punctate; palm with one to three rows of tubercles on mesial margin; dactyl with deep concavity on basal half of opposable margin. Form I gonopod terminates in two elements, both curved at an angle of about 90° to the principal axis of the gonopod: a distally rounded sclerotized central projection and a short proximally thick mesial process with a peglike tip. Dorsal color variable, usually olive brown with dark brown blotches, but often a uniform light brown to rust red.

Distribution and Habitat.—*F. fodiens* is the most wide-ranging species in its genus, extending, in the Great Lakes (except Lake Superior) and Mississippi River drainages, from southern Ontario to western Kentucky (Fig. 156). South of Kentucky it is replaced by the closely related, and probably conspecific (Burr & Hobbs 1984; H. H. Hobbs

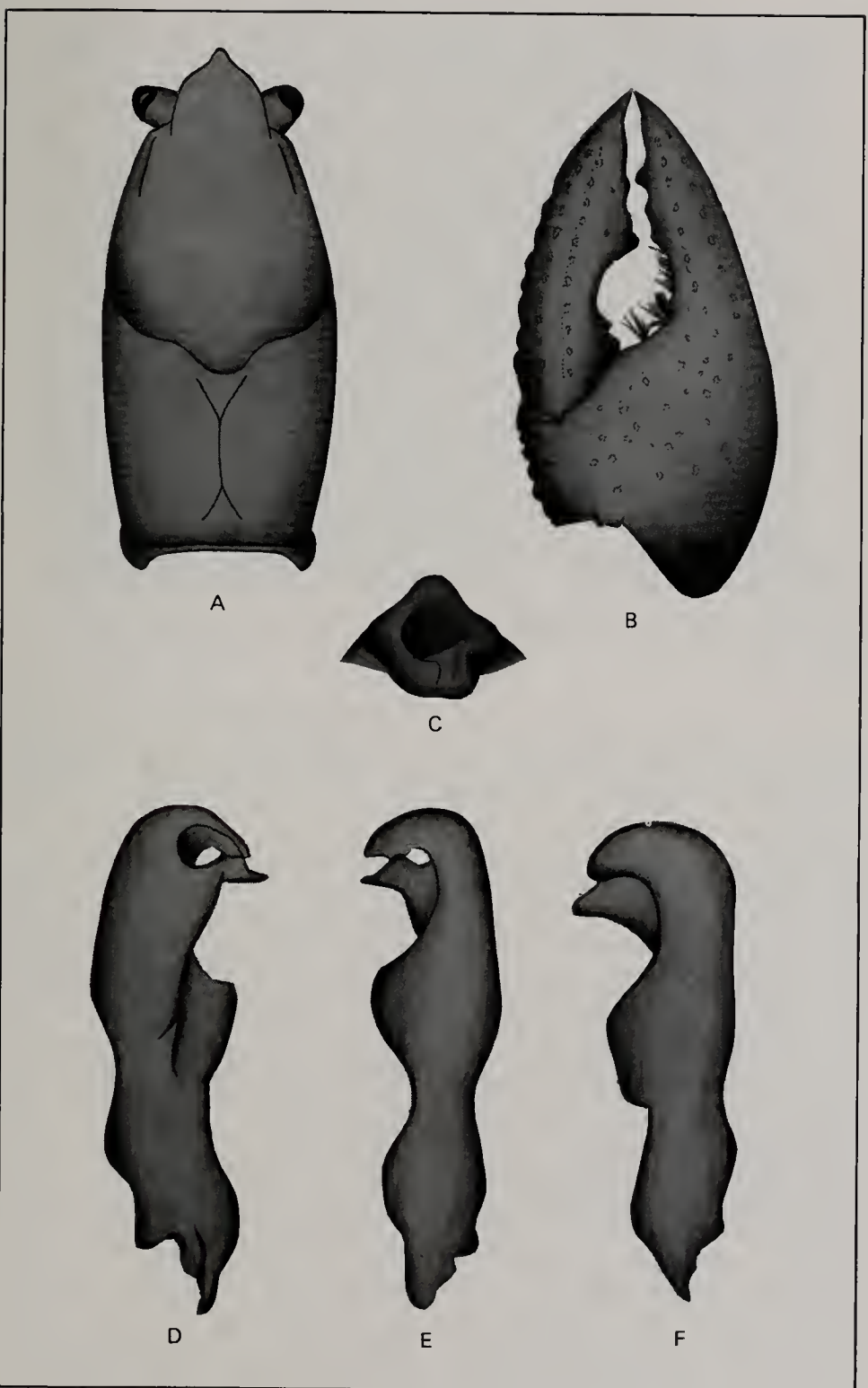

Fig. 155.—*Fallicambarus fodiens*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 156.—Total distribution of *Fallicambarus fodiens*. The southern limit of its range is unknown.

Fig. 157.—Distribution of *Fallicambarus fodiens* in Illinois. Large circles = 1890–1901 collections; small circles = collections made in the 1950's; black dots = 1972–1982 collections.

personal communication), *F. hedgepethi*, which ranges to the Gulf Coast and into Gulf drainages from Georgia to Texas.

In Illinois it is known from the Ohio (including the Wabash), Big Muddy, Sangamon, Illinois, and Lake Michigan drainages (Fig. 157). It appears to be absent from western and extreme northern Illinois and is rare in central Illinois. Although difficult to collect because of its burrowing habits, present records suggest that it remains common in southern Illinois in the Ohio, Big Muddy, Saline, and Little Wabash systems.

During the present survey, *F. fodiens* was collected in central Illinois only on the Sangamon River floodplain at Allerton Park in Piatt County; however, historical records suggest that the species was formerly more common in central and northern Illinois. The northernmost records shown in Fig. 157 are based on a collection at the Illinois Natural History Survey labelled "Ottawa, LaSalle Co., Ill., Sept. 1901," on Bovbjerg's (1952) study of *F. fodiens* and *O. propinquus* in the Lake Michigan drainage of southern Cook County, and Bovbjerg's (1952) mention of the presence of *F. fodiens* in Dead River at Zion, Lake County, also a tributary of Lake Michigan. Brown (1955) found *F. fodiens* in a woodland pond (Sangamon River system) 2.5 km SW Langleyville, Christian County.

In Illinois, *F. fodiens* lives on wooded floodplains (Fig. 158) or where wooded floodplains formerly occurred. It lives in deep burrows and is in surface waters (usually floodplain ponds) only during floods; 27 of 31 collections of *F. fodiens* made in Illinois since 1972 were made from February through May, the period of late winter-spring flooding, although specimens also have been caught above

Fig. 158.—Lower Simmons Creek, 5 mi N Golconda, Pope County, Illinois (26 October 1983). *Fallicambarus fodiens* is common in burrows along the stream banks and, during floods, in the stream.

ground in June, July, August, and September. As floodwaters recede and floodplain ponds dry, *F. fodiens* burrows underground. In southern Illinois, chimney-topped burrows on wooded floodplains usually are those of *F. fodiens*. Stands of river birch (*Betula nigra*) are especially good indicators of the likely presence of *F. fodiens*. In Ontario, *F. fodiens* inhabits marshes, drainage ditches, and ponds (Crocker & Barr 1968).

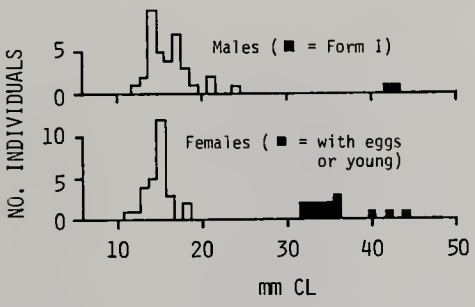

Fig. 159.—Size-frequency distribution of *Fallicambarus fodiens* collected in April in southern Illinois.

Table 18.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Fallicambarus fodiens*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
February	4	0	0	1	25	1	25
March	4	0	0	2	50	1	25
April	15	2	13	0	0	4	27
May	4	0	0	0	0	0	0
June	1	0	0	0	0	0	0
July	1	0	0	0	0	0	0
August	1	0	0	0	0	0	0
December	1	0	0	0	0	0	0

Burrows constructed by *F. fodiens* typically have one to three entrances, often capped by chimneys, leading to an oval resting cavity (Faxon 1885) and leading down from the cavity 30–60 cm is a narrow escape tunnel (Crocker & Barr 1968). Soils having a high clay content are probably necessary for the deep burrows constructed by *F. fodiens* (Crocker & Barr 1968).

Life History.—In a study in southern Cook County, Illinois, Bovbjerg (1952) found juveniles and gravid females in woodland ponds as early as March. By June the adults had disappeared, presumably into burrows, and only young remained in the ponds. By 2 weeks prior to the drying of the pond, all crayfish had disappeared from the pond, either by burrowing or emigrating. Individuals were found (one at a depth of 1.2 m) throughout the summer by digging in the dry pond bed down to the water table. The refilling of the pond in the fall was followed by a reinvasion of *F. fodiens*, which was active in the pond in November under a 5-cm ice cover.

F. fodiens can survive out of water (at 20.5°C and 66 percent relative humidity) for about 12 hours (Bovbjerg 1952), and overland migrations of *F. fodiens* on warm (>5°C) humid nights in March–May were documented by Cummins (1921). *F. fodiens* is omnivorous, and in northern Illinois specimens, stomach contents included plant fragments (especially grass seeds), insect fragments, crayfish appendages, an isopod, and a salamander larva (Bovbjerg 1952).

Sexually mature (form I) males occur in March and April in Michigan (Cummins 1921) and in April (Table 18), August, and October (Brown 1955) in Illinois. The two form I males collected during the present survey had carapace lengths of 42 and 43 mm.

In Michigan, females have been found with eggs in March and April and with young in April and May (Pearse 1910; Cummins 1921; Creaser 1931), in Indiana with eggs and young in April (Hay 1896; Williamson 1907), in Ontario with eggs in March and April and young in May (Crocker & Barr 1968), and in Illinois with eggs in February and March and young in February, March, and April (Table 18). Brown (1955) dug a female with attached young from a burrow in southern Illinois in October.

In the present survey, three females with eggs and 24 females with attached young were collected. The females with eggs were 22, 28, and 35 mm CL, with 48, 68, and 162 eggs, respectively. Eggs on the two smaller females, one collected each in February and March, averaged 2.2 mm in diameter; those on the largest female, collected in March, averaged 2.5 mm. Seven females collected in February and March (30–44 mm CL) had 96–201 (mean, 132.1) young attached.

The size-frequency distribution of southern Illinois, April-collected *F. fodiens* suggests that the species reaches sexual maturity and dies in its second year. Only males over 40 mm CL (second year) among the individuals collected were form I, and all females over 30 mm CL (second year) were carrying young. All smaller males and females were immature (Fig. 159). The sex ratio among the combined April samples was 44 males: 42 females.

Genus **Cambarus** Erichson

Cambarus Erichson 1846
Bartonius Ortmann 1905

Gonopod with two large terminal elements curved at about 90° angle to shaft; central projection large and bladelike. Ischium of third pereiopod of male with hook. Opposable margin of dactyl of chela without deep concavity.

Cambarus contains about 77 species (Hobbs 1981), of which four occur in Illinois. Two of the Illinois species (*tenebrosus* and *rusticiformis*) belong to the subgenus *Erebicambarus*, one (*diogenes*) to *Lacunicambarus*, and one (*robustus*) to *Puncticambarus*. The wide-ranging *C. diogenes* appears to be a complex of species (Hobbs 1974b),

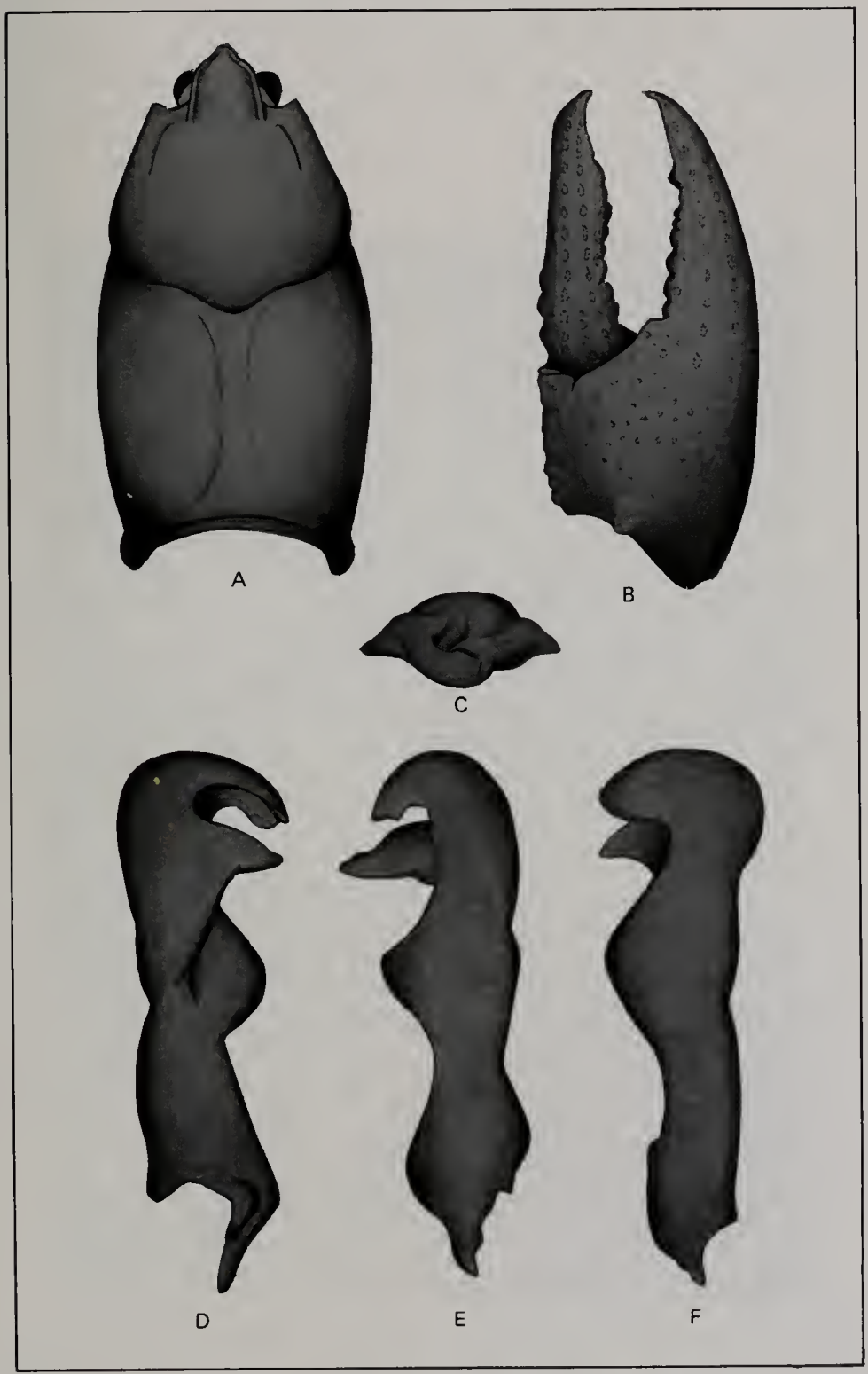

Fig. 160.—*Cambarus tenebrosus.* A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

more than one of which may occur in Illinois, as discussed in the species account below.

Cambarus tenebrosus Hay
(Fig. 160)

Cambarus bartoni tenebrosus Hay 1902
Cambarus bartoni laevis Faxon 1914

Description.—Rostrum broad, shallowly excavated, lacking median carina; margins slightly converging anteriorly, lacking terminal tubercles or spines; acumen short. Carapace dorsoventrally flattened, cervical spines absent (northern population) or present (southern population); suborbital margin gently angular. Areola moderately wide, narrowest part about 13–14 percent of length, with at least four punctations across. Chela large, heavily punctate; palm with one or two rows of tubercles on mesial surface. Form I gonopod terminates in two elements, both curved at an angle of more than 90° to the principal axis of the gonopod: a distally rounded sclerotized central projection, and a large tapering to broadly rounded mesial process. Dorsally rust red overall, with abdomen slightly browner than carapace.

In a discussion of the distribution and phylogeny of species of *Cambarus*, Hobbs (1969) depicted the range of *C.* (*Erebicambarus*) *laevis* as occurring mostly north of the Ohio River and that of the consubgeneric *C. tenebrosus* as being south of the Ohio River. Hobbs (1974b) separated the two species on the relative width of the areola ("at least 4 punctations across narrowest part" in *C. tenebrosus;* "no more than 3 punctations across narrowest part" in *C. laevis*) and the shape of the mesial process of the gonopod ("broadly rounded distally" in *C. tenebrosus;* "strongly tapered, often subacute" in *C. laevis*).

Populations of the subgenus *Erebicambarus* occurring in southern Illinois have been referred to as *C. bartoni brevis* (Rietz 1912), *C. bartoni laevis* (Brown 1955), *C. laevis* (Hobbs 1968,

Fig. 161.—Total distribution of *Cambarus tenebrosus.*

Fig. 162.—Distribution of *Cambarus tenebrosus* in Illinois; black dots = 1972–1982 collections.

1969, 1972a; Page 1974b; Peck & Lewis 1977), *C. ornatus* (Peck & Lewis 1977), and *C. tenebrosus* (Peck & Lewis 1977). It now appears that the correct name for the southern Illinois populations is *C. tenebrosus*. Populations extend across the Shawnee Hills of southern Illinois, into the Cumberland River drainage of western Kentucky, and into the general range of *C. tenebrosus* with no noticeable morphological discontinuities.

In Vermilion County in east-central

Fig. 163.—Spring emptying into Big Creek in Hardin County, Illinois (8 October 1984). This and other springs in the Shawnee Hills provide the best habitat in Illinois for *Cambarus tenebrosus*.

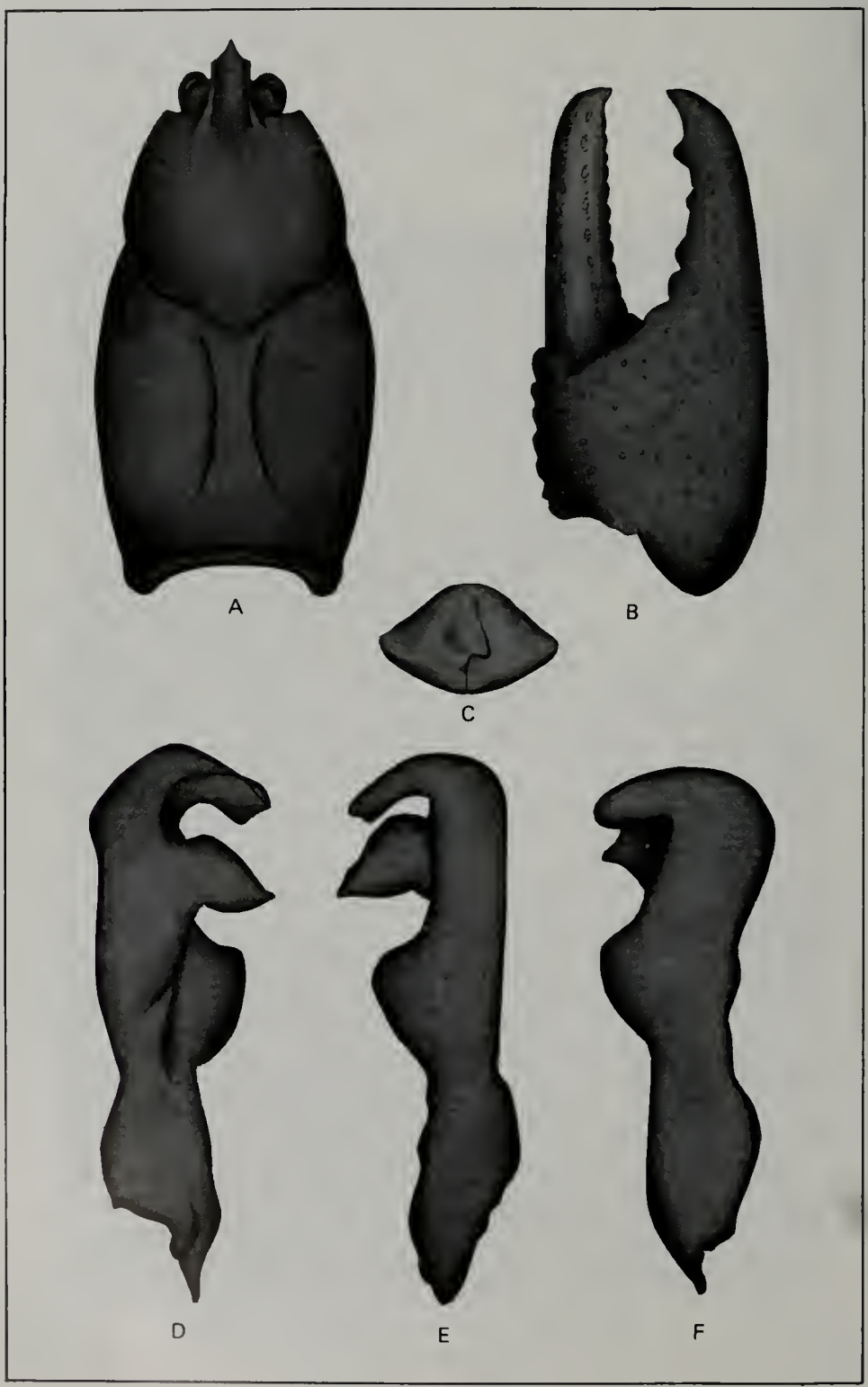

Fig. 164.—*Cambarus rusticiformis*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Illinois is a population of *Erebicambarus* discovered in 1977. It differs from *C. tenebrosus* in southern Illinois by having a narrower areola and by lacking cervical spines (although tubercles often are present). No form I males have been found. If *C. laevis* is a valid species, the Vermilion County population is morphologically and geographically (*fide* Hobbs 1969) referable to that taxon. However, the absence of discontinuities in the geographic variation in morphology among populations assignable to the *C. tenebrosus-C. laevis* complex suggests a lack of reproductive isolation among populations and that only one species is recognizable. Individuals in the northern part of the range of the species have narrower areolae, lack cervical spines, and apparently have more tapered mesial processes on the gonopods. H. H. Hobbs, Jr. (personal communication 1983) suggests that "when adequately studied, *laevis* will prove to be a synonym of *tenebrosus*." Pending such a study, all Illinois populations are referred to as *C. tenebrosus*.

Distribution and Habitat.—*C. tenebrosus* occurs in central and southeastern Indiana, the Vermilion River system in east-central Illinois, the Shawnee Hills of Illinois, western and central Kentucky, central Tennessee, and northern Alabama (Fig. 161). It appears to be absent in southwestern Indiana.

In Illinois and elsewhere, *C. tenebrosus* occupies rocky springs and spring-fed headwaters and creeks. It hides under stones, sometimes forming shallow excavations in the stream bed. Brown (1955) cited "small piles of mud at the edge of rocks" as an indicator of the presence of the species. Its affinity for spring-fed headwaters often results in its occupancy of caves.

In southern Illinois, *C. tenebrosus* is restricted to the Ohio River drainage of Hardin, Pope, Johnson, and Union counties (Fig. 162). It is most common in Big Creek, a moderate-sized stream in Hardin County fed by numerous

Fig. 165.—Total distribution of *Cambarus rusticiformis*.

Fig. 166.—Distribution of *Cambarus rusticiformis* in Illinois; black dot = 1975 collection.

springs (Fig. 163). Elsewhere in Illinois it has been found only in Willow Creek (Vermilion River system) in Vermilion County, Illinois (Fig. 162), where it presumably is distributionally contiguous with the Indiana population.

The Illinois and total ranges of *C. tenebrosus* are quite similar to those of the zigzag salamander (*Plethodon dorsalis*) although the salamander has dispersed into Clear Creek, a tributary of the Mississippi River, in Alexander, Union, and Jackson counties (Smith 1961).

C. tenebrosus, first recorded in Illinois (as *C. bartoni brevis*) by Rietz (1912), probably has essentially the same distribution now as it had prior to the arrival of man. However, the water table of southern Illinois has been lowered within historic times, and some springs may have disappeared or at least are smaller than before, reducing the habitat available for *C. tenebrosus*. Such reductions in habitat have caused some spring-inhabiting fishes (*Phoxinus erythrogaster, Rhinichthys atratulus*) to disappear from southern Illinois (Smith 1979).

Life History.—Prins (1968) studied *C. tenebrosus* in a stream system in Kentucky and found it to be most common in constant-temperature headwaters. Most adults were found in burrows or under large rocks, but young and subadults were found in open-stream environments. The diet consisted primarily of vascular plants, especially fallen leaves from the riparian habitat, and filamentous algae. Other food items included detritus, aquatic insects, and crustaceans. Hatching occurs in July and August after eggs have been carried by the female for at least 25–30 days. Growth continues throughout the year, including winter, and sexual maturity is reached at about 20–22 months and 40 mm CL. Mating occurs in winter and spring. Mature females oviposit in June and July at about 22–23 months and probably again at 34–35 months. Egg counts on seven females (44–52 mm CL) ranged from 186 to 266. Maximum CL was found to be about 65 mm and maximum longevity about 36–38 months. The sex ratio among 3,235 specimens was 1 male:1.03 females.

No form I males or females carrying eggs or young were present among the 40 collections of Illinois *C. tenebrosus* made during the present survey (all months except September). Brown (1955) reported collecting form I males in August and October and a female with attached young in October. All of Brown's collections were made in Hardin and Pope counties, Illinois. A 46.6-mm CL female from Big Creek is the largest Illinois specimen.

Cambarus rusticiformis Rhoades (Fig. 164)

Cambarus rusticiformis Rhoades 1944

Description.—Rostrum narrows anteriorly; margins elevated, concave, and tipped with large knobs; acumen moderate, elevated anteriorly; median carina lacking. Carapace dorsoventrally flattened, with large cervical spine, small suborbital angle. Areola moderately wide, narrowest part 16–18 percent of length. Chela large, heavily punctate; palm with single row of flattened tubercles along mesial surface. Form I gonopod terminates in two elements, both directed caudally at an angle greater than 90° to the principal axis of the gonopod: a distally rounded, sclerotized central projection and a large distally tapering mesial process.

Distribution and Habitat.—*C. rusticiformis* occupies the Cumberland River drainage and the Barren River system (Green River drainage) of Kentucky and Tennessee (Bouchard 1976) and, judging from one Illinois collection, the lower Ohio River (Fig. 165). Two juvenile males (11.7 and 14.6 mm CL) were collected in a rocky backwater of the Ohio River near Lock and Dam 53, 4 km NE Olmsted, Pulaski County, Illinois, (Fig. 166) on 16 July 1975. Several later attempts to find *C. rusticiformis* at the same and other sites on the lower Ohio River were unsuccessful.

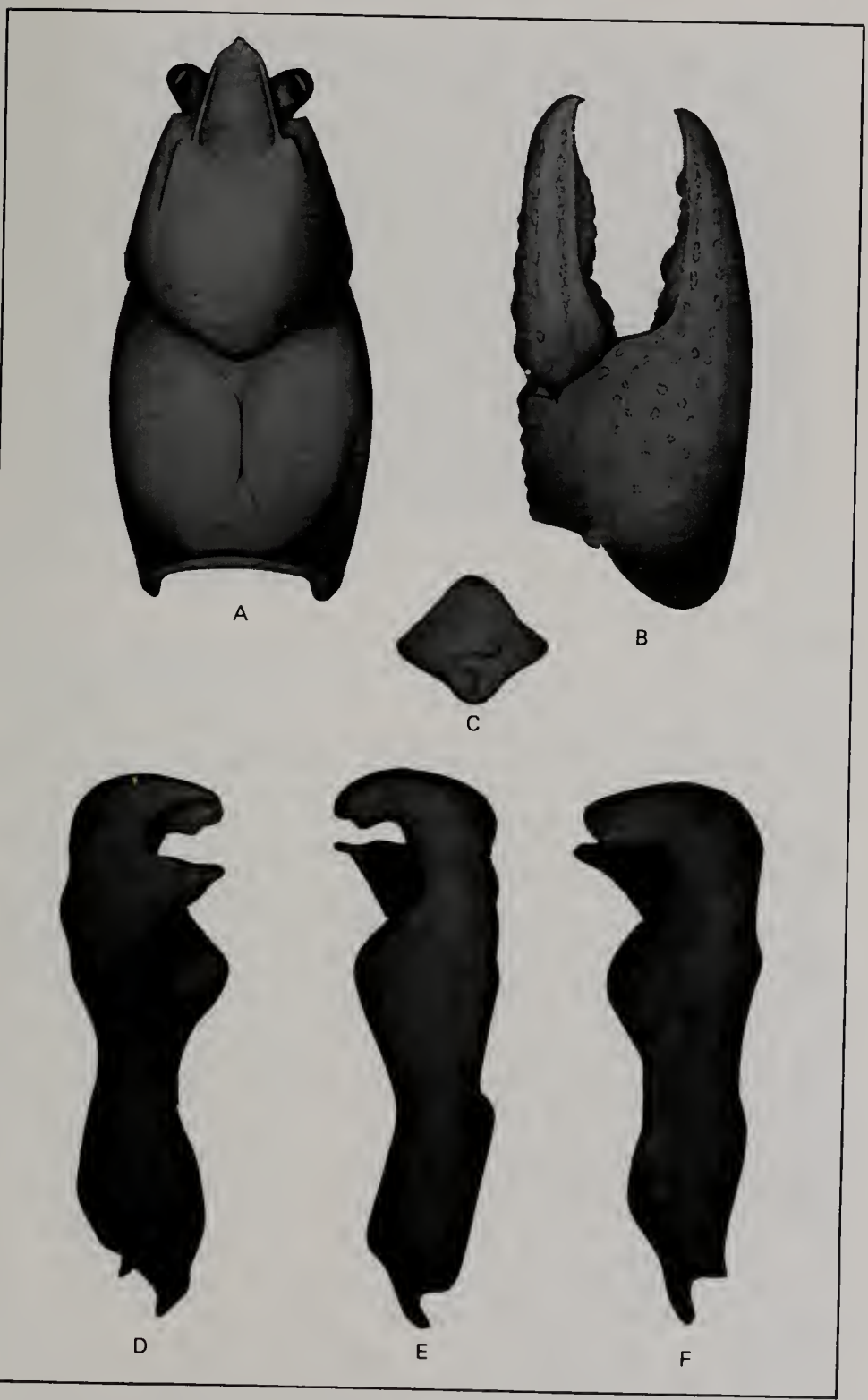

Fig. 167.—*Cambarus diogenes*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

Fig. 168.—Total distribution of *Cambarus diogenes*.

The Ohio River site is about 67 river km (42 miles) below the mouth of the Cumberland River. The two specimens may represent one of the westernmost natural populations of the species, they may have been waifs captured during a downstream dispersal, or they may have been transplanted as the result of human activities. *C. rusticiformis* has been introduced into the Paint Rock River (Tennessee River drainage), Alabama (Bouchard 1976). Collected in the Ohio River with *C. rusticiformis* were 12 *Orconectes placidus*, a species with a similar overall distribution.

Elsewhere, *C. rusticiformis* lives in rocky runs and adjacent pools and riffles of fast-flowing creeks and small rivers. Other ecological characteristics are unknown.

Cambarus diogenes Girard (Fig. 167)

Astacus fossor Rafinesque 1817. (Name suppressed by International Commission on Zooligical Nomenclature, Opinion 522, 1958.)
Cambarus diogenes Girard 1852
Cambarus nebrascensis Girard 1852
Cambarus obesus Hagen 1870
Cambarus Diogenes var. *Ludoviciana* Faxon 1885

Description.—Rostrum broad, excavated, with short acumen, lacking marginal spines or tubercles, lacking median carina. Carapace compressed, lacking cervical spines; suborbital margin angular. Areola obliterated. Chela large, heavily punctate; palm with two or three rows of tubercles on mesial surface; dactyl with broad shallow concavity on basal half of opposable margin. Form I gonopod terminates in two elements, both directed caudally at an angle slightly more than 90° to the principal axis of the gonopod: a distally rounded, sclerotized central projection and a slender mesial process. Dorsal color varies from uniformly

Fig. 169.—Distribution of *Cambarus diogenes* in Illinois; black dots = 1972–1982 collections.

Fig. 170.—Chimney-topped burrows of *Cambarus diogenes* on the floodplain of a slough, 2 mi N Pleasant Grove, Johnson County, Illinois (9 July 1972).

red brown (with thorax lighter red) to green with red outlining abdominal segments, tips of chelae, and margins of rostrum.

Marlow (1960) examined geographic variation in *C. diogenes* and concluded that only two subspecies could be recognized: *C. d. ludovicianus* in the Lake Ponchartrain drainage and southern Louisiana and *C. d. diogenes* throughout the rest of the range of the species. However, according to Hobbs (1969, 1974b), *C. diogenes* is a complex of forms, and *C. d. ludovicianus* probably is more widespread than Marlow thought. Illinois specimens show tremendous variation in the shape of the carapace and rostrum and in coloration. If several taxa presently are included in "*C. diogenes*," more than one may be found in Illinois. The only other described species in the subgenus *Lacunicambarus* are *C. acanthura*, restricted to the Tennessee and Alabama drainages of Tennessee, Alabama, and Georgia (Hobbs 1981) and *C. miltus* from Baldwin County, Alabama (Fitzpatrick 1978b).

Distribution and Habitat.—*C. diogenes* ranges along the Atlantic Piedmont and Coastal Plain from New Jersey and Pennsylvania south to central Georgia, in Gulf drainages from Georgia to eastern Texas, and north in the Mississippi and Great Lakes basins to western New York and Pennsylvania, Michigan, Wisconsin, Minnesota, and North Dakota. The westernmost populations occur in the Platte River drainage of Colorado and Wyoming (Fig. 168).

C. diogenes occurs statewide in Illinois (Fig. 169) and is generally common. It is abundant in the Shawnee Hills and on the Coastal Plain of southern Illinois, less common in northern and western Illinois. Its burrowing habits preclude easy collecting, and consequently, the number of collections (Fig. 169) does not adequately reflect its abundance in Illinois.

C. diogenes first was recorded from Illinois by Hagen (1870), who described the specimens collected at Lawn Ridge (Marshall County), Belleville, and Evanston as a new species, *Cambarus obesus*. Forbes' (1876) only comments on "*C. obesus*" were: "Very common. The largest in the state."

The burrowing behavior of *C. diog-*

Table 19.—Frequency of occurrence of form I males, females carrying eggs (ovigerous), and females carrying young, in Illinois collections of *Cambarus diogenes*.

Month	Number of Collections	Number and Percent of Collections with					
		Form I Males		Ovigerous Females		Females with Young	
January	7	0	0	1	14	0	0
February	7	4	57	0	0	0	0
March	14	8	57	1	7	0	0
April	22	4	18	3	14	0	0
May	34	0	0	3	9	1	3
June	46	1	2	0	0	2	4
July	60	1	2	0	0	0	0
August	45	0	0	0	0	0	0
September	34	0	0	0	0	0	0
October	55	3	5	0	0	0	0
November	15	4	27	0	0	0	0
December	3	0	0	0	0	0	0

enes is described by Grow (1981). In contrast to other Illinois burrowing crayfishes, *P. gracilis*, *P. viaeviridis*, and *F. fodiens*, which burrow in prairie marshes, swamps, and on wooded floodplains, respectively, *C. diogenes* lives primarily along streams. Populations also are found away from streams in lowland areas (Fig. 170) having clay soil, especially on the Coastal Plain. Such colonies often are marked by hundreds of chimneys.

Burrows characteristically are relatively shallow (10–30 cm) in Illinois but vary in depth in relation to the size of the crayfish and may extend down a meter. Hobbs (1981:226–227) observed burrow openings in banks 5 m above water level of the Apalachicola River in Georgia. Usually a chimney-topped hole in a stream bank leads to an underwater chamber and a second, nearly horizontal, tunnel leading into the stream. Large individuals may have more elaborate dwellings with several tunnels and several openings with or without chimneys. Burrows may be found along any stream in Illinois but are most common in rocky areas.

Retrieving a *C. diogenes* from a burrow seldom requires excavating the entire burrow but does require patience. If the water at the entrance of the burrow is disturbed, the curious crayfish eventually will investigate the disturbance and can be grabbed as it surfaces. The wait is usually only a few minutes.

Life History.—*C. diogenes* leaves its burrows in late winter–early spring and in fall to mate in open water (Hargitt 1890; Hay 1896; Williams & Leonard 1952). Presumably they then return to their burrows, although ovigerous females and females with young are found both in burrows and in open water (Williamson 1907). When young leave the mother, they seek cover in rocky parts of streams or marginal vegetation of standing water bodies until large enough to burrow. When they reach about 20 mm total length, they have begun burrowing.

Nothing of the food habits, growth, or longevity of *C. diogenes* is known, presumably because of the difficulty in obtaining adequate series of specimens. Presumably it leaves the burrow at night to forage on vegetation (Crocker & Barr 1968). The largest specimens in the Illinois Natural History Survey collection are a 61.3-mm CL ovigerous female and a 61.0-mm form I male in a jar labelled "Morris & Marseilles, Grundy & LaSalle counties, Illinois" (no date). The right chela of the male measures 57.5 mm in length; that of the female measures 46.9 mm.

In the present survey, form I males

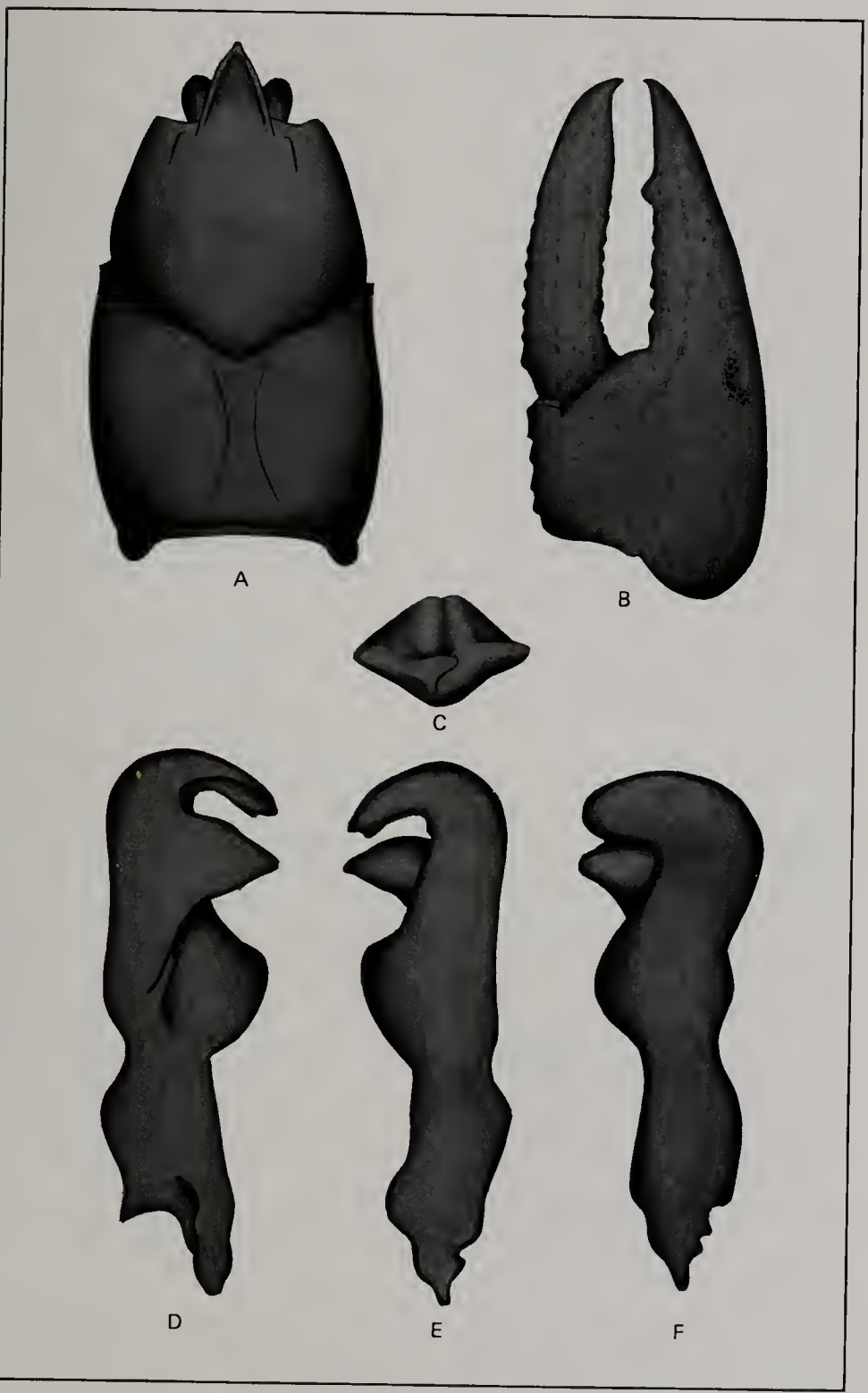

Fig. 171.—*Cambarus robustus*. A, dorsal view of carapace; B, dorsal view of right chela; C, annulus ventralis; D, mesial view of gonopod of form I male; E, lateral view of gonopod of form I male; F, lateral view of gonopod of form II male.

were collected from February through July (except in May), and in October and November (Table 19); Brown (1955) found form I males in Illinois from March through September, except in July. The primary peak of occurrence is in February and March, and a secondary peak occurs in November (Table 19). Elsewhere, matings have been observed in March, April, May (Hargitt 1890; Hay 1896; Evermann & Clark 1920), and October (Williams & Leonard 1952). In Louisiana, form I males were found in March, April, and October (Penn & Marlow 1959) and in Georgia in January, April, and October (Hobbs 1981). Ortmann (1906) recorded form I males in Pennsylvania from March through November. Among the *C. diogenes* examined by Marlow (1960), form I males were present in every month except January, but were most prevalent in April and September. Although the occurrence of form I males suggests that mating in *C. diogenes* may occur in almost any month, activity probably peaks in late winter–early spring (February–April) and in fall (September–November).

Ovigerous females have been found in January (Bundy 1877), April (Hay 1896; Evermann & Clark 1920; Creaser 1932), and May in Indiana (Williamson 1907); in April and May in Pennsylvania (Ortmann 1906) and Iowa (Phillips 1980); in April (Williams & Leonard 1952) and May in Kansas (Harris 1900); from late March to May in Wisconsin (Graenicher 1913); and in September in Georgia (Hobbs 1981). Marlow (1960) examined ovigerous females from March (1 female), April (19), May (17), and October (1). Females carry young in May and June in Pennsylvania (Ortmann 1906) and in Indiana (Williamson 1907; Evermann & Clark 1920), and in June in Michigan (Creaser 1932). In Illinois, females were found to carry eggs from January through May, except

Fig. 172.—Total distribution of *Cambarus robustus*.

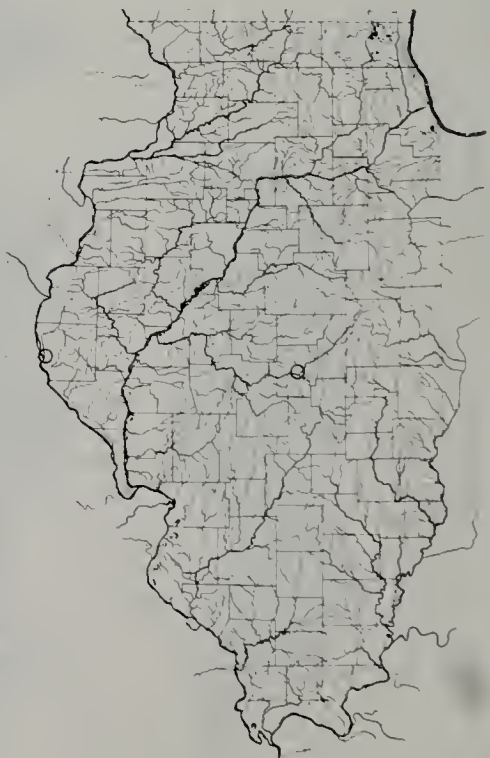

Fig. 173.—Distribution of *Cambarus robustus* in Illinois. The two records (Adams and Macon counties) are from Faxon (1885) and Rietz (1912).

in February, and young in May and June (Table 19).

Because of the difficulty in obtaining adult *C. diogenes*, few females with eggs or young attached were collected in the present survey. Five females (43.7–56.4 mm CL) collected in April and May were carrying 183–518 (mean, 295.2) eggs. The highest number of eggs was on the smallest female. Eggs varied in diameter from 2.1 to 3.0 mm, and unlike other crayfishes examined during the present survey, in *C. diogenes* egg diameter has a significant correlation ($r = 0.97$) with length of the female: egg diameter = $-1.280 + 0.077$ CL.

A 48.5-mm CL female collected in Johnson County on 19 May 1973 had 606 early-instar young attached; a 47.2-mm CL female collected in Christian County on 8 June 1979 had 45 late-instar young attached. Two females collected in Indiana in 1906 were carrying 87 and 215 young (Williamson 1907).

Cambarus robustus Girard
(Fig. 171)

Cambarus robustus Girard 1852

Description.—Rostrum moderately broad, shallowly excavated, lacking median carina; margins converge anteriorly, lack terminal tubercles or spines; acumen moderately large. Carapace dorsoventrally flattened, with large cervical spines; suborbital margin angular. Areola moderately wide, narrowest part about 12–17 percent of length. Chela large, heavily punctate; palm with two rows of tubercles on mesial surface; base of fixed dactyl with deep dorsal and ventral impressions. Form I gonopod terminates in two elements: a distally rounded, sclerotized central projection curved at an angle of more than 90° to the principal axis of the gonopod, and a large gently tapering mesial process curved at about 90° to principal axis. Dorsally green brown.

Distribution and Habitat.—*C. robustus* ranges from Connecticut and southern Ontario south to northwestern North Carolina and eastern Kentucky and west to Michigan and central Indiana (Fig. 172). It occupies rocky areas of fast-flowing streams, and sometimes is found in rocky lakes and ponds (Crocker & Barr 1968; Berrill 1978).

The only Illinois records (Fig. 173) are from the late nineteenth and early twentieth centuries. Faxon (1885) reported *C. robustus* from Decatur (Macon County, Sangamon River system), and Rietz (1912) reported four specimens from Quincy (Adams County, Mississippi River drainage). Although the Quincy specimens cannot be located, the Decatur specimens are in the U.S. National Museum (USNM 63291) and unquestionably document the former presence of the species in the state. *C. robustus* is rare even as far west as Indiana (Eberly 1955), and the Illinois collections must have represented relict populations left over from a more widespread distribution in a cooler postglacial climate. Many streams today around Quincy are spring-fed, and considerable effort was expended in unsuccessful attempts to locate surviving populations of *C. robustus* in what appear to be suitable habitats. The Sangamon River, flowing through Decatur, was badly polluted in the early part of this century (Jewell 1920), is now impounded by Lake Decatur, and appears unlikely to support a population of *C. robustus*.

Life History.—Crocker (1957) reported form I males in New York collections made from April through October and observed copulation in October and May (the latter in a lamprey trap). Form I males have been collected in Pennsylvania in May and July–November; the smallest was about 63 mm total length (about 32 mm CL) (Ortmann 1906). In southern Ontario, form I males were 25–55 mm CL (Berrill 1978). Ovigerous females have been found in July in New York (Crocker 1957) and Pennsylvania (Ortmann 1906); the Pennsylvania female, 84 mm total length (about 42 mm CL), carried 228 eggs. Females with young attached

have been observed in April and August in New York (Crocker 1957). Young feed on immature insects; adults feed mainly on aquatic plants (Creaser 1934).

CONSERVATION

Unfortunately, it appears that *Macrobrachium ohione* and *Cambarus robustus* already have disappeared from Illinois. *C. robustus* may have disappeared from Illinois naturally rather than because of man-induced changes in the environment. Our earliest records indicate that it was relict in Illinois, presumably having been reduced from a more widespread distribution to small areas near Quincy and Decatur. Elsewhere it inhabits cool to cold streams and apparently was reduced in warm postglacial Illinois (probably during the Xerothermic period) to small populations that subsequently were unable to perpetuate themselves. *M. ohione* probably disappeared because of the extensive modification and degradation of Illinois' large rivers. Especially harmful to *M. ohione* would have been the loss of aquatic vegetation associated with increased siltation, channelization, and chemical pollution.

Unless protective measures are taken, several more species of native decapods are likely to disappear from Illinois. The following four species have restricted ranges in the state and are threatened with extirpation. They should receive as much protection as possible by our adding them to the Illinois List of Endangered and Threatened Species and protecting their habitats.

The distribution of *Orconectes indianensis* has been reduced dramatically in Illinois as a result of severe pollution and other major modifications of the Saline River system. Remaining populations are restricted to the South Fork of the Saline River in Gallatin, Johnson, Pope, Saline, and Williamson counties, Robinette (Eagle) Creek in Gallatin County, and Honey Creek in Hardin County. Elsewhere the species occurs only in a small area of Indiana.

Orconectes kentuckiensis occurs only in Big, Hosick, and Peters creeks in Hardin County, and although the distribution of this species in Illinois probably has changed little historically, its persistence is threatened by modifications of the riparian habitats in Hardin County. Trees have been removed from many miles of stream bank, resulting in less shading of the stream and higher water temperatures. Water has been diverted in ever-increasing amounts from its natural drainage for use in agriculture. The lowered water table is reducing the size of Big Creek. Elsewhere, *O. kentuckiensis* occurs only in a small area of northwestern Kentucky.

Orconectes placidus is common throughout much of Kentucky and Tennessee, but in Illinois it maintains a sizeable population only in Big Creek in Hardin County and is threatened by the same stream modifications threatening *O. kentuckiensis*.

Orconectes lancifer is restricted in Illinois to Horseshoe Lake in Alexander County. Although under the supervision of the Illinois Department of Conservation, the lake has been severely modified in recent decades, and much of it now is surrounded by agricultural fields and grasses. If the unusual biota of Horseshoe Lake is to persist, subsequent modifications of the lake should be allowed only after careful consideration of their environmental impact. Elsewhere *O. lancifer* occurs uncommonly throughout the former Mississippi Embayment.

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