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The Decapod Crustaceans of Iowa[1]

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From March 1977 to September 1978, a survey was conducted to determine the species of decapod crustaceans present in Iowa and their distribution. During this time period, all of Iowa's 99 counties were surveyed. A total of 2390 specimens representing 500 lots were collected from 492 different sites. An additional 1944 specimens were examined from existing collections. Seven species of Cambaridae (*Cambarus diogenes diogenes* Girard, *Orconectes immunis* (Hagen), *Orconectes iowaensis* Fitzpatrick, *Orconectes rusticus* (Girard), *Orconectes virilis* (Hagen), *Procambarus acutus acutus* (Girard), and *Procambarus gracilis* (Bundy)), and a single species of Palaemonidae *(Palaemonetes kadiakensis* (Rathbun)), were identified. *O. virilis* and *C.d. diogenes* occurred statewide while *O. immunis, O. iowaensis, O rusticus, P.a. acutus, P. gracilis,* and *P. kadiakensis* had limited distributions. Data on life history, habitat, and ecology are included.
INDEX DESCRIPTORS: Crustacea, Decapoda, Cambaridae, Palaemonidae, Iowa.

Although decapods are of little economic importance in Iowa, being neither abundant enough to be harvested nor to cause destruction of agricultural crops as in some parts of the United States, they are nevertheless important members in the food chains of most aquatic communities within the state. Hobbs and Hall (1974) suggested the importance of crayfish as environmental indicators in aquatic environments and stressed the need for additional work concerning their distribution and habits. Page (1974) indicated that state lists should be useful to persons involved in the identification of aquatic organisms and the preparation of environmental impact statements. For these reasons, this study was undertaken to provide an extensive and reliable source of information on the decapods of Iowa.

Study of the distribution and habits of the decapod crustaceans in the north central United States began with the field observations of Girard (1852). State surveys by Forbes (1876) for Illinois, Bundy (1882) for Wisconsin, Herrick (1882) for Minnesota, and Hay (1896) for Indiana followed and contributed considerable knowledge to the distribution, life history, and ecology of crayfish in the Midwest. During this time, the first monographic work on North American crayfish was completed by Hagen (1870). In this paper, previous work was thoroughly reviewed, new species were described, taxonomic relationships of the species were discussed, and an assessment of the ranges of the species treated was given. Faxon's *Revision of the Astacidae* (1885a), however, represents the real basis for modern work. He reviewed the work of his predecessors, described new species, gave a detailed account of the distribution of known species, and formulated a system which showed the relationships of the species. He followed this monographic work with a series of papers which added to the list of known species and supplied additional locality data on those previously known. Faxon (1885b) listed *Cambarus diogenes* Girard, *Cambarus blandingii acutus* Girard, *Cambarus gracilis* Bundy, *Cambarus immunis* Hagen, *Cambarus propinquus* Girard, *Cambarus rusticus* Girard, and *Cambarus virilis* Hagen as occurring in Iowa. Later (1898), he gave locality data for 4 previously reported species and added *Cambarus neglectus* Faxon for Iowa. Shortly after the turn of the century, the state survey of Missouri by Steele (1902) and the ecological catalogue by Harris (1903), which included Iowa, were completed. These studies, along with previous works, represent the initial period of interest in the decapod crustaceans for the north central states.

A lapse of interest in the crayfish in the Midwestern United States followed and activity was not renewed until Engle (1926) published on the crayfishes of Nebraska and eastern Colorado, and Turner (1926) published his survey of the crayfishes of Ohio. A number of works followed, including those of Creaser (1931, 1932) on the decapods of Michigan and Wisconsin, and Creaser and Ortenburger (1933) on the decapods of Oklahoma. In Creaser's (1932) paper on the decapods of Wisconsin, he suggested the occurrence of *C. diogenes, C. b. acutus, C. gracilis, C. virilis, C. immunis, C. propinquus,* and *Palaemonetes exilipes* in Iowa.

Hobbs (1942) revised the subfamily Cambarinae and split the genus *Cambarus* into 6 genera (i.e. *Procambarus, Troglocambarus, Paracambarus, Cambarellus, Orconectes,* and *Cambarus*). This revision clarified the status of several groups of North American crayfish and aided in correlating past studies. State surveys by Rhoades (1944a, b) for Kentucky and Ohio, Williams and Leonard (1952) for Kansas, Williams (1954) for the Ozark Plateau and Ouachita Province of southern Missouri and northern Arkansas, Eberly (1955) for Indiana, Threinen (1958b) for Wisconsin, and a survey of the province of Ontario, Canada, by Crocker and Barr (1968) have since been completed.

While studying the Propinquus Group, Fitzpatrick (1967) examined specimens collected in Iowa which he believed were closely related to but different from *Orconectes propinquus*. A new species, *Orconectes iowaensis,* was subsequently described (Fitzpatrick, 1968). Natural history studies of *Orconectes virilis* and *Orconectes immunis* have been conducted by Caldwell and Bovbjerg (1969) in northwestern Iowa. Bovbjerg (1970) also studied the ecological isolation and competitive exclusion of these 2 species.

Hobbs (1972) listed *Cambarus diogenes diogenes, Orconectes immunis, Orconectes iowaensis, Orconectes rusticus* (?), *Orconectes virilis, Procambarus acutus acutus,* and *Procambarus gracilis* as occurring in Iowa. This is the most recent and comprehensive consideration of the Iowa decapods.

Many of the previously cited publications listed species collected in Iowa and suggested distribution patterns for certain species within the state. However, prior to this study no comprehensive survey had yet been completed for the state.

METHODS AND MATERIALS

A survey of the decapod crustaceans found in Iowa was conducted from March 1977 to September 1978. Sites surveyed included aquatic environments located in all 99 counties in the state as well as those portions of the Mississippi, Des Moines, Missouri, and Big Sioux Rivers which form natural boundries. Field collections were made by seining, dip netting, hand collecting, excavation, and trapping. Specimens retained were killed and preserved in a 5% formalin solution as

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described by Edmonds (1976).

Additional collections made by Dr. Richard W. Coleman, Dr. Nixon A. Wilson, Dennis Rowray, and fisheries biologists of the Iowa Conservation Commission were examined and included in my survey. Collections located at Coe College, Iowa State University, Luther College, and the University of Northern Iowa were also examined. Information was obtained on Iowa decapods stored at the National Museum of Natural History, the Museum of Comparative Zoology, and on specimens reported in the literature. These collections and information are summarized in Table 1.

Table 1. *Summary of specimens of Iowa decapod crustaceans examined or noted.*

Collection/Collector	Number of Specimens	Number of Lots	Number of Species
Phillips	2390	500	8
Coe College	1508	201	8
Iowa State University	133	42	7
Luther College	54	15	4
University of Northern Iowa	58	16	6
National Museum of Natural History	111	22	6
Museum of Comparative Zoology	11	4	3
Iowa Conservation Commission	42	7	4
Dr. R. W. Coleman	12	2	2
Dr. N. A. Wilson	5	1	1
D. Rowray	10	2	1
Literature records	Unknown	32	7

Specimens examined during this survey were identified using Hobbs (1972) and Pennak (1978). Verification of identification of representative specimens was made by Drs. Horton H. Hobbs, Jr., Lawrence M. Page, and Guenter Schuster. Representative identified specimens are deposited as follows: specimens from southwestern and eastern Iowa were sent to the State Biological Survey of Kansas and the Illinois Natural History Survey, respectively; specimens from locations throughout the state are deposited in the National Museum of Natural History; and specimens remaining from throughout the state were retained by the Department of Biology, University of Northern Iowa.

RESULTS AND DISCUSSION

A total of 2390 specimens representing 500 lots was collected during 84 days spent in the field. (A lot refers to the total number of specimens of 1 or more species retained from each collection site during a single visit.) Seven species of Cambaridae and 1 species of Palaemonidae were identified. Based on the checklist of Hobbs (1974), these species are classified as follows:

Family Cambaridae
- Genus *Cambarus*
  - *Cambarus diogenes diogenes* Girard
- Genus *Orconectes*
  - *Orconectes immunis* (Hagen)
  - *Orconectes iowaensis* Fitzpatrick
  - *Orconectes rusticus* (Girard)
  - *Orconectes virilis* (Hagen)
- Genus *Procambarus*
  - *Procambarus acutus acutus* (Girard)
  - *Procambarus gracilis* (Bundy)

Family Palaemonidae
- Genus *Palaemonetes*
  - *Palaemonetes kadiakensis* (Rathbun)

Data for an additional 1944 specimens were obtained from existing collections and were included in this survey. While the data obtained from collections made by others were useful, especially for distribution purposes, they did not contain any species not collected by the author.

The locations of the collection sites of the specimens collected during this survey, as well as those examined from known existing collections and the literature records, are shown for each species in Fig. 1. Copies of my thesis containing locality data for each species are deposited in the office of the Registrar of the National Musem of Natural History (File number 337063) and the University of Northern Iowa library.

Specimens were collected at 492 different sites representing all counties in the state. Six of these sites were surveyed twice, and 1 site was surveyed 3 times. These are recorded by type of habitat in Table 2. These data represent only those sites where specimens were actually collected.

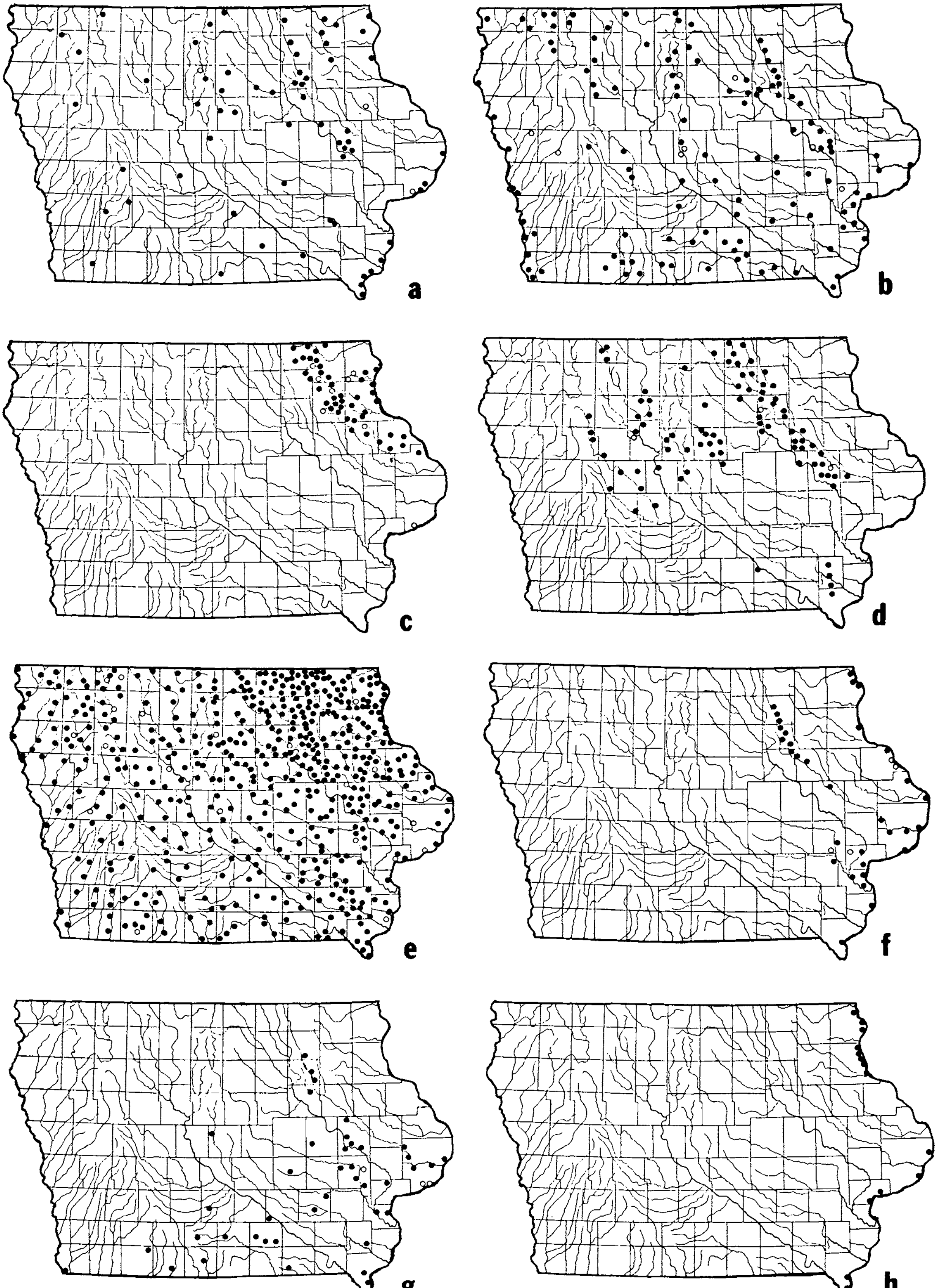
In Iowa, the distribution of decapods is determined by the presence of varying aquatic environments. Variation of habitat can be attributed primarily to the effects of 4 periods of glaciation. According to Ruhe (1969), the first glacial period was the Nebraskan and is evidenced by

Table 2. *Number of collection sites in various habitats.*

Habitat Type	Number of Collection Sites
*Temporary Bodies of Water	25
Marsh Areas	39
Natural Lakes	20
Artificial Lakes	66
**Cold Water Streams	12
Warm Water Streams	330
Total	492

*Those bodies of water which typically dry up annually and which do not support the growth of permanent stands of aquatic vegetation.
**Those streams which occur in northeast Iowa and which are stocked with trout by the Iowa Conservation Commission throughout the entire summer.

Figure 1. *Distribution of Iowa decapod crustaceans. a,* Cambarus diogenes diogenes; *b,* Orconectes immunis; *c,* Orconectes iowaensis; *d,* Orconectes rusticus; *e,* Orconectes virilis; *f,* Procambarus acutus acutus; *g.* Procambarus gracilis; *and h,* Palaemonetes kadiakensis. *(●) Records of specimens examined. (○) Records based on literature and reports only.*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isolated patches in the extreme northeastern portion of Iowa. The second glacial advance was the Kansan which deposited till over most of the state. A narrow belt of till in southeastern Iowa indicates the presence of Iowa's third glacier, the Illinoian. The flat lake country of the north central and northwestern portions of the state is the result of the most recent glacial period, the Wisconsin. During this last glacial period, loess deposits were laid down over much of Iowa.

As the last glacier receded, weathering of the glacial and loess material left behind gave rise to Iowa's present landforms and aquatic environments. As this weathering progressed, watersheds and drainage systems were established, which resulted in 2 great waterways. The Mississippi River and its tributaries drain the eastern three-quarters of Iowa, while the Missouri River and its major tributary, the Big Sioux River, drain the remaining western quarter of the state.

Tributaries of the Mississippi River are relatively clear during normal flow with variations of rock and sand bottoms and light silt loads in the northeast and north central areas, but they become more turbid in the southeast and south central portions of the state. Tributaries of the Missouri River are relatively clear in the northwest during normal flow but usually carry heavy silt loads in the southwestern portion of Iowa.

The natural lakes and marshes of Iowa are primarily confined to the north central and northwestern portions, while the man-made lakes are found primarily in the southern half of the state. Natural lakes in Iowa are the result of the scouring action of glacial ice sheets. Natural marshes are old glacial lakes which have become almost filled by wind-blown and water-carried silt, shore erosion, and accumulations of vegetative remains.

Based on Iowa's past history of glaciation, which according to Ruhe (1969) ended 13,000 years ago, one must assume that Iowa decapods are recent immigrants from glacial refugia in the southern and eastern areas of the United States. This assumption is substantiated by the fact that there has not been the abundant speciation within Iowa as in the southern United States where there is a long history of continuous decapod habitation. It is further substantiated by the fact that species diversity of decapods in Iowa decreases as one proceeds in a northerly and westerly direction. This trend, however, is also affected by the post-glacial climatic factors which have been responsible for the transition from forest to grassland that also occurs when progressing westerly in Iowa. Because of the reduction in variety of aquatic habitat which occurs with this transition, Iowa appears to provide the western and northern limits for some species requiring specific habitat conditions. Only 3 highly tolerant species, *C. d. diogenes, O. immunis,* and O. *virilis*, have been able to extend their range beyond Iowa into the northern great plains (Hobbs, 1972).

Systematic Account of Iowa Decapod Crustaceans

Seven species of Cambaridae and a single species of Palaemonidae are known to exist in Iowa. An account of each species, including distribution in Iowa, range, ecology, and taxonomic remarks where applicable, is provided as follows:

1. *Cambarus diogenes diogenes* Girard

Distribution in Iowa (Fig. 1a): *C. d. diogenes* was collected in 33 counties and reported from an additional 7 counties. The distribution of these collections indicates a statewide distribution. Gaps in locality data are due, in part, to the intensive burrowing behavior of this species which frequently made collection of specimens difficult. There appear to be no ecological restrictions on the distribution of *C. d. diogenes* in Iowa.

Range: Hobbs (1974) stated that *C. d. diogenes* is very widespread east of the Rockies and south of the Great Lakes, except peninsular Florida and the Alleghenies; not reported northeast of New Jersey in the East and east of western Pennsylvania in the Mississippi drainage system. The range of *C. d. diogenes* in the north central states (Fig. 2a) is based upon information from Engle (1926), Turner (1926), Creaser (1931, 1932), Rhoades (1944a, b), Williams and Leonard (1952), Williams (1954), Eberly (1955), Crocker and Barr (1968), Hobbs (1972), and Page (1974).

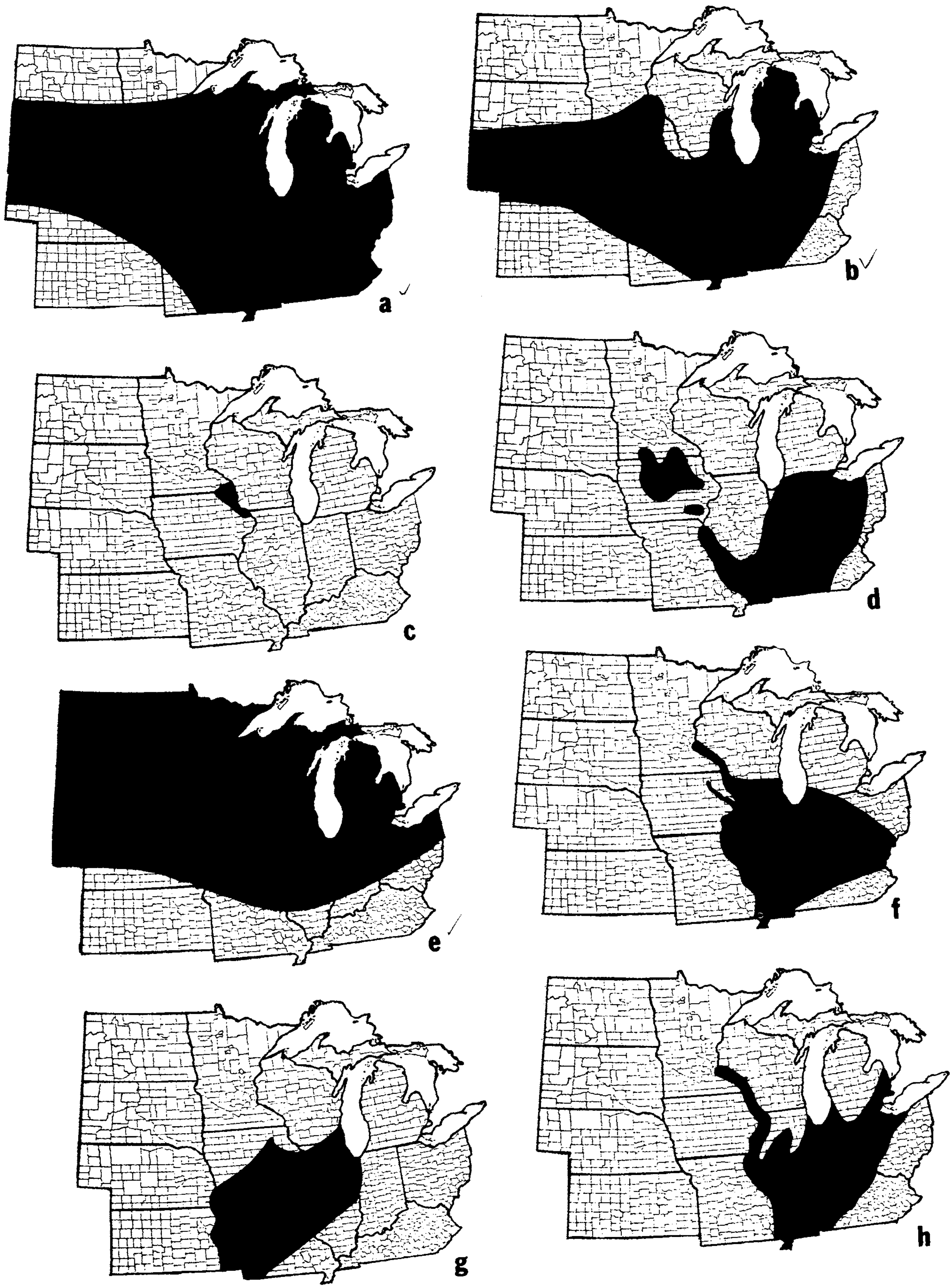
Ecology: In Iowa, individuals of *C. d. diogenes* are typically found in burrows constructed in marshes and along the shorelines of lakes and streams. A "chimney" made of mud removed from the burrow is usually associated with the entrance to each burrow, and its presence greatly facilitates the location of this species. During this survey 65 % of the specimens collected were taken from burrows. These burrows occurred in a variety of settings, including the shorelines of both natural and artificial lakes, along the banks of trout streams and warm water streams and rivers, as well as in swampy or marsh areas. While most burrows were encountered in small colonies of from 3 to 10 burrows, solitary burrows were also encountered on occasion. In several marshy areas along the Wapsipinicon River in Bremer Co., extremely large colonies comprised of several hundred burrows were encountered. Creaser (1932) recorded similar situations where it was a common site to see hundreds of burrows of this species.

Burrows of *C. d. diogenes* commonly extended nearly vertically to a depth of 75 to 100 cm and terminated in a chamber ranging from 8 to 12 cm in diameter. Deeper burrows were encountered, but collection of specimens beyond this depth was impracticable. Bundy (1882) traced a *C. d. diogenes* (his *Cambarus obesus*) burrow for 4 m at varying depths without reaching the end of the burrow. Tarr (1884) found enlargements in deep burrows which he considered as former terminations of the burrow at prior high water levels. During the spring and early summer months of 1977, near drought conditions accompanied by a lowering water table existed in Iowa, and numerous burrows showing this condition were encountered. Crocker and Barr (1968) stated that the burrows of *C. d. diogenes* differ from those of *O. immunis* in that they have a resting chamber near the entrance and from the burrows of *Fallicambarus fodiens* (Cottle) in that there is no deep escape tunnel leading down to the chamber. Such conditions were not noted in Iowa. When encountered in a solitary or small colony setting (less than 10 burrows), burrows were typically vertical shafts, each ending in a terminal chamber. Variations of this style were frequently encountered with many burrows having several shafts and 2 or more chambers. Under these conditions, never more than 1 specimen was found in a burrow system. However, in large colonies, honeycomb networks of burrows were encountered with many interconnecting burrows and often more than 1 specimen was present in a burrow system.

Specimens were also collected from habitats other than burrows. These collections occurred primarily in the spring of the year and were made from bodies of water in close proximity to existing burrows along their shorelines. Williams and Leonard (1952) reported collecting *C. d. diogenes* in Kansas along stream banks; in a marshy area fed by an artesian well; in a muddy burrow by a spring fed pool; and from a farm pond. In Ontario, *C. d. diogenes* is typically found constructing colonies of burrows in wet meadows and marshes (Crocker and Barr, 1968).

No complete study of the life history of *C. d. diogenes* has been conducted; however, a summary of some of the main events can be

Figure 2. *Range of Iowa decapod crustaceans in north central United States. a.* Cambarus diogenes diogenes; *b,* Orconectes immunis; *c,* Orconectes iowaensis; *d,* Orconectes rusticus; *e,* Orconectes virilis; *f,* Procambarus acutus acutus; *g,* Procambarus gracilis; *and h,* Palaemonetes kadiakensis.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obtained from the literature. In Kansas, Williams and Leonard (1952) observed specimens copulating in October under laboratory conditions, and females in berry were collected in April. Bundy (1877) recorded a *C. d. diogenes* (his *Cambarus obesus*) female in berry in Indiana in January. In Indiana, Hay (1896) reported specimens copulating in early April. In this case, eggs were laid in late April. Pearse (1910) reported a female with young taken in Michigan in June. Collection data would indicate an early spring mating season in Iowa. During this study, females were collected in berry on 22 April 1977 (1 specimen) and 17 May 1978 (3 specimens). The specimen collected on 22 April was taken to the laboratory and maintained in an aquarium where hatching occurred on 16 May. The young were carried for approximately 3 weeks, with all young having left the female by 8 June. On 11 June the female molted.

Fragments of *C. d. diogenes* were frequently observed near the mouths of their burrows. Tracks of raccoons (*Procyon lotor* (L.)) and their scats containing crayfish remains were frequently noted near these fragments. Such signs, together with evidence of their probing at burrow mouths, were indicative of raccoon predation.

C. d. diogenes is associated with all other species of decapods found in Iowa.

✓ 2. *Orconectes immunis* (Hagen)

Distribution in Iowa (Fig. 1b): *O. immunis* is distributed statewide except for the extreme northeastern portion of Iowa. This area of restricted distribution corresponds closely with that portion of the state affected by only the Nebraskan Glacier. Referred to as the "driftless area" because of the nearly complete erosion of glacial till following the retreat of the Nebraskan Glacier, this area exhibits rugged topography, numerous exposures of Cambrian and Ordivician rock formations, and clear, cold, rock-bottomed streams. These characteristics and the paucity of marshland and ponds in this area appear to serve as ecological barriers to the distribution of *O. immunis*.

Range: Hobbs (1974) stated that the range of *O. immunis* extends from Massachusetts to Wyoming and Alabama to Ontario. The range of *O. immunis* in the north central states (Fig. 2b) is based upon information from Engle (1926), Turner (1926), Creaser (1931, 1932), Rhoades (1944a, b), Williams and Leonard (1952), Williams (1954), Eberly (1955), Crocker and Barr (1968), Hobbs (1972), and Page (1974).

Ecology: In Iowa, *O. immunis* is typically found inhabiting both temporary and permanent bodies of water. Specimens were collected from roadside ditches, overflow pools, marsh areas, natural and artificial lakes and from the headwaters of small, warm water streams. A distinct preference for a mud substratum was noted with 91% of the lots containing this species being collected over mud. Of these lots, 74% were collected from sites with dense aquatic vegetation associated with a mud substratum. Caldwell and Bovbjerg (1969) reported collecting *O. immunis* in northwest Iowa from temporary and permanent ponds, large shallow sloughs, small muck-bottomed lakes, and slowly moving soft-bottomed portions of rivers and smaller streams. In Michigan, Creaser (1931) recorded the greatest abundance of this species in stagnant ponds, but noted it is sometimes found in slowly moving waters or in lakes with mud bottoms. Crocker and Barr (1968) reported collecting *O. immunis* in Ontario from stagnant ponds and ditches or slow moving streams, seldom more than 30 to 60 cm in depth. Thus, it seems clear from both the data of this study and previous studies that *O. immunis* prefers mud bottoms with abundant aquatic vegetation.

While typically an open water species, *O. immunis* will burrow extensively during dry periods. As temporary ponds containing *O. immunis* dry during the summer, increased burrowing activity can be noted. Caldwell and Bovbjerg (1969) noted burrowing on the upper reaches of the Little Sioux River which becomes seasonally intermittent. Burrowing was also noted during this study, with 4 lots being taken from burrows. Burrow construction characteristically anticipates complete drying, but the specific stimulus to which crayfish are responding has not been defined (Caldwell and Bovbjerg, 1969).

In temporary ponds, *O. immunis* avoids winter freezing by deep burrows which extend below the frost line, while in permanent ponds these animals move to deep water and hide under bottom debris or burrow in the mud. However, *O. immunis* is not always successful in avoiding winter freezing. During the winter of 1976-77, extremely cold weather conditions prevailed, and many permanent pond habitats of *O. immunis* were largely destroyed. In many areas, large numbers of dead specimens were noted littering pond bottoms after the spring thaw.

Tack (1941) reported copulation of *O. immunis* in New York from mid-July to early October. Eggs were laid in late October, carried through the winter, and hatched during the last half of May. Goellner (1943), however, reported that in Michigan only a few females laid eggs in the fall. Engle (1926) found 2 females in berry in Lancaster Co., Nebraska, on 25 April; Creaser and Ortenberger (1933) reported females with eggs in Cass Co., North Dakota, on 6 June; and Williams and Leonard (1952) reported a specimen from Kansas taken on 30 October with eggs which were hatching. In Ontario, Crocker and Barr (1968) reported females with young on 25 May. Caldwell and Bovbjerg (1969) published an extensive study of the life history of *O. immunis* as it occurs in Dickinson Co. in northwestern Iowa. A summary of their work follows.

Copulation occurs from late June to the following April, with the exception of the winter months when the animals are extremely torpid. Eggs are laid in October and in April. If water is available in October, many females will lay eggs at this time and carry them through the winter. However, if water is not available, females will delay egg laying until spring rather than lay the eggs while in burrows. Hatching time varies widely, depending on the time of egg laying and temperature, but characteristically occurs from mid-April to mid-May. Two females carrying eggs were collected as late as 12 June. After hatching, the young remain attached through their first 2 stadia, which may last a total of 7 to 19 days. After leaving the female, the young *O. immunis* molt frequently. The extent of their growth during the first summer is highly variable, depending in part on abundance of food and whether they are forced to burrow due to summer drying. In ponds that become dry in mid-summer, few of the young mature by the end of their first summer, while in permanent ponds most individuals mature during their first growing season. Molting of mature, form I males to form II begins as early as mid-April and continues through mid-May. A second molt which returns form II males to the form I condition typically begins in mid-June and progresses through mid-July. Molting of adult females occurs shortly after the young leave. Life span of both sexes appears to depend upon the time of maturation. Those individuals which mature during their first year generally die following the spring molt of the second year. Conversely, those failing to mature during the first summer usually live for 2 full years.

Observations made during this survey corroborate the life history information of Caldwell and Bovbjerg (1969). In Iowa, females in berry were collected on 22 April 1977 (1 specimen), 17 May 1978 (2 specimens), and 20 May 1978 (1 specimen). One specimen with young was collected on 20 May 1977. In 1977, because of the extremely early spring, most form I males had completed their spring molt in early May. As a result, form I males began to appear in early June in 1977. In 1978, the annual cycle corresponded to that reported by Caldwell and Bovbjerg (1969).

Both Tack (1941) and Goellner (1943) reported the spring molting period as a time of heavy mortality among adult males. This appears to account for the large reduction of adult males from the population at this time. Similar periods of heavy mortality are noted for adult females in the spring after the young have become independent and for adult males in August and September after breeding. Caldwell and Bovbjerg (1969) reported heavy raccoon predation in early summer when crayfish remains were frequently found in association with tracks and again in early fall when they were found near the ruins of recently constructed burrows. Similar observations were made during this study. In addition to raccoons, Tack (1941) reported *O. immunis* being preyed upon by fish, salamanders, toads, frogs, turtles, snakes, and birds.

O. immunis was found associated with *C. d. diogenes, O. virilis, P. a. actus,* and *P. gracilis.*

3. *Orconectes iowaensis* Fitzpatrick

Distribution in Iowa (Fig. 1c): The distribution of *O. iowaensis* is confined to 4 major drainage systems in Iowa; the Upper Iowa, Yellow, Turkey, and Maquoketa. Within these drainage systems, specimens have been collected from 9 counties. These counties are Allamakee, Chickasaw, Clayton, Delaware, Dubuque, Fayette, Howard, Jackson, and Winneshiek. This area, located in extreme northeast Iowa, corresponds closely to the "driftless area" and exhibits geological features not found elsewhere in the state. Among these features are the clear, cool, rock-bottomed streams which are inhabited by *O. iowaensis.* Lack of similar streams to the west and south of this area appears to place ecological restrictions on *O. iowaensis.*

Range: Hobbs (1974) stated that the range of *O. iowaensis* is restricted to the Mississippi River drainage in eastern Iowa. Fig. 1c shows the range of *O. iowaensis* in the north central states.

Ecology: *O. iowaensis* was found most frequently in clear, cool streams with rock bottoms. In these streams, it was typically found in large numbers in riffle areas during the spring and summer months. With falling temperatures in the fall of the year, *O. iowaensis* was most abundant in deeper water at the head of riffle areas. Large populations were encountered in the middle portions of the Yellow River, the upper part of the Turkey and Maquoketa Rivers, and the middle and lower portions of the Volga River, a tributary of the Turkey River. While common in many smaller streams, only in Catfish Creek, Dubuque Co., were populations of similar size encountered. *O. iowaensis* was also taken along wing dams of the Mississippi River below Locks and Dams 9 and 10. No specimens of *O. iowaensis* were obtained from lake environments, and only 3 lots of specimens were taken from regions of streams with mud or sand bottoms. Although hides under flat rocks were commonly encountered while collecting this species, no evidence of burrowing was noted.

Whereas the range of *O. iowaensis* appears restricted to streams in northeast Iowa, it is closely related to *O. propinquus* and as such can be expected to have similar ecological needs (Fitzpatrick, 1968). Page (1974) reported *O. propinquus* from rocky streams in eastern and northern Illinois. In Wisconsin, Creaser (1932) noted that *O. propinquus* was typically found in clear, rock-bottomed streams but may also be collected from lakes with stony bottoms and in streams with dense mats of aquatic vegetation. Crocker and Barr (1968) reported that populations of *O. propinquus* were larger in ponds than rivers but noted that a polluted stream in southwestern Ontario yielded a high-density population.

While no study has been made of the life history of *O. iowaensis*, its close taxonomic relationship with *O. propinquus* suggests a life history similar to that species. According to Van Deventer (1937), the life history for *O. propinquus* is as follows.

Mating between mature females and form I males occurs from approximately mid-July through September. Eggs are laid the following spring, from late April to early June, and are carried for 4 to 6 weeks. Hatching takes place from mid-May to mid-July. The young are carried for about 2 weeks and become free-swimming following their second molt. Adult females that have borne young molt shortly after the brood leaves. Form I males molt earlier, going from the form I winter condition to form II. A second molt from form II to form I occurs in mid-July, just prior to mating. Juveniles molt 6 to 10 times during the summer and typically attain a carapace length of 16 to 20 mm by late September. Individuals at this time are usually mature, and mating may occur during the first fall. Most individuals that mature by the first fall die during the following summer. Those that do not mature the first year mate the second fall and lay eggs the following spring. Few individuals live to mate during the third fall.

In Iowa, females of *O. iowaensis* in berry were collected on 30 April 1977 (2 specimens) and 11 May 1978 (1 specimen). In 1977 the molt of *O. iowaensis* from form I to form II occurred in early May, while in 1978 this molt took place in late May. Return to form I occurred in late June 1977 and in mid-July in 1978. The somewhat early dates for 1977 were probably due to the extremely early spring that year.

O. iowaensis was frequently associated with *O. virilis* and occasionally with *C. d. diogenes.*

Taxonomic Remarks: The primary problem encountered with *O. iowaensis* is taxonomic. While studies of the ecology and physiology of *O. iowaensis* might explain the restriction of this species to the streams of northeast Iowa, the question of species validity is of more serious concern. Fitzpatrick (1968) showed that no significant statistical differences in morphology existed between *O. iowaensis* and *O. propinquus.* Nevertheless, he described *O. iowaensis* as a new species based upon small differences in the mesial process of the gonopods of form I males and the sculpturing and shape of the annulus ventralis of the female. Such characteristics, however, were difficult to interpret in specimens collected during my study. Furthermore, Fitzpatrick (1968) suggested that the Mississippi River has served as a barrier isolating *O. iowaensis* from *O. propinquus* for over 100 years. This does not appear valid, as I collected *O. iowaensis* from the Mississippi River at Guttenberg, Clayton Co. and Harper's Ferry, Allamakee Co. where fairly large populations were encountered.

The difficulty of distinguishing the taxonomic characteristics upon which species identification of *O. iowaensis* is based and the fact that the Mississippi River does not appear to serve as a barrier indicates that a detailed analysis of the validity of *O. iowaensis* as a species is required.

4. *Orconectes rusticus* (Girard)

Distribution in Iowa (Fig. 1d): Hobbs (1972) questioned the occurrence of *O. rusticus* in Iowa. Prior to this study only 3 records were known from the state. Collections made during this study and a review of existing collections have verified these records and show that *O. rusticus* is a fairly common and widely distributed species in Iowa. The distribution of *O. rusticus* is strongly affected by drainage systems with its natural occurrence limited to those tributaries of the Mississippi River south and west of the Maquoketa River. The western limit for this species is the Raccoon River drainage system.

Distribution of *O. rusticus* is unusual in that 2 separate natural populations exist within the state. A small population is located in southeast Iowa where it occurs in some of the small, clear, rock-bottomed tributaries of the Des Moines and Skunk Rivers. This population appears confined to portions of Davis, Henry, Jefferson, Lee, Van Buren, and Wapello Counties. A second population exists in the eastern, central, and north central portions of the state where it can be found in the headwaters and middle reaches of the Wapsipinicon, Cedar, Iowa, Skunk, Des Moines, and Raccoon Rivers. *O. rusticus* was not found inhabiting the lower reaches of these rivers or the Mississippi River. Existence of the southeast Iowa population, however, suggests that it once occurred in the lower portions of these rivers and may have been contiguous with populations in northeast Missouri. The present absence of *O. rusticus* in the lower reaches of these rivers may be due to an ecological requirement for clean waters. Harlan and Speaker (1969) cited similar upstream withdrawals of several species of darters due to the degradation of eastern Iowa rivers.

A third, disjunct population of *O. rusticus* can be found inhabiting the Maquoketa River in a riffle area below the Lake Hartwick dam south of Delhi, Delaware Co. The limitation of this species to a single site on the Maquoketa River suggests that its presence there may be the result of artificial introduction, probably by local bait dealers and /or fishermen.

Range: Hobbs (1974) stated that the range of *O. rusticus* is Michigan, Ohio, Indiana, Kentucky, Tennessee, and south Ontario and that it had been introduced into Massachusetts. Crocker (1979) subsequently reported it from 7 isolated localities in Maine, Massachusetts, New Hampshire, and Vermont. The range of *O. rusticus* in the north central states (Fig. 2d) has been determined based upon information from Turner (1926), Creaser (1931), Rhoades (1944a, b), Eberly (1955), Crocker and Barr (1968), Hobbs (1972), Page and Burr (1973), and Page (1974).

Ecology: O. rusticus was typically collected in Iowa from 2 major types of aquatic habitats. In southeastern Iowa, it was found in rocky pool and riffle portions of small, clear streams; in eastern, central, and north central sections of the state, it was found in the rock riffle areas of medium and large warm water streams. In all areas, *O. rusticus* is usually found hiding under and among rocks. During this survey 97% of the lots containing *O. rusticus* were collected from sites with a substratum covered with rocks.

Rhoades (1944a) recorded collecting *O. rusticus* from swift, rock-bottomed streams in Kentucky and noted a relationship between the occurrence of limestone exposures and the distribution of this species. He also recorded this species from streams flowing through areas of limestone exposures in Ohio (Rhoades, 1944b). Page and Burr (1973) took *O. rusticus* from riffle habitats in 2 river systems in northeastern Missouri. Creaser (1931) reported similar habitat preferences in Michigan for *O. rusticus*. He collected it from a small stream with gravel and stone bottom where individuals were taken from under stones.

Collections of *O. rusticus* from fish ponds in Ohio were noted by Langlois (1935). Specimens were also collected from burrows around these ponds. While no burrowing activity was noted for *O. rusticus* in Iowa, excavations constructed under flat stones in streams were common. These hides typically face upstream. In Ontario, Crocker and Barr (1968) recorded *O. rusticus* from stony lakes of the Precambrian Shield. Only 2 lots containing this species were collected by the author from standing water in Iowa. The sites of these collections were located along the rocky shorelines above shallow, low-head impoundments on rivers containing large populations of *O. rusticus*.

Langlois (1935) noted the principal mating season for *O. rusticus* in Ohio as September and October. Following copulation, the females burrowed into the pond banks where they remained until the following spring. While a few females were observed ovipositing in late October, most waited until April or May. Eggs were observed hatching approximately 20 days after laying. In another 3 to 5 days the juveniles became free-living. Almost all young of the year were sexually mature after 1 summer's growth and participated in the fall mating period. In Kentucky, Rhoades (1944a) reported that *O. rusticus* rears its young in late April and early May.

In Iowa, females in berry were collected on 15 April 1977 (1 specimen) and 26 April 1978 (5 specimens). Juveniles were encountered in large numbers in late May. A general molt of males from form I to form II was noted in 1977 in late April and in 1978 in mid-May. Molting from form II to form I appears to occur in Iowa from mid-July to mid-August. Specimens collected in September and placed in an aquarium in the laboratory were observed mating soon after they were collected.

O. rusticus is frequently associated with *O. virilis* and occasionally with *C. d. diogenes*.

Taxonomic Remarks: Two features used by Hobbs (1972) to distinguish *O. rusticus* are the lack of a median carina on the rostrum and a central projection of the form I male gonopod which is less than one third of the total length of the gonopod. Specimens taken from the Lake Hartwick site show no medial carina and have a central projection length to total gonopod length ratio of approximately 0.3:1.0. These characteristics concur with the characteristics cited by Hobbs for *O. rusticus*. Specimens from the remainder of Iowa typically show a median carina and exhibit a central projection length to total gonopod length ratio of approximately 0.4:1.0, which exceeds the ratio suggested by Hobbs. Based on the variation of these and other key morphological characteristics which can be noted in most Iowa specimens from typical *O. rusticus* specimens known heretofore and the fact that the naturally occurring Iowa populations have been isolated from parent populations for at least 50 years, a separate species designation may be warranted for Iowa populations exclusive of those from the Lake Hartwick site. This taxonomic problem deserves additional study and attention.

5. *Orconectes virilis* (Hagen)

Distribution in Iowa (Fig. 1e): Specimens of *O. virilis* were taken from all 99 counties in Iowa, making it the most common species collected during this survey. There appears to be no ecological restrictions on the distribution of this species in Iowa.

Range: Hobbs (1974) stated that the range of *O. virilis* is from Saskatchewan to Ontario, Canada, and from Montana and Wyoming to New York and southwestern Maine and that it has been introduced into California, Maryland, part of New England, and Tennessee. The range of *O. virilis* in the north central states (Fig. 2e) has been determined based upon information from Turner (1926), Engle (1926), Creaser (1931, 1932), Rhoades (1944a, b), Eberly (1955), Crocker and Barr (1968), Hobbs (1972), and Page (1974).

Ecology: During this survey, specimens of *O. virilis* were taken from virtually every type of aquatic habitat sampled. However, it is typically a stream dwelling species in Iowa with 81% of the collections from permanent flowing bodies of water. While a preference was noted for substratum types with rocks (57% of the collections) or debris (22% of the collections) present for cover, 11% of the collections containing this species were collected from sites with bare substrata and 10% from sites with vegetation. Caldwell and Bovbjerg (1969) reported *O. virilis* as occurring in rock-bottomed rivers and smaller streams and in lakes with rocky shores, in northwest Iowa. Creaser (1931) took *O. virilis* from every major drainage system in Michigan. It occurred abundantly in streams, rivers, and lakes, and had a decided habitat preference for a stream bottom with stones, under which it could hide. In Michigan it is found in even the coldest trout streams and this is also true in northeast Iowa. In Wisconsin, *O. virilis* was typically found under stones in lakes, streams, and rivers but was also collected from muddy creeks and in aquatic vegetation (Creaser, 1932). In Ontario, Crocker and Barr (1968) reported *O. virilis* frequently occurring in lakes with stony bottoms where it often inhabits deep water. Momot et al. (1978) reported similar findings in the marl lakes of northern Michigan where *O. virilis* is the sole crayfish inhabitant. *O. virilis* is occasionally taken in slow-moving, mud and sand bottomed streams in association with *O. immunis* as mentioned by Crocker (1957) for New York, Crocker and Barr (1968) for Ontario, and Caldwell and Bovbjerg (1969) for the Little Sioux River in northwest Iowa. This condition was noted in a number of streams along the Minnesota border in north central and northwestern Iowa which included the Little Rock River (Lyon Co.), Little Sioux River (Dickinson Co.), Otter Creek and Ocheyedan River (Osceola Co.), Waterman Creek (O'Brien Co.), and Lime Creek (Winnebago Co.).

While *O. virilis* is regarded as a nonburrowing species, 1 specimen was taken on 24 May 1977 from a burrow along the shore of Split Rock Lake in Chickasaw Co. This burrow was approximately 30 cm deep, slanted at a 45° angle, contained 2 terminal chambers, and possessed a chimney approximately 5 cm tall. A specimen was also taken from Panther Creek, Lee Co., from a submerged hole in a dirt bank. The hole was a 15 cm horizontal cavity, approximately 25 cm below the water's surface. Construction of hides under rocks or debris was also observed but was not considered as burrowing activity.

Pennak (1978) reported that *O. virilis* may occur in water over 30 m in depth, indicating the wide range of habitats utilized by this species. During this survey, specimens of *O. virilis* were trapped in Beeds Lake, Franklin Co., in water approximately 1.5 m deep and in Lake Darling, Washington Co., in water approximately 1.2 m deep. Crocker and Barr (1968) collected a specimen from Shirley Lake, Ontario, at a depth of 9.1 m. In New Hampshire, large populations were encountered in Lake Winnipesaukee in 6 to 12 m of water with specimens being taken as deep as 20 m (Aiken, 1965).

An extensive study of the life history of *O. virilis* as it occurs in Dickinson Co. in northwest Iowa was published by Caldwell and Bovbjerg (1969). A summary of their work is given here.

Copulation occurs from early July until mid-April, with the exception of the period of winter torpor. Oviposition occurs from mid-March to mid-April, with hatching usually occurring in mid-May. Most young leave the females by early June. Females with young were, however, noted as late as 19 June. The timing of the hatching and release of the young are such that the time of spring floods is ordinarily past before the immatures leave the female. Maturity is not reached during the first growing season but is normally attained during their second summer in time to participate in the late summer breeding period. Adult form I males undergo a spring molt to form II between mid-May and mid-June. A molt from form II to form I begins in early July and continues through August.

In Iowa, females in berry were collected on 15, 22, 23 April 1977 (1 specimen each date), 26 April 1977 (2 specimens), 29 April 1978 (1 specimen), 17, 21 May 1978 (1 specimen each date), 23 May 1978 (2 specimens), and 24 May 1978 (1 specimen). Females with young were collected on 16, 17 May 1977 (1 specimen each date). In 1977, because of the extremely early spring, the spring molt from form I to form II occurred in April, with very few form I males present after the first of May. The molt from form II to form I was likewise advanced, with form I males appearing again as early as mid-June. In 1978, the molt cycle closely approximated that described by Caldwell and Bovbjerg (1969).

For those populations occurring in southwest Iowa, this cyclic pattern appears to be much more strictly defined than in other parts of the state, especially regarding the molting periods of adult males. Collections in this area in late May 1977 and 1978 yielded no form I males, suggesting a molt period in late April or early May. Form I males did not appear again in this area until late August. This cycle is considerably different than that noted for *O. virilis* throughout the remainder of the state.

Momot (1967) and Threinen (1958a, b) reported no copulation before mid-August for *O. virilis* in Michigan and Wisconsin, respectively. Females have been observed with eggs in Michigan and Wisconsin before the last of April (Creaser 1931, 1932). Threinen (1958b) stated that the young grow for 2 summers before reaching maturity, then in late summer of their second year, breeding activity begins. These same individuals may participate in mating again the following spring when the males regain form I condition. Following this mating period, most males die while the females produce a brood, after which they usually die (Threinen, 1958a). In Ontario, Crocker and Barr (1968) collected females with eggs as late as 11 July.

O. virilis moves to deep water and buries itself among the rocks to escape winter freezing; if it remains inactive, it is soon covered by silt (Aiken, 1968). According to Caldwell and Bovbjerg (1969), this retreat occurs early in autumn in northwestern Iowa and movement back into shallow water occurs after the spring thaw. On 8 April 1977, I observed a large number of specimens in the Cedar River at Cedar Falls, Black Hawk Co., moving from deep water below the dam into shallow water. All 22 specimens collected were large form I males. On 29 October 1977, specimens were collected from the Iowa River, Iowa Co., by digging them from the mud under debris. Specimens were covered by approximately 2 to 3 cm of mud.

O. virilis was collected in association with all other species of Iowa decapods.

Taxonomic Remarks: O. virilis is represented in southwestern Iowa by a striking variant. Specimens were collected from the Boyer, Nishnabotna, Nodaway, Platte, Grand, and Chariton River drainage systems. Initially it was thought that this variant might be *Orconectes nais* (Faxon). Thus, comparisons were made between groups of *O. virilis* collected in eastern, northwestern, and southwestern Iowa and *O. nais* collected in northeastern Kansas. Study of the gonopods of 140 form I males revealed the following ratios of central projection length to total length of gonopod: *O. virilis* from eastern Iowa, 0.45:1.00; *O. virilis* from northwestern Iowa, 0.44:1.00; *O. virilis* from southwestern Iowa, 0.36:1.00; and *O. nais* from northeastern Kansas, 0.27:1.00. Observations of the mesial process of the gonopods of form I males for *O. virilis* from eastern and northwestern Iowa showed a slightly spatulate structure, specimens of *O. virilis* from southwestern Iowa a strongly spatulate structure, and specimens of *O. nais* from northeastern Kansas a moderately spatulate structure. The tip of the central projection of *O. virilis* in eastern, northwestern, and southwestern Iowa extends to the caudad border of the bases of the chelipeds when the abdomen is flexed; in *O. nais* from northeastern Kansas, the tips of the central projection reach only the second pereiopods when the abdomen is flexed. In *O. virilis* from eastern and northwestern Iowa, the terminal processes are subparallel, slightly separated, and only gently curved caudad at the tips. In many individuals, only the central projection shows any curving. Specimens from southwestern Iowa show a moderate separation of the terminal processes, which are subparallel for approximately one half their total length before curving strongly caudad. Specimens of *O. nais* exhibit terminal processes which are non-parallel, diverging from each other at an angle of approximately 30°. Both processes curve moderately caudad.

Differences in the length of the antennae were also noted. Specimens of *O. virilis* from eastern and northwestern Iowa exhibited antennae which were only slightly longer than the cephalothorax. *O. virilis* from southwestern Iowa and *O. nais* from northeastern Kansas exhibited antennae as long as, or longer in the case of some *O. virilis,* than, the total body length. The chelae of specimens of *O. virilis* from southwestern Iowa and *O. nais* from northeastern Kansas were typically weaker and more slender than those of *O. virilis* from eastern and northwestern Iowa.

The relationship between *O. virilis* and *O. nais* has been in question for many years (Hobbs, 1974). The presence of a population of crayfish in Iowa which shows some intermediate traits between these 2 species precisely at the location where the ranges of these 2 species would be expected to overlap is of considerable interest. While they are presently considered a variant population of *O. virilis,* subsequent collections in southwest Iowa, southeast Nebraska, northwest Missouri, and northeast Kansas would no doubt yield the specimens necessary to conduct a detailed taxonomic study which would elucidate their true status.

6. *Procambarus acutus acutus* (Girard)

Distribution in Iowa (Fig. 1f): *P. a. acutus* exhibits a unique distribution pattern in Iowa. It is restricted to the bottomlands associated with the Mississippi River, the extreme lower reaches of the Iowa and Cedar Rivers, and the Wapsipinicon River. While movement up the Iowa and Cedar Rivers has been restricted to less than 30 km upstream, movement up the Wapsipinicon River valley has exceeded 90 km. The backwaters along the Wapsipinicon and Cedar Rivers are similar in many ways, but the backwaters along the Cedar are more susceptable to drying and freezing. These conditions may represent climatic limitations for *P. a. acutus* and may explain why it has not become established west of the Wapsipinicon River in northern Iowa. Movement up other major tributaries of the Mississippi River was not noted. Absence of extensive marshland and the landforms associated with such habitat seem to be the primary ecological features limiting its distribution.

Range: Hobbs (1974) gave the range of *P. a. acutus* as the costal plain and piedmont from Maine to Georgia, from the Florida panhandle to Texas, and from Minnesota to Ohio. In southwestern Texas and northern Mexico, it intergrades with *Procambarus acutus cuevachicae* (Hobbs). The range of *P. a. acutus* in the north central states (Fig. 2f) has been determined based upon information from Turner (1926), Creaser (1931, 1932), Rhoades (1944a, b), Williams (1954), Eberly (1955), Hobbs (1972), and Page (1974).

Ecology: Hobbs and Marchand (1943) collected *P. a. acutus* from woodland swamps, bogs, swiftly flowing streams, creeks, rivers, ditches, and ponds. In the region of Reelfoot Lake, Tennessee, they reported it from streams, ponds, and ditches where the bottom is mud or clay. In Iowa *P. a. acutus* frequently occurs in temporary bodies of water, small marsh areas, and the backwaters of large, warm water rivers. A preference for mud bottoms was also noted during this survey; 92% of the collections of this species were made over mud substrata. Creaser (1932) stated that *P. a. acutus* was never collected from rapidly flowing water in Wisconsin. This was also true in Iowa. Creaser further reported that this crayfish occurs in temporary ponds where it excavates shallow burrows. During this survey a single lot of specimens was taken from burrows along the margin of a nearly dry drainage ditch in southern Bremer Co. Burrows constructed by *P. a. acutus* varied from horizontal shafts leading into a bank at water level to vertical shafts with terminal resting chambers. The deepest burrow encountered was approximately 60 cm deep. Williams (1954) took *P. a. acutus* from drainage ditches and stagnant, warm, muddy streams in southeastern Missouri and from cool, springfed streams in central Arkansas. Meredith and Schwartz (1960) collected *P. a. acutus* from burrows in Maryland salt marshes which were covered twice daily by tides. In other regions of Maryland, they found this species occurring in areas of pollution or in swamps which possessed deep muck and decaying matter. They regarded it as tolerant of a wide range of limnological conditions, from highly acid to highly alkaline, and of such factors as temperature, vegetation, turbidity, and bottom composition. In Iowa, the largest populations of *P. a. acutus* encountered were found in roadside ditches.

Little is known about the life history of *P. a. acutus* in the north central states. Turner (1926) recorded this species as carrying eggs or young in Ohio during the months of March, July, and September. During this survey no females with eggs or young were collected. Large populations of juveniles were encountered in late May. Presence of these juveniles which had carapace lengths of 10 mm or greater suggests that hatching occurs very early in the spring. Hobbs and Marchand (1943) found form I males from Tennessee in June and July, and Williams (1954) found form I males from the Ozark Plateau and Ouachita Province in August and September. In Iowa, form I males were collected from May to August. Based on the information available thus far, it appears that *P. a. acutus* does not have a restricted breeding season. Creaser (1932) recorded *P. a. acutus* constructing burrows around temporary ponds which he suggested were for mating. During this study a burrow was excavated on 15 June 1977 which yielded a form I male and a female. This was the only instance where a solitary burrow yielded 2 specimens of *P. a. acutus*.

This species is associated with *C. d. diogenes, O. immunis, O. virilis, P. gracilis,* and *P. kadiakensis*.

7. *Procambarus gracilis* (Bundy)

Distribution in Iowa (Fig. 1g): The distribution of *P. gracilis* is restricted to the eastern, southeastern, south central, and extreme southwestern portions of Iowa. *P. gracilis* has extended the northern limits of its distribution in Iowa along the Wapsipinicon River and was collected as far north as central Chickasaw Co. Elsewhere in Iowa, its northern limits of distribution are not as extensive. With the exception of a single, old, unpublished record from Story Co., all other collection sites lie outside the area covered by the Cary Lobe of the Wisconsin Glacier. Because of the burrowing nature of this species, soil types associated with this last period of glaciation may, in part, serve as an ecological barrier.

Range: Hobbs (1974) stated that the range of *P. gracilis* is from Wisconsin to Texas and from Illinois to Oklahoma. The range of *P. gracilis* in the north central states (Fig. 2g) has been determined based upon information from Creaser (1932), Rhoades (1944a), Williams and Leonard (1952), Williams (1954), Eberly (1955), Hobbs (1972), and Page (1974).

Ecology: P. gracilis is seldom found in Wisconsin along streams, rivers, or lakes but is frequently collected in the vicinity of small ponds (Creaser, 1932). Bundy (1882) reported *P. gracilis* as abundant along water courses in early spring in McLean Co., Illinois, and very common on prairies in Racine Co., Wisconsin, where it burrowed in low lying areas. It has been collected in abundance from stagnant ponds in Kansas in early spring (Harris, 1900). Males and females were collected in August from the mouths of burrows near these ponds. In Kansas, Williams and Leonard (1952) collected *P. gracilis* from ponds, roadside ditches, burrows in low wet ground, and from a small creek.

While juveniles are frequently taken from aquatic habitats, most adults inhabit extremely deep burrows. During this survey, only 3 specimens of *P. gracilis* were collected from burrows. These were the only mature specimens taken. This is due, in part, to the fact that most burrows encountered were over 1 m deep, making excavation difficult. Burrows were encountered by Creaser (1932) which extended over 2 m in depth before the water level was reached. The deepest burrow excavated during this study was approximately 120 cm deep, although the average burrow encountered was considerably deeper. The burrows of *P. gracilis* typically descend vertically into the ground, the main tunnel varying from 2 to 3 cm in diameter. Those burrows excavated were terminated by a flask-shaped enlargement, the greatest of which was about 10 cm in diameter. This enlargement was partially filled with mud and water. These findings agree with those of Steele (1902) for Missouri specimens.

The remaining specimens of *P. gracilis* collected in Iowa were taken from aquatic habitats which included temporary bodies of water, marsh areas, and small artificial lakes. No specimens were collected from streams. While *P. gracilis* is noted for its deep burrows, it frequently leaves these burrows at night or during heavy rains and can be found wandering overland on low, wet ground (Williams and Leonard, 1952).

Little can be said about the life history of *P. gracilis* in Iowa, since only 3 mature specimens were collected and no other literature on Iowa specimens exists. Faxon (1885c) and Harris (1903) noted that male *P. gracilis* were rarely found. During this survey, no form I males were observed in the field. Several form I males taken on 7 June were noted in the Coe College collection. No females with eggs or attached young were collected. While most juveniles were found in May and June, in 1977 a number of juveniles with carapace measurements of less than 10 mm were collected in late September suggesting that they hatched in early August. This would correspond with the beginning of a rainy period which broke the drought conditions that existed in Iowa at that time. Harris (1900) observed females in Kansas in early spring with young attached but never with eggs attached. Adults and young appeared in the spring, and young appeared again in the fall. Creaser (1932) reported females in Missouri with young attached as late as October. Williams and Leonard (1952) collected females with young attached in early spring and form I males in June in Kansas.

P. gracilis was found associated with *C. d. diogenes, O. immunis, O. virilis,* and *P. a. acutus*.

8. *Palaemonetes kadiakensis* (Rathbun)

Distribution in Iowa (Fig. 1h): In Iowa, *P. kadiakensis* is restricted to the Mississippi River where it is typically found among aquatic vegeta-

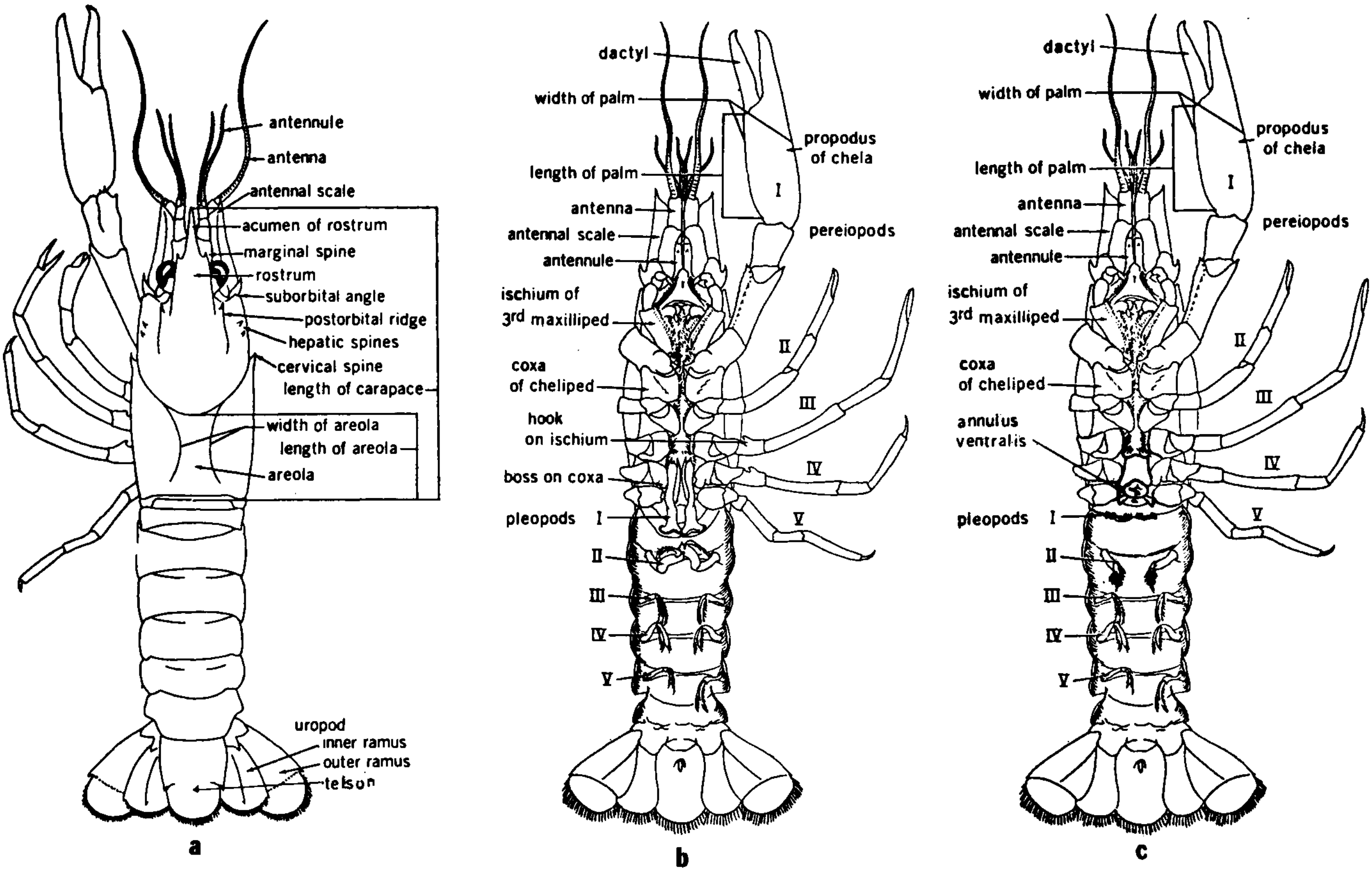

Figure 3. *Generalized figure of crayfish showing important structures and measurements. a, Dorsal view of male cambarid crayfish. b, Ventral view of male cambarid crayfish. c, Ventral view of female cambarid crayfish. (after Hobbs, 1972).*

tion above the U.S. Army Corps of Engineers navigation dams. *P. kadiakensis* does not appear to have moved up any of the tributaries of the Mississippi River. Lack of large, sluggish rivers with heavy stands of aquatic vegetation is probably the primary ecological factor limiting the distribution of this species in Iowa.

Range: Pennak (1978) stated that *P. kadiakensis* occurs sporadically in the central third of the United States west of the Alleghenies from Canada to the Gulf of Mexico. Its distribution in the north central states (Fig. 2h) is based upon Creaser (1931, 1932), Holthuis (1952), and Page (1974). Fig 2h indicates where this species might occur if the proper habitat is present.

Ecology: P. kadiakensis was typically found in sluggish, heavily vegetated aquatic habitats in Iowa. Stands of the pondweed, *Potamogeton crispus L.*, yielded the largest number of specimens. The only specimens of this species collected in Iowa were taken from the backwater areas above the navigational dams on the Mississippi River. Creaser (1931) recorded collecting *P. kadiakensis* in Michigan from slow moving rivers and streams or lakes and ponds with an abundance of vegetation. He also collected it from Wisconsin under similar conditions and found it was frequently abundant in overflow ponds where there were few fish (Creaser, 1932). Page (1974) described the habitat of this species in Illinois as areas of sluggish water.

In Iowa, 5 of the 6 lots containing *P. kadiakensis* were collected in stands of pondweed. This may be a result of the protection afforded *P. kadiakensis* in stands of this aquatic plant. Undoubtedly, *P. kadiakensis* is preyed upon by a large variety of fish species and would be readily susceptible to predation in open stands of aquatic vegetation.

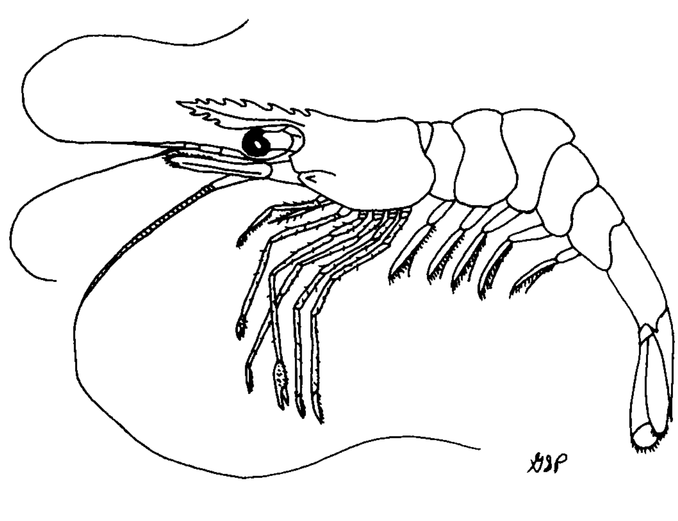

Figure 4. Palemonetes kadiakensis *(Rathbun).*

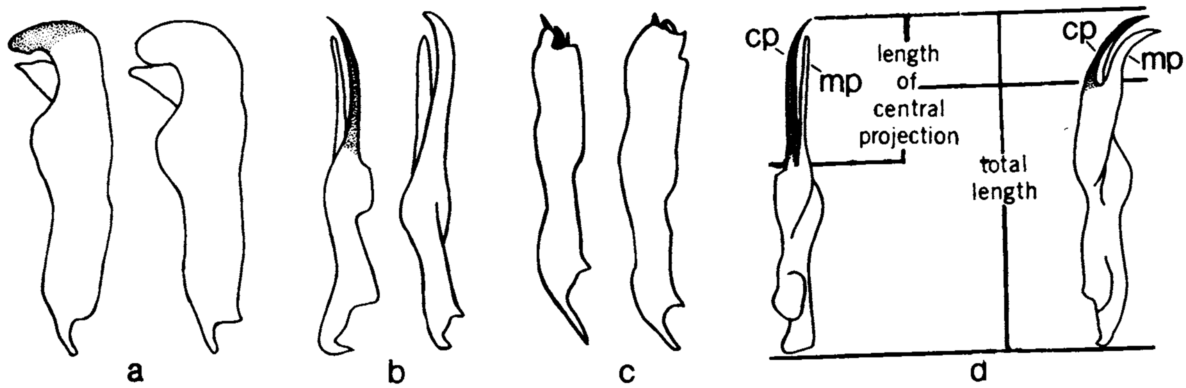

Figure 5. *First pleopods of members of Cambaridae. a-c, Lateral views of left pleopods of form I and form II males, respectively; with corneous central projection (cp) typical of form I males shaded; a,* Cambarus; *b,* Orconectes; *and c,* Procambarus. *d, Methods of measuring first pleopods (mesial view) in* Orconectes *(cp, central projection; mp, mesial process). (modified after Hobbs, 1972).*

Little is known about the life history of *P. kadiakensis*. Creaser (1932) reported collecting females from Wisconsin carrying eggs in April, July, and August and suggested that 2 breeding seasons exist. Similar observations were made in Louisiana by Meehean (1936) who noted females carrying eggs in March and again in July and reported that molting of the female usually occurred within a day after the young hatched. According to Meehean, the largest specimens observed occurred in March but disappeared entirely from the population shortly thereafter. He noted a second decline of large specimens in late July. These 2 periods appear to coincide with the completion of the hatching of young. No specimens with eggs were taken during this survey.

P. kadiakensis was found in association with *C. d. diogenes, O. virilis,* and *P. a. acutus.*

Identification of Decapod Crustaceans Iowa

Members of the Cambaridae and the Palaemonidae can be distinguished by the morphology of the rostrum, number of chelate legs, and shape of the abdomen. The Palaemonidae possess a serrated rostrum, 2 pairs of chelate legs, and a laterally flattened abdomen. The Cambaridae have a smooth rostrum, 3 pairs of chelate legs, and a dorsoventrally flattened abdomen.

Identification of crayfish is based largely upon the structure of the first pair of abdominal appendages of the male. These appendages are modified swimmerets and are located immediately posterior to the last pair of walking legs (pereiopods). They and the other swimmerets are known as pleopods. The first pair of pleopods serves as guides for sperm transfer during copulation by transporting sperm from the opening of the vas deferentia, located at the base of the fifth pair of walking legs, to the sperm receptacle of the female known as the annulus ventralis. The annulus ventralis is a cup-like structure situated on the sternum between the last 2 pairs of walking legs.

The first pleopod occurs in 2 forms in each species of male crayfish of the Cambaridae. These are usually designated as form I and form II, with form I indicative of sexual maturity and potency. According to Hobbs (1972), form I cambarid males may be distinguished from juvenile and adult form II males, which are sexually impotent, by the presence of 1 or more corneous or horny terminal elements (projections) on the distal ends of the first pair of pleopods (Fig. 5). These rigid pleopods, in their usual position, extend from the base of the abdomen forward between the bases of the pereiopods and lie against the sternum of the cephalothoracic region (Fig. 3). The first pleopods of the juvenile and form II males have no corneous terminal elements. Their projections are more bulbous and less clearly defined than in the form I males, and the entire pleopod is of similar texture (Fig. 5). In females, the first pair of pleopods is small and flexible or lacking.

Hobbs (1972) indicated that a cyclic dimorphism associated with the reproductive cycle exists for the male members of Cambaridae, which in the more northern representatives occurs typically in a circadian rhythm. Among those species that have an annual reproductive cycle, the breeding form I males in the population molt at the end of their first breeding season and are transformed to essentially juvenile morphology. This form II morphology is retained until the start of the next breeding season when a second molt returns them to the sexually functional adult form I. Thus, there is a regression to the quasi-juvenile form II stage between each breeding season which may have a duration of 3 to 6 months. For those species that have a seasonal reproductive cycle, the entire male population may be in the juvenile and quasi-juvenile stage for several months. For many species occurring in the lower temperate latitudes, there is no well defined breeding season, and the male members of the population may consist of juveniles, quasi-juveniles (form II), and breeding (form I) adults throughout the year due to irregular molting periods.

Hobbs (1972) further indicated that inasmuch as an individual may have 3 or more active reproductive periods during its life span and, with few exceptions, there is an increase in size of the individual with each molt, it is to be expected that quasi-juvenile males following their first or second breeding seasons are larger than a form I male in its first breeding season. Consequently, size alone cannot be used in distinguishing between first and second form males.

The annulus ventralis of the female is also useful in classifying crayfish. While not as reliable as the pleopods of form I males, it is a fairly good diagnostic character for some species (Williams and Leonard, 1952).

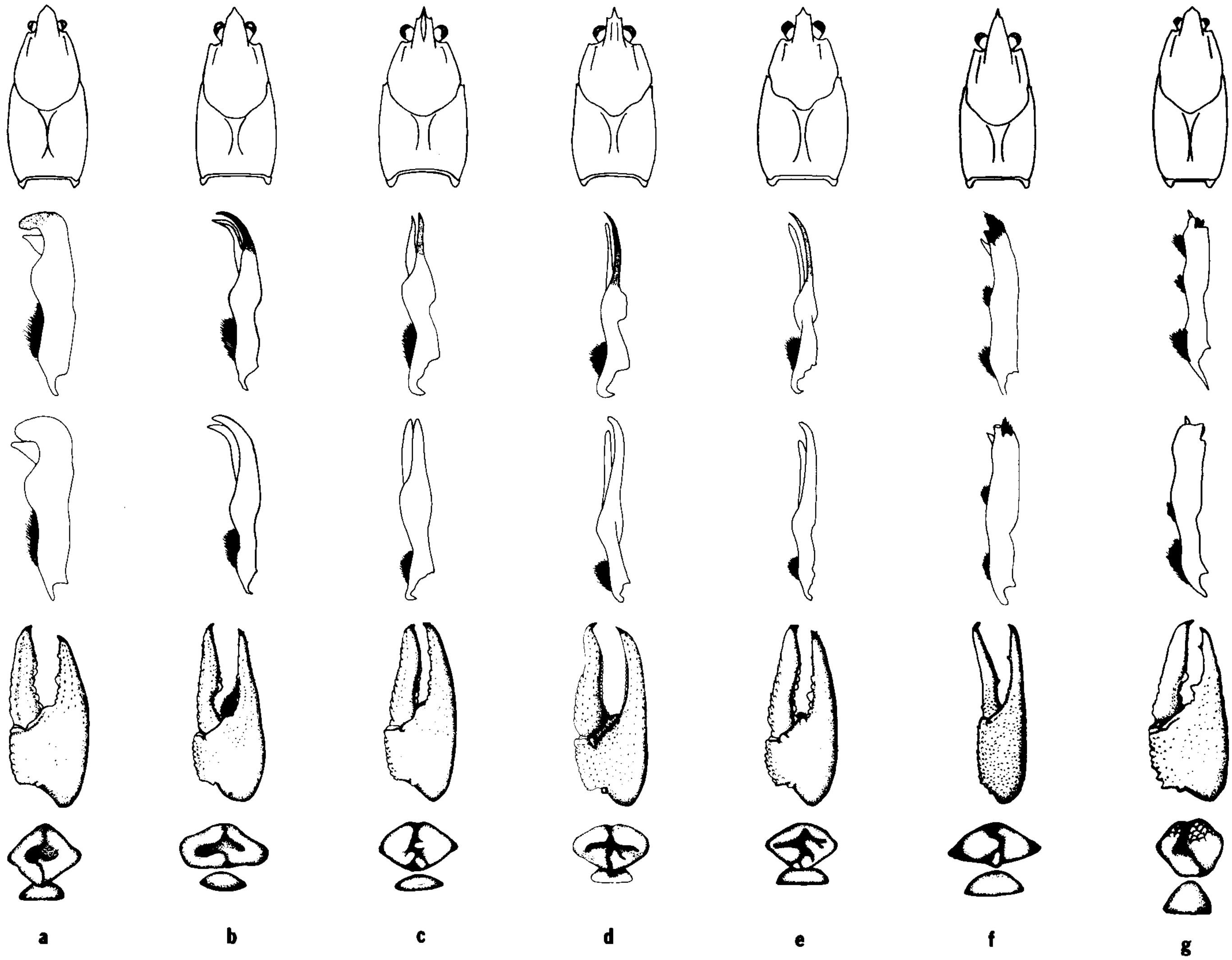

Figure 6. *From top to bottom, dorsal view of carapace of male; lateral view of first pleopod of form I and form II males, respectively; dorsal view of right chela of male; and annulus ventralis of female. a,* Cambarus diogenes diogenes; *b,* Orconectes immunis; *c,* Orconectes iowaensis; *d,* Orconectes rusticus; *e,* Orconectes virilis; *f,* Procambarus acutus acutus; *and g,* Procambarus gracilis. *(modified after Hobbs, 1974).*

TERMS USED IN IDENTIFICATION OF DECAPOD CRUSTACEANS

Many of the terms listed in this glossary are illustrated in Fig. 3 which also illustrates structures and measurements used in the identification of crayfish.

Annulus Ventralis: sperm receptacle on sternum of female between posterior 2 pairs of walking legs; also called seminal receptacle.
Areola: area (usually hour-glass shaped) on mid-dorsal surface of thorax, bound by grooves or lines marking dorsomedial limits of gill chambers.
Carapace: exoskeletal covering of cephalothorax.
Carina: median dorsal ridge near tip of rostrum.
Carpus: third segment from free tip of pereiopods (counting movable finger as segment 1).
Central Projection: strong projection formed by fusion of centrocephalic and centrocaudad processes; located centrally on tip of *Procambarus* gonopod, laterally on *Orconectes* and *Cambarus* gonopod; corneous in form I male.
Cephalothorax: fused head and thorax.
Chela: grasping pincer or claw; large chelae sometimes called hands; composed of segments called dactyl and propodus.
Corneous: of horny texture; cornified.
Coxa: proximal segment from free tip of pereiopods.
Dactyl: distal most segment of pereiopods; smaller movable part of pincer or chela; sometimes called movable finger.
Fossa: wide, deep cavity or sinus in surface of annulus ventralis.
Gonopod: modified first abdominal swimmeret of male.
Ischium: fifth segment from free tip of pereiopods.
Marginal Spines: lateral spines at base of acumen on rostrum.
Mesial Process: process located caudomesially on *Procambarus* gonopod; mesially on *Orconectes* and *Cambarus* gonopod.
Pereiopod: any of 10 walking legs on thoracic region.
Pleopod: any appendage on abdominal segments excluding uropods;

also called swimmerets.

Rostrum: dorsomedial, cephalic extension of carapace partially covering eyestalks and bases of antennae and antennules.

Sternum: ventral, sclerotized plate or bar of a segment.

Tubercle: low, rounded eminence of exoskeleton.

KEY TO IOWA DECAPOD CRUSTACEANS

This key to the crayfishes of Iowa utilizes a wide range of morphological characteristics so that form I and form II males, as well as females and in many cases immature crayfishes, can be identified. However, the most reliable species identification character is the shape of the first pleopod of a form I male crayfish and this should be used whenever possible. For comparative purposes, all illustrations of the first pleopod are made of the left member of the pair. The illustrations in this key have been modified after Hobbs (1972) to show variation noted in Iowa specimens.

1. First 2 pairs of pereiopods chelate; cephalothorax and abdomen flattened laterally; abdomen with a sharp bend; rostrum armed with median row of laterally compressed teeth. . Family Palaemonidae
   Represented in Iowa by *Palaemonetes kadiakensis* (Rathbun) (Fig. 4)
   First 3 pairs of pereiopods chelate; cephalothorax subcylindrical; abdomen somewhat flattened dorsoventrally, without a sharp bend; rostrum without teeth . . . Family Cambaridae 2
   Represented in Iowa by 3 genera and 7 species.
2. First pleopod ending in 2 processes. If processes short, then strongly hooked (Fig. 5a); if long, usually rather straight (Fig. 5b); annulus ventralis not freely movable, firmly fused to sternum . . . Genus *Cambarus* and *Orconectes* 4
   First pleopod blunt and ending in 3 or more processes. Form I male pleopod terminating in 3 or more distinct, short, and slightly curved processes while form II male pleopod appearing rounded at end and terminal processes difficult to distinguish (Fig. 5c); annulus ventralis freely movable, not firmly fused to sternum . . Genus *Procambarus* 3
3. Hooks present only on ischium of third pereiopods; areola obliterated, at least at mid-length; rostrum short and blunt; chela broad and flattened; annulus ventralis rounded (Fig. 6g) . . . . *Procambarus gracilis* (Bundy)
   Hooks present on ischium of third and fourth pereiopods; areola not obliterated; rostrum long and pointed; chela slender, rounded, and with long, pointed fingers; annulus ventralis not rounded (Fig. 6f) . . . . *Procambarus acutus acutus* (Girard)
4. First pleopod terminating in 2 elongate processes, both never bent at an angle as great as 90° to principal axis of appendage; rostrum long, pointed, and never greatly curved downward; areola never obliterated; annulus ventralis usually oval . . . Genus *Orconectes* . . . 5
   First pleopod terminating in 2 short processes hooked no less than 90° to principal axis of appendage; rostrum short, blunt, and greatly curved downward; areola obliterated at least in middle; annulus ventralis quadrangular (Fig. 6a) . . . . *Cambarus diogenes diogenes* Girard
5. Terminal process of first pleopod straight or slightly curved; dactyl of chela without notch at base on inner side; rostrum usually with marginal spines; fossa of annulus ventralis central 6
   Terminal process of first pleopod strongly curved caudally; dactyl of chela with notch at base of inner side; rostrum usually without marginal spines; fossa of annulus ventralis off to 1 side, not central (Fig. 6b) . . . . *Orconectes immunis* (Hagen)
6. Central projection of first pleopod more than ¼ total length of appendage (Fig. 5d); median spine or tubercle present on ventral distal margin of carpus of first pereiopod; usually without rostral carina 7
   Central projection of first pleopod less than ¼ total length of appendage (Fig. 5d); median spine or tubercle absent on ventral distal margin of carpus of first pereiopod; rostral carina present (Fig. 6c) . . . . *Orconectes iowaensis* Fitzpatrick
7. First pleopod not reaching coxa of first pereiopod when abdomen flexed; sides of rostrum usually slightly concave; chela lacking large tubercles on dorsal surface; carina frequently present; fossa of annulus ventralis small (Fig. 6d). . . *Orconectes rusticus* (Girard)
   First pleopod reaching coxa of first pereiopod when abdomen flexed; sides of rostrum usually straight; chela usually with large tubercles on dorsal surface; carina never present; fossa of annulus ventralis large (Fig. 6e) . . . . *Orconectes virilis* (Hagen)

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