

THE CRAYFISHES OF NEW ENGLAND

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Abstract.—Ten crayfish species have been collected in New England. On the basis of the known limits of their geographic distribution elsewhere, 3 species, *Procambarus (Scapulicambarus) clarkii* (Girard), *Orconectes rusticus* (Girard), and *O. obscurus* (Hagen) have been introduced into the area by man. The time, place, and persons involved in the introductions are unknown. For 3 other species, *O. limosus* (Rafinesque), *O. immunis* (Hagen) and *O. virilis* (Hagen), though a natural entry into New England can be postulated (with greatest confidence for *O. limosus*), there probably has been considerable transfer inter- and intraregionally by man. Four species have distributions in New England which largely have been attained naturally: *Cambarus (Cambarus) bartonii* (Fabricius), *C. (Puncticambarus) robustus* Girard, *O. propinquus* (Girard), and *Procambarus (Ortmannicus) acutus acutus* (Girard). Life history information is tabulated. A systematic list, figures, and distribution maps for each species are provided.

The presence of crayfishes in New England, with species unidentified, has been recorded by historians and essayists (Williamson, 1832:165; Thoreau, 1864:237). Information on the distributions of particular species began to accumulate with the recording of *Astacus bartonii* (now *Cambarus bartonii*) in Massachusetts by Gould (1841:330) and in Vermont by Thompson (1842:170). Hagen's monograph of 1870 adds to the distributional picture of *C. bartonii* in New England by including the Lake Champlain drainages in Vermont. He lists Maine, New Hampshire, Connecticut, and Rhode Island as being without crayfishes. Walter Faxon's several major crayfish studies and lists, while taxonomically important, add relatively little to the distributional picture in New England. He confirms the earlier records of *C. bartonii* in Massachusetts and Vermont, and adds Maine (1885a:143; 1885b:158-159). In his last work on crayfishes (1914) he adds *Cambarus affinis* (now *Orconectes limosus*) to the crayfish fauna of Massachusetts (Essex and Berkshire counties, pp. 372-373) and *Cambarus immunis* (now *Orconectes immunis*) to Massachusetts and New Hampshire (p. 378). He is puzzled by the records of *O. limosus* in Massachusetts but gives anecdotal evidence for its introduction by man into Berkshire Co. After several pages of discussion, he concludes that the presence of *O. immunis* in Berkshire Co., Massachusetts, is natural, but that the New Hampshire and other Massachusetts records represent introductions by man.

Scattered reports over the following 45 years have added species localities and a few new state records, but the distribution in New England of all these species has remained poorly delineated.

Findings of these reports are summarized briefly as follows: Rathbun (1905), *C. bartonii* in Connecticut (?), Maine, Massachusetts, Rhode Island (?), and Vermont; Norton (1909), *C. bartonii* in Maine; Osburn (1912), *O. limosus* introduced into Connecticut; Creaser (1933), *O. immunis* in Massachusetts and New Hampshire; Webster (1944), *O. immunis* and *O. limosus* in Connecticut; Crocker (1957), *O. limosus* in Maine; Crocker and Barr (1968:73), *O. propinquus* in Vermont; Camougis and Hichar (1959), *O. virilis* in Massachusetts. Two more recent and more extensive studies are those of Aiken (1965) who studied *O. immunis*, *O. limosus*, and *O. virilis* in lakes and ponds in New Hampshire, and of Bell (1971) who gives new state records for *C. robustus* in Connecticut and for *O. obscurus* and *O. virilis* in Vermont. Hobbs (1974b:53) gives the range of *Procambarus a. acutus* as (in part), "Coastal plain and piedmont from Maine to Georgia . . ." Thus Maine is clearly cited (although without a specific locality) and other New England states by inference are possible components of its range. He also (p. 43) includes Maine in the natural range of *O. virilis*.

These cited works place 7 crayfish species in the 6 New England states as follows:

CONNECTICUT—*C. bartonii* (?), *C. robustus*, *O. immunis*, *O. limosus*

MAINE—*C. bartonii*, *O. limosus*, *O. virilis*, *P. a. acutus*

MASSACHUSETTS—*C. bartonii*, *O. immunis*, *O. limosus*, *O. virilis*

NEW HAMPSHIRE—*O. immunis*, *O. limosus*, *O. virilis*

RHODE ISLAND—*C. bartonii* (?)

VERMONT—*C. bartonii*, *O. limosus*, *O. obscurus*, *O. propinquus*, *O. virilis*

This is the framework on which I have attempted to round out the species patterns of distribution. I have collected or have been given a total of 10 species of crayfishes from 274 collecting sites in New England. All specimens on which these records are based are in the collections of the National Museum of Natural History (NMNH). Another 63 species localities have been taken from the literature. These 337 localities are represented in Fig. 2. The coverage of the 6 states and of areas within them is uneven by reason of collecting difficulties, source of gift specimens, location of my base of operations, and some conjecture as to where the areas of interest might be. Collecting has been done largely by hand picking but with the use of a 10 ft seine where conditions permit and when an assistant is available.

Systematic List of the Crayfishes of New England

Hobbs (1974a:1-4) places the families of crayfishes in the astacuran Infraorder Astacidea, Superfamily Astacoidea. See also his checklist of North and Middle American crayfishes (Hobbs, 1974b) for full synonymies.

Family Cambaridae Hobbs, 1942

Subfamily Cambarinae Hobbs, 1942

Genus *Cambarus* Erichson, 1846Subgenus *Cambarus* Erichson, 1846

Cambarus (Cambarus) bartonii (Fabricius), 1798. [*C. (C.) bartonii* is considered now to be without subspecies following Bouchard (1975:587).]

Subgenus *Puncticambarus* Hobbs, 1969

Cambarus (Puncticambarus) robustus Girard, 1952

Genus *Orconectes* Cope, 1872

Orconectes immunis (Hagen), 1870

Orconectes limosus (Rafinesque), 1817

Orconectes obscurus (Hagen), 1870

Orconectes propinquus (Girard), 1852

Orconectes rusticus (Girard), 1852

Orconectes virilis (Hagen), 1870

Genus *Procambarus* Ortmann, 1905. (Proposed as subgenus by Ortmann, raised to generic rank by Hobbs, 1942.)

Subgenus *Ortmannicus* Fowler, 1912

Procambarus (Ortmannicus) acutus acutus (Girard), 1852

Subgenus *Scapulicambarus* Hobbs, 1972

Procambarus (Scapulicambarus) clarkii (Girard), 1852

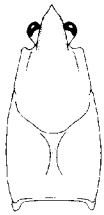
Identification of species can be accomplished relatively easily by comparing specimens with the drawings (Fig. 1), supplied by H. H. Hobbs, Jr. Sexually mature male crayfishes undergo a seasonally cyclical change in the shape of the copulatory appendages (first pleopods). Form I males are capable of mating successfully. Form II males cannot do so and their first pleopods more nearly resemble those of immature males. Both forms are illustrated in Fig. 1. The copulatory appendages together with the female's

→

Fig. 1 (pp. 228 and 229). The 10 species of crayfishes in New England. With the exception of *Procambarus (Ortmannicus) acutus acutus* and *P. (Scapulicambarus) clarkii* the sequence of figures from left to right is the same: 1, Dorsal view of carapace of male, form I; 2, First pleopod of male, form I, mesial view; 3, same, lateral view; 4, same, form II, lateral view; 5, Annulus ventralis (seminal receptacle) of female; 6, Dorsal view of right chela of male. For the 2 *Procambarus* species, the third drawing is 2 enlarged views of the first pleopod of a first form male, lateral view above, mesial view below.



Orconectes virilis



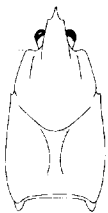
Orconectes immunis



Orconectes rusticus



Orconectes propinquus

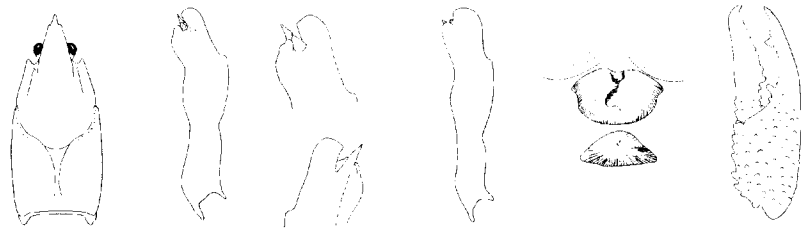


Orconectes obacurus

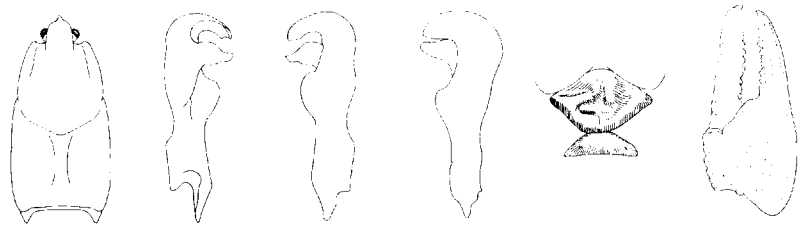




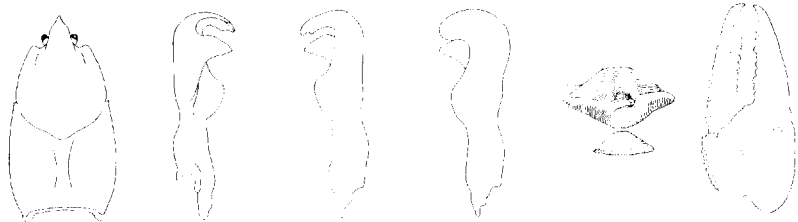
Procambarus (Ortmannicus) acutus acutus



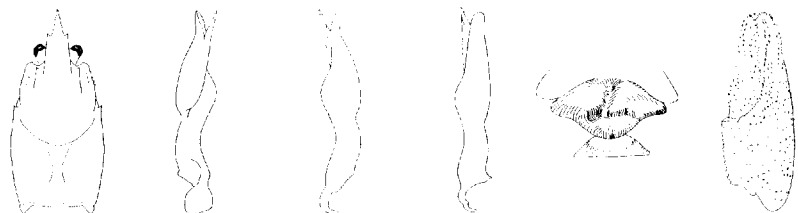
Procambarus (Scapulicambarus) clarkii



Cambarus (Cambarus) bartonii



Cambarus (Puncticambarus) robustus



Orconectes limosus

Table 1. Seasonal events for males of *Orconectes propinquus* in New England.

quarter	June		July				August			
	2	3	1	2	3	4	1	2	3	4
form I	0	0	2	0	30	4				
form II	1	16	0	0	0	0				

annulus ventralis, into which the sperm mass is introduced, are especially useful in distinguishing among species.

Life History Information

Although the emphasis of the study is distribution, collections of crayfishes contain life history information which, when added to other information, contributes to a knowledge of their total biology. Some life history information and an entry into the literature for several of the New England species occurring in New York and Ontario is given by Crocker (1957) and Crocker and Barr (1968). A current summary of the population dynamics of crayfishes and their role in ecosystems is given by Momot *et al.* (1978).

The following data are summarized from all collections taken in New England over a period of 20 years. Thus, for several species, the data represent an average of the effects of climatic factors over the entire region and of variations in seasonal weather during the years when collecting was done. Thus the data may not necessarily represent precisely the timing of life cycle events in a particular locality in a given year. A population of a species in southern New England or a warmer body of water would be expected, for example, to lay eggs earlier than populations of the same species in more northern parts or colder water. Also, the time of seasonal molt would be less extended in any one particular locality or any one year than over the region as a whole, or over the entire period of collecting.

Too few adult males of the following species were captured to permit gaining information about seasonal molting: *Cambarus bartonii*, *C. robustus*, *Orconectes immunis*, *O. rusticus*, *Procambarus a. acutus*, and *P. clarkii*. Females of these species with eggs or young were taken as follows:

Table 2. Seasonal events for males of *Orconectes limosus* in New England.

quarter	June				July				August			
	1	2	3	4	1	2	3	4	1	2	3	4
form I	2	2	1	1	0	0	0	2	4	2	1	21
form II	4	1	3	0	8	0	9	15	11	6	1	5

Table 3. Seasonal events for males of *Orconectes virilis* in New England.

quarter	June		July				August			
	3	4	1	2	3	4	1	2	3	4
form I	3	2	1	0	2	5	3	1	9	29
form II	3	5	4	1	9	10	7	5	2	9

Orconectes immunis: 2 females with eggs, Rhode Island, 2 May 1966 and 31 May 1958. Aiken (1965:242) reports that all female *O. immunis* collected from Newfound Lake, New Hampshire, on 13 and 14 June 1963 were carrying young.

O. rusticus: 2 females with young, Maine, 11 June 1959.

Procambarus a. acutus: 1 female with young, Rhode Island, 12 Aug 1971.

An extensive bibliography for this species and for *P. clarkii* is given by Spohrer *et al.* (1975).

For the remaining 3 species the data, though far from satisfactory, are more suggestive of seasonal events.

Orconectes propinquus: Seasonal events for males are given in Table 1. The earliest spring form II male was taken 11 June 1953 in Massachusetts. The taking of 30 males in the third week of August, all of them form I, suggests that the majority of individuals are form I by that time. I have no records of females with eggs or young from New England.

Orconectes limosus: Seasonal events for males are given in Table 2. The lack of collecting in March, April, and May prevents documenting the time of the spring molt, but the data strongly suggest that the late summer molt occurs among most individuals during the last 2 weeks of August. Individual adult males taken in months other than those tabulated above are all form I (April—1, September—9, October—11). A female with eggs was collected in Rhode Island on 9 May 1965. Aiken (1965:241) reports taking several egg-bearing females from the Newfound River, N.H. on 13 June 1963.

Orconectes virilis: Seasonal events for males are given in Table 3. Again, data are suggestive only for the late summer molt of adult males. As with *O. limosus*, it appears that this molt occurs most frequently in the last two

Table 4. Seasonal events for males of *Orconectes virilis* in New Hampshire (data from Aiken, 1965:242–243).

	19 June	22 June	27 June	7 July	24 July– 20 Aug	27 Aug	2 Sept
% form I	93	91	55	39	28	85	93
% form II	7	9	45	61	72	15	7

weeks of August. Individual adult males taken in months other than those tabulated are all form I (April—2, September—2, October—12).

Aiken (1965:242–243) reports for this species the results of trapping in Lake Winnepesaukee, N.H. during the spring, summer and fall of 1962. He gives the actual number trapped only for the 24 July–20 August sample (938 males). For this locality the data summarized in Table 4 show that the early summer molt occurs primarily in the last week of June and that the late summer molt occurs in the last week of August. I have four dates for the capture of females with eggs or young as follows: female with eggs, 24 April 1952 (N.H.), 2 May 1966, and 12 May 1965 (R.I.); 4 females with young, 25 June 1959 (Maine).

Introductions and Transfers

Three species occur in New England as isolated populations so far removed from the known geographic limits of the main distributional area of their conspecifics that I can only attribute their presence in New England to introduction by man.

Orconectes obscurus: Insofar as one may judge from published data, *O. obscurus* has as its natural range eastern Ohio, western Pennsylvania, West Virginia, and the Allegheny, Genesee, and upper Mohawk rivers in New York (Crocker and Barr, 1968:84). The New England localities now reported for the first time (Fig. 3) are (1) Greenwater Pond and Goose Pond, each only a few miles from East Lee, Berkshire Co., Massachusetts, and (2) Lake Webb in Franklin Co., Maine. I made the Massachusetts collections on 25 August 1952 after finding in 1950 or 1951, 5 dry apparently uncataloged specimens of this species in the Museum of Comparative Zoology, Cambridge, Massachusetts. These are 3 males I, 1 male II, and one female. The label reads "Goose Pond, East Lee, Mass./Rev. Robt. Keating Smith/July, 1917." The specimens were obtained from the Maine locality by me on 22 August 1956 and by Douglas Mathieu, a collecting assistant, on 6 August 1959.

The region between the localities in the upper Mohawk in New York and in East Lee, Massachusetts, has been well sampled for crayfishes (see Crocker, 1957, figures 4 and 5 on pages 73 and 78), but *O. obscurus* has not been collected there.

Bell (1971:16) reported taking *O. obscurus* at Hartland, Vermont, on the Connecticut River.

Crocker and Barr (1968:81–84) recorded the introduction of *O. obscurus* into southeastern Ontario.

Orconectes rusticus: This species does not quite reach Pennsylvania at the easternmost limit of its natural distribution. I cannot explain the following New England localities (Fig. 4) except as introductions by man—4 lo-

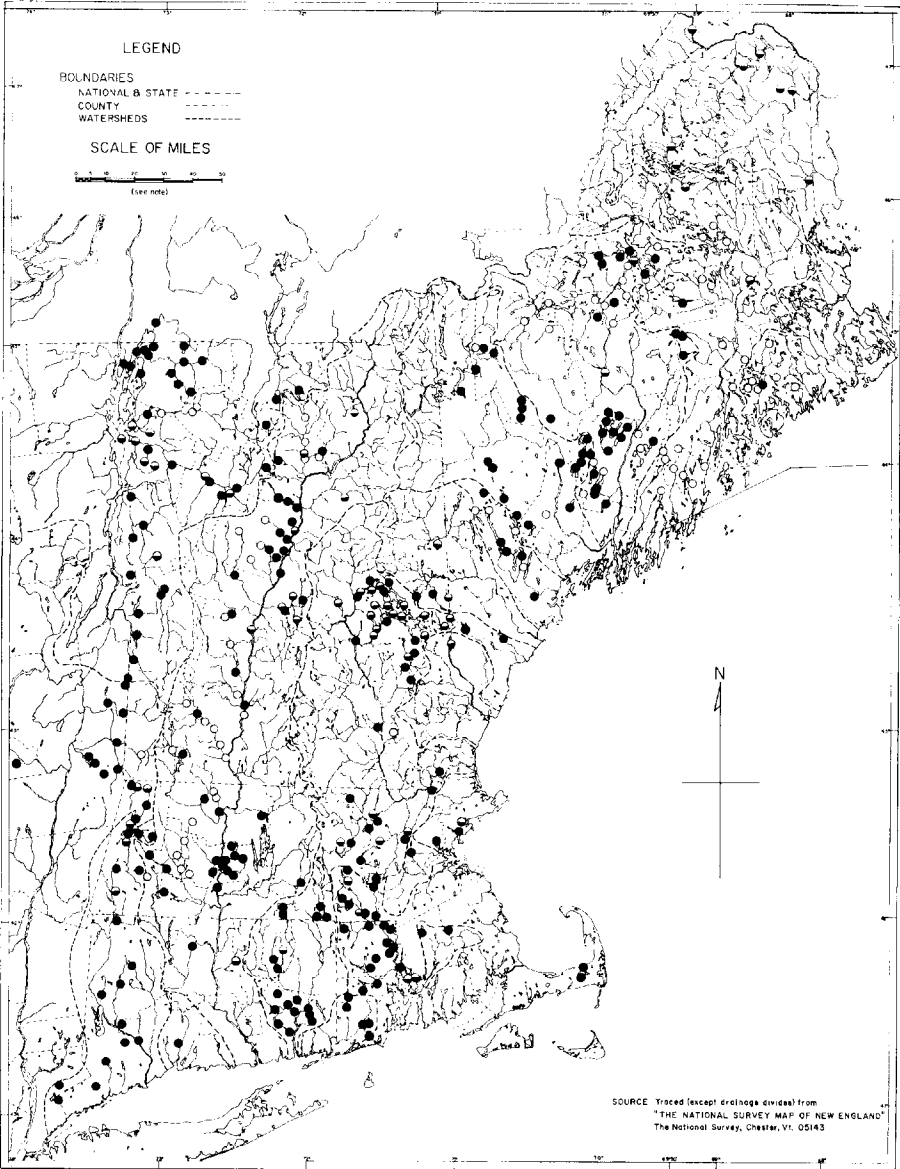


Fig. 2. Collection sites for crayfishes in New England. Dark circles = collections in National Museum of Natural History; half dark circles = literature reports of species localities; open circles = locations where at least 0.5 hr of collecting yielded no crayfishes.

calities of which occur in the Connecticut River system, and all in or within 5 mi of the mainstream of the river itself:

- (1) Conn. R. at N Walpole, Cheshire Co., N.H.
- (2) Conn. R. at N Thetford, Orange Co., Vt.
- (3) Wells R. about 1.5 mi NW of town of Wells River, Orange Co., Vt.
- (4) Stony Brook, S Hadley, Hampshire Co., Mass. (This locality was discovered independently by Douglas G. Smith of the Museum of Zoology, Univ. Mass., in collecting between 1972 and the present.)
- (5) Fenton River, Mansfield, Tolland Co., Conn., Thames River system.
- (6) Great Pond, North Pond, and Long Pond, Kennebec River drainage in Kennebec-Somerset Co., Maine.
- (7) Flying Pond in town of Vienna, Kennebec Co., Maine, Androscoggin River drainage.

The Massachusetts, Connecticut, and Maine collections were made between 1952 and 1959; those from New Hampshire and Vermont were made in 1970.

I report here also for the first time the collection in 1968 of *O. rusticus* in New York: artificial pond about 1.25 mi N of Rynex Corners (about 6 mi W of Schenectady), Schenectady Co., Mohawk-Hudson River drainage. Crocker and Barr (1968:88-90) record the introduction of *O. rusticus* into southeastern (4 localities) and western (1 locality) Ontario.

Procambarus clarkii: A single juvenile female of this species has been identified by H. H. Hobbs, Jr. in a collection from University of Rhode Island: Outlet of Arcadia Pond, Mike MacCrae, 5 April 1970. This site is about 0.5 mi N of Arcadia, Washington Co., R.I., at an edge of the Arcadia Management Area and near the Arcadia Warm Water Research Station. Two other URI collections from this area contain *P. a. acutus*. The range of *P. clarkii* is given by Hobbs (1974b:65) as northern Mexico to Escambia Co., Florida, and N to southern Illinois.

Transfers.—Through conversations in the summer of 1969 with Dr. Donald Mairs of the Maine Department of Inland Fisheries and Game, and with Mr. Robert Knowlton of the New Hampshire Fish and Game Department, I have learned that transfers of crayfishes between lakes within each of these states have been undertaken. I have been unable to obtain data on numbers and species transferred in New Hampshire, but in Maine, both *O. virilis* and *O. limosus* have been transferred between lakes in at least 6 instances, the numbers ranging from 36 to 4300. It is most likely that *O. virilis* is the species transferred in New Hampshire. Therefore, seemingly aberrant distributions of *O. virilis* in both states and *O. limosus* also in Maine may be the result of these attempts to establish crayfishes where they formerly were rare or absent.

Interpretation of Distributional Data

The locality records for *Orconectes rusticus*, *O. obscurus*, and *Procambarus clarkii* have been explained as introductions by man. It is difficult to assess how much influence introductions have had on the current distributions of other species. Though some recent introductions and transfers have been documented and though further interviewing and correspondence may gain more information, there is small likelihood that records survive, if they were kept at all, of earlier attempts and their success. The following quotations offer tantalizing suggestions of former crayfish abundance, a decline, and a later increase due to introduction. Documentation is not given for the general statements, however.

. . . why is it that in New England crayfish are almost altogether absent . . . [Andrews, 1906a:100].

A crayfish from the Charles River, collected and contributed by Mr. Alden Cheever adds to the evidence that this animal is increasing in Massachusetts waters. Crayfishes were once common in eastern New England, but as natives they almost disappeared. Their presence today is largely due to their introduction as food for fishes [Sanford, 1932:18].

For many years before the government stocked the ponds with crayfishes, as food for bass and other game fishes, these crustaceans were not common in New England, especially east of the Connecticut River. They are now breeding rapidly, however, and it is interesting to note that their mud houses, erected on the banks of ponds and streams, but connected with the water by underground passages, are becoming more numerous. Lewis Babbit has contributed some of these crayfishes, collected in Connecticut [Sanford, 1936:11].

. . . Prof. E. P. Larkin informs me that about forty years ago crayfishes (*C. bartonii*?) were not uncommon at Westerly, R.I. . . . [Faxon, 1885b:62].

Faxon (1885b:98) reports that *O. virilis* and *O. immunis* are two of the crayfish species most esteemed as food and that they are sometimes sent to the New York market from Milwaukee and other western cities. He also says (p. 89), "*C. affinis* [= *O. limosus*] is the common crayfish exposed to sale in the markets of New York and other eastern cities." Andrews (1906b) gives the sources of crayfishes shipped to New York City (and I would conjecture to New England cities as well) as being Potomac River, Montreal, Milwaukee, and possibly Chicago. It seems a logical assumption that industrialization in the latter half of the nineteenth century reduced crayfish populations in parts of New England and that sport fishing, gastronomic and

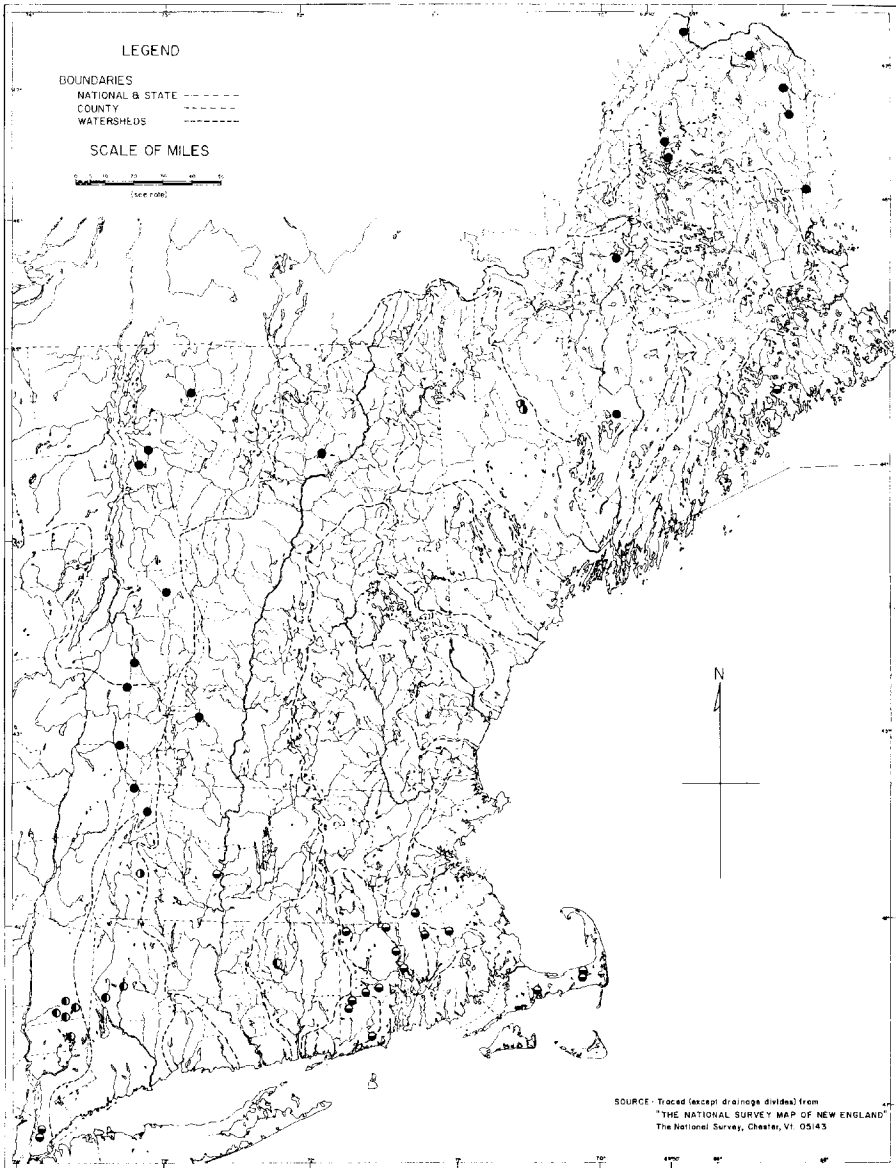


Fig. 3. Species localities for 4 species of crayfishes in New England. Black circles = *Cambarus bartonii*; circles half dark at left = *C. robustus*; circles half dark below = *Procambarus a. acutus*; circles half dark at right = *Orconectes obscurus*.

other interests would work to replace them. Unfortunately, the total number of collections of New England crayfishes prior to 1952 either reported in the literature or on deposit in MCZ or NMNH is too small to permit documenting this assumption.

Although the preceding information demands caution in the interpretation of distributions, I shall assume, unless specific known instances of introduction suggest the contrary, that distributions are natural if they have an inherent consistency and/or if Pleistocene glacial events and other geological data offer reasonable explanations for them.

Procambarus (Ortmannicus) acutus acutus (Girard)

Populations of crayfishes now referred to this subspecies and occurring naturally from Massachusetts to Georgia, formerly were referred to *Procambarus blandingii blandingii* (Harlan). Hobbs (1974b:53–54 and personal communication) now restricts *P. blandingii* to South Carolina and southern North Carolina, and he locates *P. a. acutus* as now understood, not only in the coastal plain and piedmont area referred to above, but also from the Florida panhandle westward to Texas and northward to the SE corner of Minnesota. It thus has an extensive range on both sides of the Appalachian chain. New England localities are shown in Fig. 3. The 2 New York localities shown in the figure are the Bronx River and are taken from Crocker (1957:70). Specific localities for New England have not been published and therefore I list the following 21 records by state.

MAINE

- (1) Hancock Co., George's Pond in Franklin, coll. by W. F. Reid, Jr., 29 Aug 1970.

MASSACHUSETTS

7 collections made by Tom J. Andrews:

- (2) Worcester Co., Upton township, inlet to Pratt Pond, draining Dean Pond, near Upton-Hopkinton Rd., 6 June 1956.
- (3) Plymouth Co., Bridgewater township, Lake Nippenicket near Lakeside Drive and rt. 104, 25 Nov 1955.
- (4) Bristol Co., Dorchester Brook, 50 yds below Monte Pond in Brockton, 20 June 1953.
- (5) Bristol Co., Norton township, SW end of Norton Reservoir, 31 Aug 1957.
- (6&7) Barnstable Co., Mill Pond in Brewster-Harwich townships, 28 Sept 1958 and 25 Aug 1959.
- (8) Barnstable Co., Brewster township, Small's Pond, 25 Aug 1959.

2 collections made by Bruce B. Collette:

- (9) Barnstable Co., Mills R. at rt. 28, 19 Sept 1957 (BBC 380).
- (10) Norfolk Co., Eagle Brook along rt. 140 between Foxboro and Wrentham, 21 Aug 1956 (BBC 247).

1 collection which I made:

- (11) Hampshire Co., Easthampton topographic sheet, Mill R. upstream from bridge at crossing of rt. 10, 1 mi SW of Northampton, Conn. R. drainage, 8 Aug 1953. This locality has been discovered independently by Douglas Smith of the Museum of Zoology, Univ. Mass., in collecting between 1972 and the present.

RHODE ISLAND

2 collections made in Kent Co. by D. W. and R. A. Crocker on 27 Aug 1971:

- (12) trib. of Big R. at rt. 3, 0.3 mi S of Noosneck at Noosneck Hollow Bridge.
- (13) S arm of Flat R. Reservoir at Harkney Hill rd. crossing.

8 collections from the Dept. of Zoology, Univ. R.I.:

- (14) Kent Co., small pond in W Warwick, SW of junc. of London turnpike and rt. 3, coll. by H.J.C., 15 April 1963.
- (15) Kent Co., Breakhart Brook at NE edge of Arcadia Management Area in West Greenwich, coll. by Mallen, 24 April 1965.
- (16) Providence Co., stream at crossing of rt. 103, 0.5 mi E of Riverside, coll. by Brewster, no date.
- (17) Providence Co., N shore of Sneecech Pond about 0.5 mi NE of Cumberland Hill, coll. by P. Izra, 1 April 1962.
- (18) Providence Co., Olney Pond in Lincoln Woods State Park, coll. by Harting, 12 May 1956.
- (19) Providence Co., Clear R. near junc. with Wilson Reservoir in Burrelville, coll. by D. J. Zinn, 22 April 1952.
- (20) Washington Co., Carolina Hatchery at Arcadia, coll. by Woods and Bishop, 20 July 1960.
- (21) Washington Co., stream in Tuckertown entering Worder Pond, coll. by J. Stedman, 1 May 1963.

The single locality in Maine is so distant from those in Massachusetts that I regard it as an introduction by man, especially so in that 16 coastal collection sites, 6 of them in the general area of this locality, produced no

crayfishes at all. The locality close to the Connecticut River in Massachusetts results from collecting on 8 Aug 1953 (Mill R. upstream from bridge at crossing of Mass. rt. 10, 1 mi SW of Northampton). The continued presence of *P. a. acutus* at this site is documented by 2 lots in the Museum of Zoology, University of Massachusetts, taken between 1972 and the present, reported to me by Douglas G. Smith (pers. comm.) of the Museum.

The northern natural limit for this species in the east lies in the southern half of Massachusetts as may be seen in Fig. 3. Although there are no records from Connecticut, this state also probably contained and may yet be found to contain *P. a. acutus*. The distribution in New England as now known strongly suggests a movement into Cape Cod through Connecticut, possibly via marginal glacial lakes.

Cambarus (Puncticambarus) robustus Girard

The cluster of 5 New York localities (Fig. 3) is taken from Crocker (1957:82, Fig. 6). These lower Hudson River sites were then known to be connected with 12 others in the upper Hudson and upper Mohawk Rivers by only one collection: Schoharie Creek in Schoharie County (New York State Museum crayfish collection no. 2514, taken on 26 July 1934). This collection consists of only one very small female and the identification might be questioned, but in June 1971 I located *C. robustus* in quantity in Rensselaerville, New York, in a tributary of Catskill Creek only 13 mi E of the Schoharie Creek site. Thus a population of *C. robustus* about half way between the southern and northern Hudson River drainage populations is assured.

On the basis of the distribution of *C. robustus* as we knew it when Barr and I were studying crayfish distributions in Ontario, it appeared that although the 5 southern New York collections could represent a relict population, they might have been derived from introductions by man. Therefore, they were omitted from the general distribution of the species (Crocker and Barr, 1968:121, inset map in Fig. 82).

Now, however, I am able to report *C. robustus* from 4 localities in Connecticut (Fig. 3). A fifth locality is given by Bell (1971:14), "Bigelow Brook, Ashford [Windham Co.]." This and my localities 1 and 2 (below) are in the Thames R. system. My 4 localities are:

- (1) Fenton River, Tolland Co., Mansfield; collected by Mildred C. Rokowski, 15 April 1953.
- (2) Fenton River, Tolland Co., Gurleyville; collected by Univ. Connecticut Field Zoology class, 20 July 1954.
- (3) West Branch Aspetuck River, Housatonic R. drainage, Litchfield Co., about 2 mi W of Northville; collected by D. W. and R. A. Crocker, 14 Aug 1971.

- (4) Shepaug River, Housatonic R. drainage, Litchfield Co., Woodville; collected by D. W. and R. A. Crocker, 24 Aug 1971.

There are thus 2 sets of sites, separated from each other by the Connecticut River drainage system. If we assume that this gap is an artifact of collecting or a result of recent extinction from this system, then it now appears that the localities for *C. robustus* in the lower Hudson drainage are not introductions by man or relict populations, but are part of an east-west series of populations extending into New England.

The total distribution of *C. robustus* is, in addition to the above, largely in portions of the states of Pennsylvania, Ohio, Michigan, Indiana, West Virginia, and Kentucky. It is known also from small parts of the states of Virginia, Tennessee, and North Carolina in the region where these three states meet (Crocker and Barr, 1968:121, inset map in Fig. 82; Hobbs, 1969:134, Fig. 7; Hobbs, 1974b:22). *C. robustus* is absent from eastern West Virginia (Newcombe, 1929), Maryland (Meredith and Schwartz, 1959), eastern Pennsylvania (Ortmann, 1906), New Jersey (Francois, 1959) and the Delaware and Susquehanna river systems in New York (Crocker, 1957:82). The current study has not found *C. robustus* in either Massachusetts or Vermont. It follows from the fact of the absence of *C. robustus* from these areas that its entry into Connecticut, the only New England state in which it is found, must have been at the western edge of the state via the lower Hudson River system. Thus, *C. robustus* is like *P. a. acutus* in having entered New England at its southwestern corner, but *C. robustus* entered from a northwesterly instead of a southerly direction. It seems reasonable to assume that *C. robustus* entered New England later than *P. a. acutus* since its movement eastward in New York must have been to the north of the Susquehanna and Delaware drainage systems. Such movement could not have occurred until recession of the glacial margin to that drainage border which lies about 125 mi N of the southernmost point at which *P. a. acutus* could have entered Connecticut. The validity of this assumption is strengthened by the extension of the range of *C. robustus* less far eastward than that of *P. a. acutus*.

Cambarus (Cambarus) bartonii (Fabricius)

Fig. 3 shows this species to be distributed in New England in association with the Appalachian mountain chain. This is in accord with Ortmann (1906:447) with whom both earlier and later students agree that, "We clearly see that its range follows the main strike of the Appalachian system, and . . . that ecologically this species is a form of the rapid and cool waters of the uplands and mountains, living preferably in small streams and even springs . . ." Water temperatures for 5 August collections made in Massachusetts and Vermont range from 14°C to 21°C with a mean of 17.7°C.

The northernmost locality in Vermont, though not typical of the sites sampled in this survey, is not unusual for the species and is here described as an illustration of a species habitat unique among those from which I have collected New England crayfishes, and to provide an explanation for the distribution of *C. bartonii* along a mountain chain.

The locality is Franklin County, township of Fletcher, about 4 mi S of Bakersfield on Vt. rt. 108 in a tributary to Black Creek. On 19 Aug 1970 the stream bed was dry at the road, but we followed it upstream on a 30° slope for about 0.5 mi until we reached a series of small pools. Here, searching for 45 min produced 1 male I, 2 males II, 1 female, and 10 immatures ranging from 7.0 to 16.5 mm carapace length. The water temperature was 15°C. Such habitats in gaps would allow crossing a divide overland and also they are susceptible to stream capture.

The apparent rarity of *C. bartonii* probably is in part an artifact of sampling. Relatively few typical sites were visited, and also it is my impression that even in those localities where it exists it is less abundant than other species of crayfishes. Scattered observations of feeding activities suggest that *C. bartonii* is more consistently carnivorous than other New England crayfishes. This would place it higher on a pyramid of numbers and would suggest a lesser abundance. However, eastern New Hampshire and Massachusetts as well as all of Connecticut and Rhode Island are coastal plain areas and their streams offer less suitable habitats for *C. bartonii*. Its absence there must be due at least in part to this ecological factor.

Hagen (1870:79) gives a seemingly anomalous locality record: "Aquarial garden, Boston." Rathbun reports (1905:19), "*C. bartoni* introduced into brook at New Haven in 1880, but none have been seen there since." Her species locality, Houlton, Maine, is the only record plotted in Fig. 3 which is taken from the literature.

Clearly an inhabitant primarily of the Appalachian chain, *C. bartonii* has moved northward into Maine, Quebec, and New Brunswick (Faxon 1885:60–61). Norton (1909) summarizes the distributional picture in Maine as known at that time. In Ontario it has become distributed as far west as the east shore of Lake Superior, but is rare in the region between Lakes Erie and Huron. Crocker and Barr (1968:113–115) document the above and describe the general distribution. Crocker (1957:84) has shown this subspecies to be widely distributed in New York, but rare in the streams entering the southern edge of Lake Ontario. It is present throughout Pennsylvania (Ortmann, 1906:381–382, 447, plate 43). In the mountains it reaches as far south as Georgia (Hobbs, 1974b:11).

Orconectes propinquus (Girard)

Fig. 4 shows that in New England *O. propinquus* is confined to the Lake Champlain and Hudson River drainage systems of Vermont and Massachu-

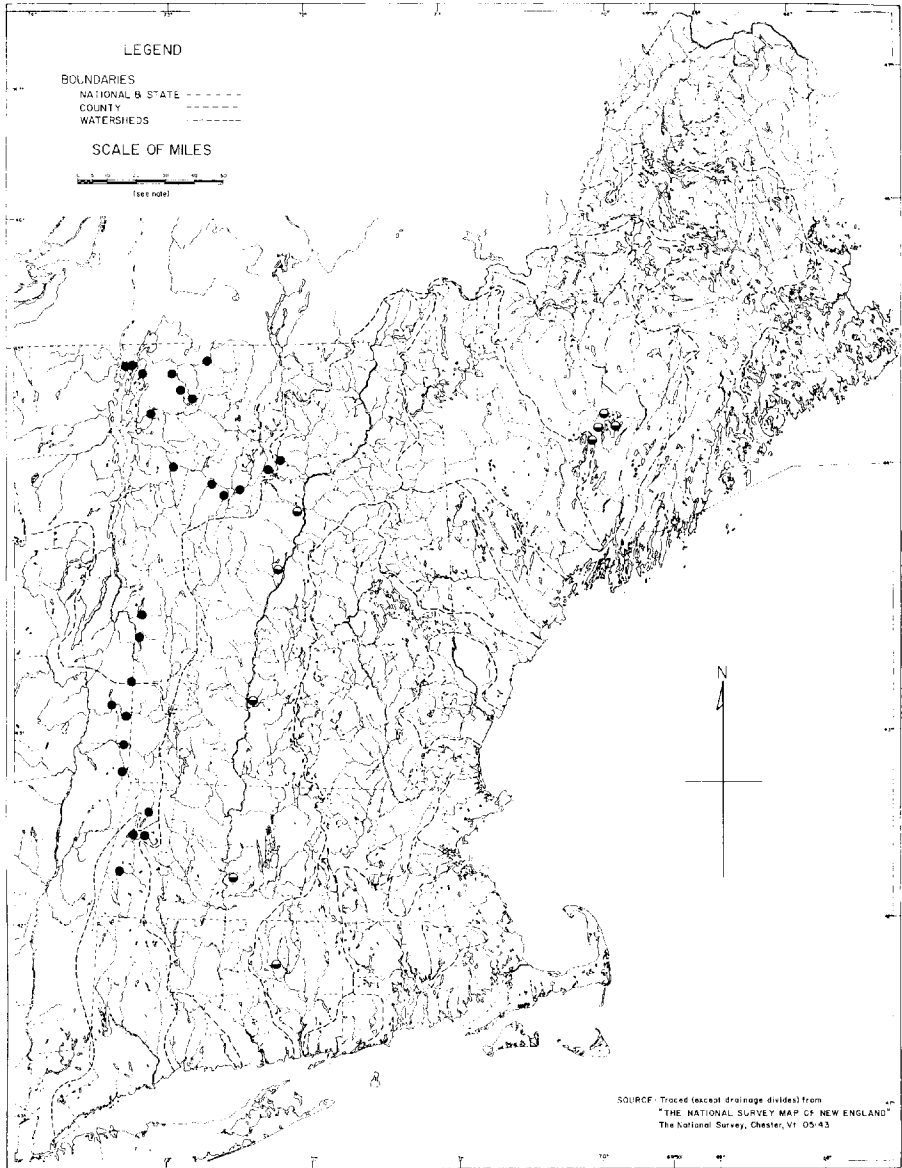


Fig. 4. Species localities for *Orconectes propinquus* and *O. rusticus* in New England. *O. propinquus* = dark circles; *O. rusticus* = circles with lower half dark.

setts with the exception of 4 localities: 1 just over the divide in the Connecticut River drainage, 2 just over the divide in the Housatonic River drainage, and 1 about 60 stream miles downstream from the previous 2 localities in the Housatonic River. The 5 New York localities in Fig. 4 are additional to those reported by Crocker (1957:78).

The distribution of this species is now fairly well known except for Quebec. Crocker and Barr (1968:71-73) delimit the general distribution as the southeastern half of Ontario reaching as far north as James Bay, the Lake Ontario drainages in New York (upper Hudson and Mohawk Rivers should have been included), and the northern border of Ohio. It is a common species throughout Indiana, and is in upper and lower Michigan, Wisconsin, and eastern Iowa.

O. propinquus apparently has entered New York and its limited area in New England by moving through glacial Lake Maumee and its subsequent stages, and by entering the St. Lawrence when it was formed.

Orconectes limosus (Rafinesque)

Localities plotted in Fig. 5 show this species in New England to be an inhabitant primarily of the coastal plain areas. The general distribution of this crayfish as previously known is northern Virginia, District of Columbia, eastern Pennsylvania, northwestern Maryland, western and northern New Jersey, Middlesex County in Connecticut, and Berkshire and Essex counties in Massachusetts (Rhoades, 1962:89). Crocker (1968:64) reports *O. limosus* to be in 3 adjacent drainages in Maine, "Sebago Lake—Presumpscot River, Kennebec—Androscoggin Rivers, and Penobscot River (and the adjacent Orland River)." Aiken (1964) found *O. limosus* in New Hampshire in Newfound Lake (and Newfound River below the lake), and in Conway Lake. Osburn (1912:924) reported receiving a letter from A. E. Ortmann with the information that *O. limosus* had been introduced into a lake in East Hampton, Connecticut. Douglas Smith (pers. comm.) adds Barnstable Co. to the Massachusetts records for *O. limosus* with 2 collections in the Museum of Zoology, University of Massachusetts: Orleans (no indication of body of water) and Brewster (Cliff Pond). Webster (1944:126) recorded the presence of *O. limosus* in Columbia Lake, Tolland Co., Connecticut. These also are coastal plain areas.

Crocker and Barr (1968) did not find *O. limosus* in Ontario. Crocker (1957:78) recorded the species as inhabiting in New York the Susquehanna, Delaware, and lower Hudson Rivers. No unquestioned localities for this crayfish have been reported previously for the Great Lakes-Lake Champlain-St. Lawrence River drainages. Crocker (1957:78-80) discussed 4 questionable localities. Fig. 5 shows localities for *O. limosus* at the N and S ends of Lake Champlain. Bell (1971:15) says it is common in shallow bays

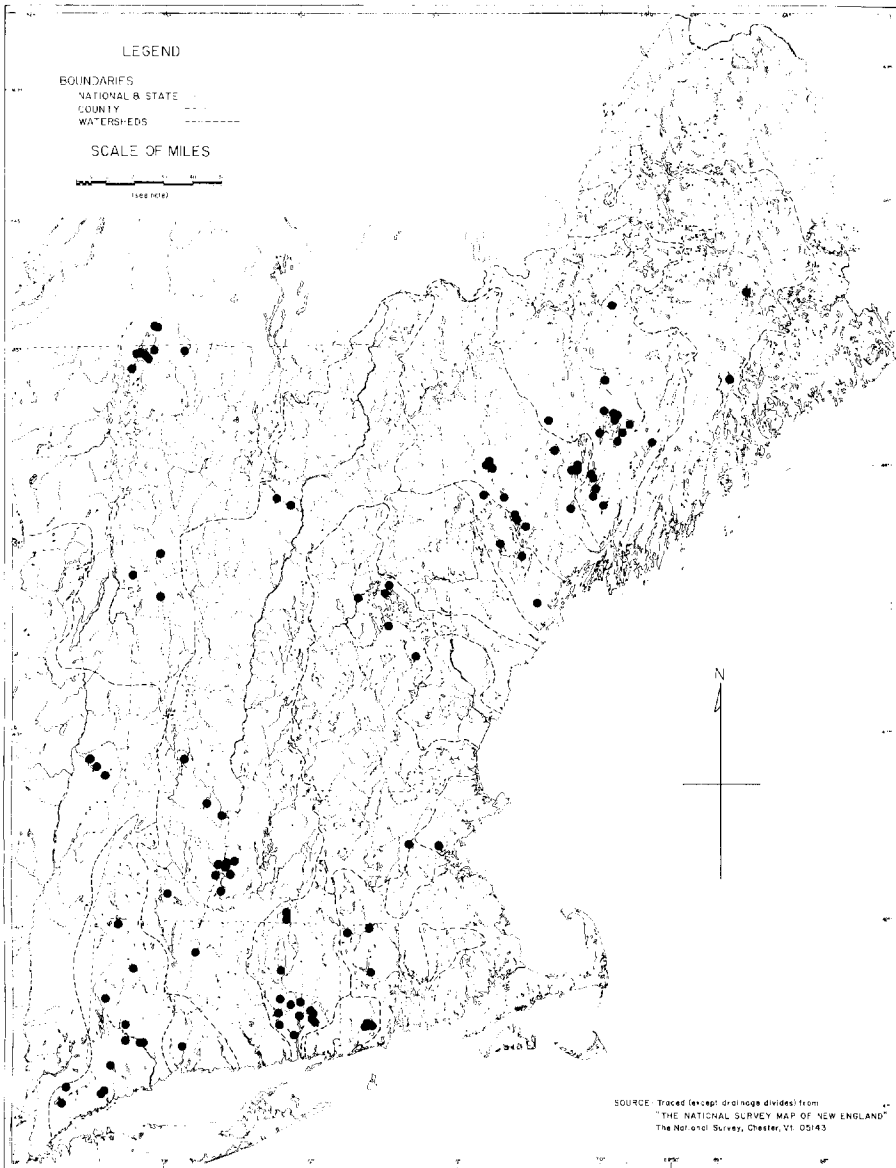


Fig. 5. Species localities for *Orconectes limosus* in New England.

of the lake and he gives 2 specific localities about midway along the length of its drainage area in Vermont: Shelbourne Pond and a pond in Winooski. At the time of my report on New York crayfishes (Crocker, 1957:78), *O. limosus* was not known in that state north of the mid-section of the Hudson River drainage, although the area was not sampled intensively. To my knowledge the western shores of Lake Champlain have not been searched for crayfishes subsequently, but I assume now that this species may be widely distributed in the Lake Champlain system.

O. limosus has entered New England from the lower Hudson River drainage system.

Orconectes virilis (Hagen)

Fig. 6 shows localities for this species in New England. In addition, 2 are included for Quebec (E shore, Three Sisters Island, Lake Memphramagog; small stream near Bedford). Six of the New York localities are repeated from Crocker (1958:71, Fig. 3), but the seventh (near the intersection of the state borders of New York, Vermont, and Massachusetts) is new. Crocker and Barr (1968:94-96) and Crocker (1957:72) give reference to studies from which the following picture of the general distribution of this species is drawn. *O. virilis* is the most widely distributed and abundant crayfish in Ontario. It ranges through the northern parts of Ohio, Indiana, Illinois, and Iowa. It occurs throughout the states of Michigan and Wisconsin. There are collections in NMNH from Atlantic Co., New Jersey and Summers Co., W. Virginia, and from several localities in Kansas and Missouri. It has not been found in Pennsylvania or Kentucky. Its southwestern limits are unclear, but several Montana localities are known.

Camougis and Hichar (1959) studied *O. virilis* in Hobbs Brook Reservoir in Lincoln, Massachusetts. Aiken (1965) reports this species from Great East Lake, Province Lake and Townhouse Pond on the Maine-New Hampshire border, and from Lake Winnepesaukee. He records its absence from Newfound Lake, and Conway Lake. In addition (pers. comm., 19 Sept 1969) he has supplied me with the following list of lakes in New Hampshire from which he has taken *O. virilis*:

Crystal	Lovell	Squam	Wentworth
Goose	Mascoma	Suncook	Wickwas
Kanasatka	Merrymeeting	Swains	Winnisquam
Little Squam	Mirror	Waukewan	

He reports the following lakes (or ponds) as lacking crayfish: Bow, Dan Hole Pond, Ossipee, Pine River Pond, Silver, Stinson. Douglas Smith (pers. comm.) reports a collection of *O. virilis* from the Connecticut River drainage of Massachusetts in the Museum of Zoology, University of Massachusetts: Hampshire Co., Mill River in Amherst.

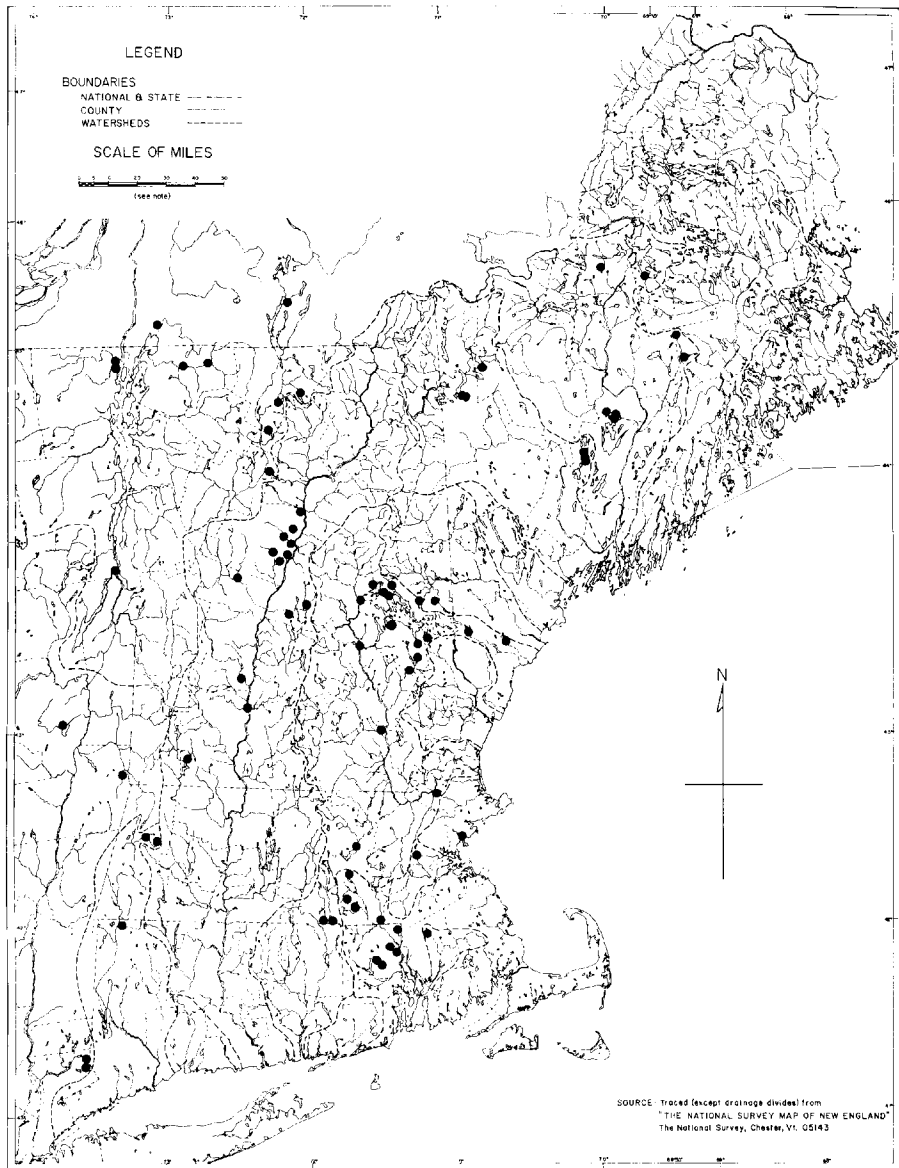


Fig. 6. Species localities for *Orconectes virilis* in New England.

I am not able to determine whether the patchwork distribution shown in Fig. 6 more nearly represents a natural or an artificial distribution, or in what proportions the agencies of man and nature have formed it. I have mentioned in an earlier section that transfers of this species within the area have occurred.

The movement of *O. virilis* eastward toward New England appears to have been through Ontario in postglacial times. In Ontario at present it is the crayfish with the most widespread distribution (Crocker and Barr, 1968:95). Five scattered localities in the Hudson River drainage system in New York seem best explained as introductions in that an early colonization probably would have achieved a spread throughout the state. Crocker (1957:71) shows that this spread has not occurred and that *O. virilis* is located only at the western, northern, and eastern borders. *O. virilis* has been shown to be an aggressive species which when introduced can expand its territory to the disadvantage of native species (Bovjberg, 1961 and 1970; Schwartz *et al.*, 1963).

Hobbs (1974b:43) includes Maine in the natural range of this species. He records it as introduced into California, Maryland, Tennessee, and “. . . parts of New England”

Orconectes immunis (Hagen)

Fig. 7 shows localities for this species in New England. The following outline of its total distribution is taken from Crocker and Barr (1968:106–107) where references are made to the supporting literature. *O. immunis* occurs throughout Indiana and Illinois. It is also in northwestern Tennessee, east-central Oklahoma, northeastern Kansas, the southern portion of Michigan, southeastern Ontario, northern New York, the southern half of Wisconsin, and southern Nebraska. Its greatest extent westward is in northwestern Colorado. This species has not been found in Pennsylvania, New Jersey, or West Virginia.

A few scattered records for New Hampshire and Massachusetts are given by Creaser (1933:16) and Faxon (1914:378). Aiken (1965) reports collecting this species in Newfound Lake in New Hampshire and he notes a collection of it in the Museum of Comparative Zoology, taken in Tilton, New Hampshire, in 1941. Douglas Smith (pers. comm.) reports a collection of *O. immunis* from Great East Lake, Carrol Co., N.H., and 2 collections from Hampshire Co., Mass. These are in the Museum of Zoology, University of Massachusetts. In the section above on introduction and transfers I pointed out that Faxon (1914) gives considerable attention to the Massachusetts records. He comes to the conclusion that (p. 381), “. . . Berkshire County is the eastern limit of the natural distribution of this species . . . ,” but he notes, “for what it is worth. . . the Berkshire countrymen whom I have

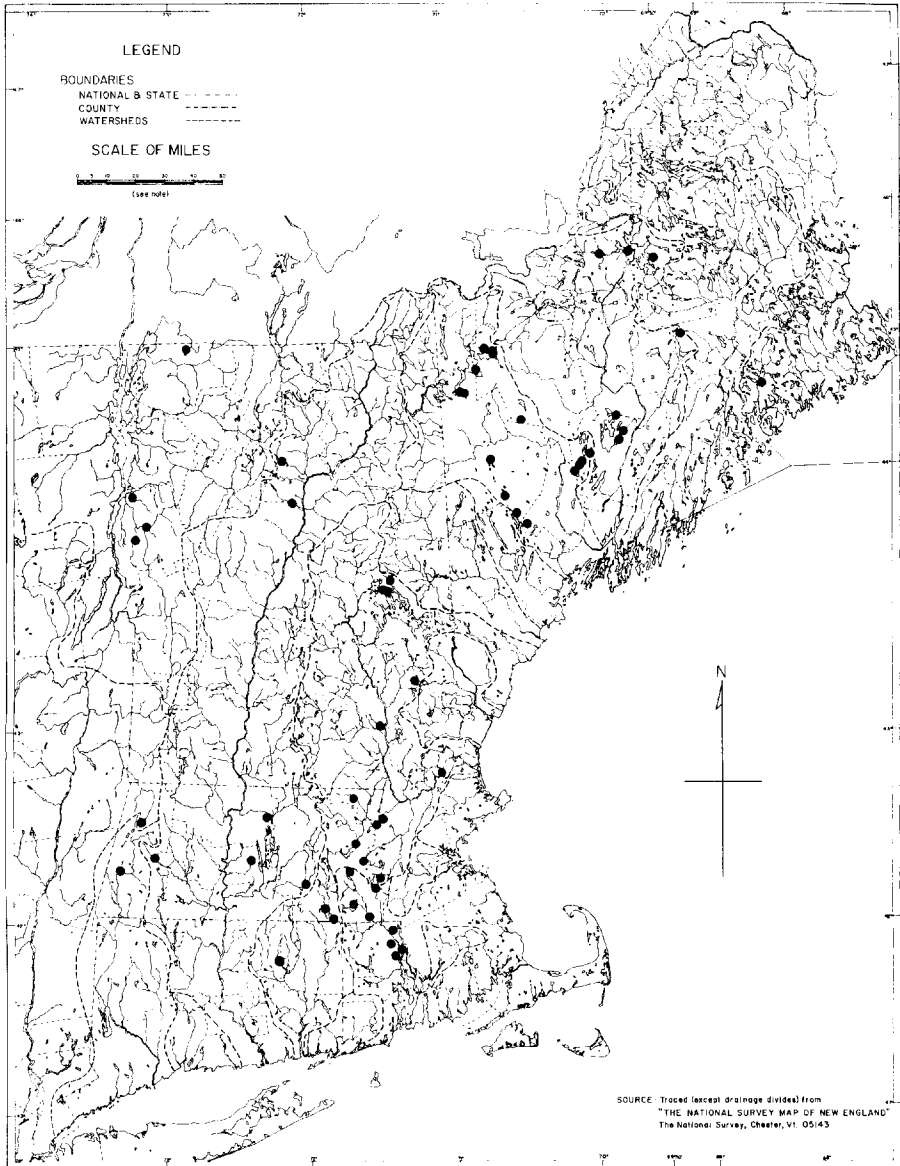


Fig. 7. Species localities for *Orconectes immunis* in New England.

questioned believe that crayfishes are a comparatively late addition to the fauna of the lakes [Pontoosuc Lake, Onota Lake, Lanesborough Pond, Goodrich's Pond]."

I am unable to offer with confidence a rationale for the distributional pattern of *O. immunis* in New England. One problem is that in my contacts with bait dealers in New York, I have found *O. immunis* to be the species most commonly propagated in artificial ponds. Forney (1956:6) recommends it as the only species of crayfish to try to culture. Some of the New England species localities for *O. immunis* may well have resulted from the activities of bait dealers and from their customers as well. This is just one aspect of the general problem of introductions and transfers discussed earlier.

Considering the direction of movement of *O. immunis* toward New England and its area or areas of entry, one can be somewhat more confident. Looking at maps of the distribution of this species in New York (Crocker, 1957:73) and Ontario (Crocker and Barr, 1968:107), this species is seen to be resident in many streams along the southern border of Lake Ontario, and well represented in Ontario in the area between Lake Erie and Lake Huron-Georgian Bay. Seven sites in the Susquehanna River drainage in New York are all close to the divide between it and the Lake Ontario watershed, and I consider them to be introductions or recent migrants over the divide southward. This picture suggests, considering also that *O. immunis* is not in Pennsylvania, that if this species moved eastward by natural means into New England, it did so at least in part through the area in New York where streams now drain northward into Lake Ontario. It could then have moved through the current Mohawk River valley and mid-portion of the Hudson River where populations of it now exist.

Did *O. immunis* move eastward through eastern Ontario and Quebec also, and enter New England from the north as well as from the west? Species localities for *O. immunis* are sparse in this area, possibly a result of inadequate sampling. Crocker (1957:73) shows a locality on the northernmost border of New York and Crocker and Barr (1968:107) show 3 localities near the outlet of Lake Ontario and a cluster of 4 localities about 100 mi NW of this area. A collection of *O. immunis* in the Museum of Natural Sciences, National Museums of Canada, from a site SE of Bancroft, Haliburton Co. is roughly midway between these 2 sets of localities (Diana Laubitz, pers. comm.). Bousfield (1969) does not include *O. immunis* among the crayfishes of the Ottawa region. Figure 7 shows 6 localities in the northern half of Vermont. If this total of 14 species localities represents a natural distribution, then either *O. immunis* has migrated eastward in Ontario via the Kirkfield or Ottawa outlets (Crocker, 1957:72) or it has reached these localities by spreading eastward and northward around the S and E sides of Lake Ontario through New York, having gained entry to that state perhaps in

Lake Maumee time. Entry into New England could have occurred in several areas along the New York-Vermont and New York-Massachusetts borders.

New State Records

To the state records for crayfish species summarized from the previous literature on page 3, the current study adds the first specific locality information for several species as follows:

Connecticut—*Orconectes rusticus*, introduced. It is still not certain that *Cambarus bartonii* is present and it is conjectured that *Procambarus a. acutus* is present.

Maine—*O. immunis* and *O. virilis* and as introductions, *O. obscurus*, *O. rusticus*, and *P. a. acutus*.

Massachusetts—*P. a. acutus* and as introductions, *O. obscurus* and *O. rusticus*.

New Hampshire—*O. rusticus* (introduced).

Rhode Island—*O. immunis*, *O. limosus*, *O. virilis*, and *P. a. acutus*; *P. clarkii* (introduced). It seems unlikely that *C. bartonii* occurs here naturally if at all.

Vermont—*O. rusticus* (introduced).

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