The Life History and Ecology of the Entocytherid Ostracod *Uncinocythere occidentalis* (Kozloff and Whitman) in Idaho

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SMITHSONIAN CONTRIBUTIONS TO ZOOLOGY • NUMBER 419

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SMITHSONIAN INSTITUTION PRESS
City of Washington
1985

ABSTRACT

Hart, C.W., Jr., Lee-Ann C. Hayek, Janice Clark, and William H. Clark. The Life History and Ecology of the Entocytherid Ostracod *Uncinocythere occidentalis* (Kozloff and Whitman) in Idaho. *Smithsonian Contributions to Zoology*, number 419, 22 pages, 8 figures, 11 tables, 1985.—A total of 10,173 ostracods was recovered from 45 crayfish collected during a water quality survey in spring, summer, fall, and winter in Eagle Drain, Ada County, Idaho. Population densities of ostracods were determined by sex, month, season, instar, and reproductive condition of the crayfish host. Ostracod shell lengths and heights were evaluated by instar, season, and sex. Water quality measurements were carried out to determine ecological conditions under which ostracods and crayfish hosts were living.

OFFICIAL PUBLICATION DATE is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, *Smithsonian Year*. SERIES COVER DESIGN: The coral *Montastrea cavernosa* (Linnaeus).

Library of Congress Cataloging in Publication Data
Main entry under title:
The Life history and ecology of the entocytherid ostracod Uncinocythere occidentalis (Kozloff and Whitman) in Idaho.
(Smithsonian contributions to zoology ; no. 419)
Bibliography: p.
Supt. of Docs. no.: SI 1.27:419
1. Uncinocythere occidentalis—Development. 2. Uncinocythere occidentalis—Ecology. 3. Crustacea—Development. 4. Crustacea—Ecology. 5. Crustacea—Idaho. I. Hart, C. W. II. Series.
QL1.S54 no. 419 [QL444.086] 595.3'3 85-600128

Contents

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Introduction

Comparatively little is known of the life history of entocytherid ostracods—a group of microscopic crustaceans known to be commensal on freshwater crayfish (North America, Mexico, Cuba, Hawaii, New Zealand, Australia, New Guinea), cave-dwelling isopods (Mexico, France, Italy, Yugoslavia, Texas), epigean, free-living isopods (Australia), wood-boring isopods (coastal waters of India and South Africa), marine amphipods (coastal waters of France and Italy), and a freshwater crab (Mexico).

Hart and Hart (1974:1–3) summarized the observations on growth and development made by Marshall (1903), Rioja (1940), Stamper (1957), and Young (1971) on four members of the subfamily Entocytherinae; by Paris (1920) and Roelofs (1968) on two members of the subfamily Sphaeromicolinae; and by Hart, Nair, Hart (1967) on the single representative then recognized in the subfamily Microsyssitrinae. To our knowledge, there have been no other detailed observations on the life history or molt stages of entocytherid ostracods, nor have there been any chemical or physical measurements of water quality directly associated with studies of these ostracods.

The present study is based on a series of crayfish collections made by one of us (WHC) from Eagle Drain, Ada County, Idaho, while carrying out a water-quality survey of the Boise River and its tributaries. The detailed analyses of the ostracod populations were made possible because each host crayfish was preserved in a separate container, thus permitting the ostracod infestations of individual crayfish to be studied.

ACKNOWLEDGMENTS.—We greatly appreciate the encouragement, advice, and manuscript criticism given by Horton H. Hobbs, Jr., National Museum of Natural History, Smithsonian Institution; and H.H. Hobbs III, Dept. of Biology, Wittenberg University, Springfield, Ohio.

Methods

COLLECTION LOCALITY.—Eagle Drain is a permanent drain carrying ground water and irriga-

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FIGURE 1.—Eagle Drain, Ada County, Idaho. Site from which crayfish, ostracods, and water samples were taken for this study.

tion return flow (in season) to the Boise River just south of Eagle, Ada County, Idaho. The collection locality (Figure 1) is located near the mouth of the drain (latitude 40°41′30″N, longitude 116°21′25″W), at an elevation of 780 m. The drain averages 3–5 m across and 1–2 m in depth at this site, and discharge during the study period ranged from 20–40 cfs. The bottom is sandy and was covered about 25%–30% by *Elodea*.

CRAYFISH HOSTS.—Crayfish (*Pacifastacus (Pacifastacus) leniusculus leniusculus* (Dana)) and their associated ostracods were collected during nine months over the period of one year (November 1977—September 1978) from Eagle Drain, a tributary to the Boise River, Ada County, Idaho. The crayfish were collected by hand or with the aid of a kick-net, and each individual was placed in a separate jar of 70% isopropyl alcohol. By keeping the crayfish separated, it was possible to make positive statements about them and their associated ostracods. Voucher specimens are deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., and in the Museum of Natural History, College of Idaho, Caldwell, Idaho.

All months were not represented in the collections, making analysis by individual months difficult. Therefore, collection data were combined into 3-month seasonal groups as follows:

winter	December*, January*, February
spring	March*, April*, May*
summer	June*, July*, August
fall	September*, October, November*

* = Months during which collections were made for this study.

Post-orbital carapace lengths were measured (mm) on the 191 crayfish collected. For each specimen sex, reproductive condition of female, and presence or absence of eggs were noted. Five crayfish were then randomly selected from each of the nine monthly collections for detailed examination of the ostracod populations.

OSTRACODS.—Ostracods collected from the Eagle Drain crayfish were identified as *Uncinocythere occidentalis* (Kozloff and Whitman, 1954).

All ostracods were removed from each of the 45 randomly selected crayfish, sorted from detritus, and mounted on microscope slides according to the methods described by Hart and Hart (1968).

A total of 10,173 ostracods was thus processed, and their sex and molt stages determined. In addition, 561 ostracods taken from crayfish collected in December 1977 were measured (length and height in μm) for an analysis of size of various instars and growth between them. Voucher specimens are deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., and in the Museum of Natural History, College of Idaho, Caldwell, Idaho.

WATER QUALITY.—Water samples were collected from Eagle Drain during five of the months when crayfish were taken—in November 1977, and January, March, June, and September, 1978. Chemical and bacteriological samples were analyzed by the State of Idaho, Department of Health and Welfare, Bureau of Laboratories, in accordance with procedures of the United States Environmental Protection Agency (1974) and the American Public Health Association (1976).

Grab samples were collected in 1-liter polyethylene Cubitainers and were preserved by cooling on ice to 4°C. In addition, samples destined for nutrient analyses were preserved with 2 ml H_2SO_4; those for trace metal analyses with 10 ml 1 :: 1 redistilled HNO_3. Samples for bacteriological analyses were collected in 250 ml sterile polyethylene bottles, treated with $Na_2S_2O_3$, and placed on ice. Dissolved oxygen (DO) and temperature data were obtained with a YSI 54A Dissolved Oxygen Analyzer; pH with a Photovolt model 126A portable pH meter; flow (discharge) with either a wade rod and Price AA Current Meter or by visual examination.

STATISTICS.—Descriptive statistics and cross-tabulations were computed for post-orbital lengths of the 191 crayfish collected. Statistical tests on the post-orbital means and F-tests on variances were used to investigate seasonal fluctuations, size, and sexual dimorphism.

For the random sample of 45 crayfish, correlations were calculated for post-orbital length and sex with ostracod measurements of shell height and length, as well as with numbers of ostracods according to instar, season, and sex. Analysis of variance methods and related tests of assumptions were used to investigate the ostracod sizes according to season, host crayfish measurements, and sex. Population densities of ostracods were determined by sex, month, season, instar, and reproductive condition of the crayfish hosts. Descriptive statistics and tests of hypotheses were also computed.

Key to the Species of the Ostracod Genus *Uncinocythere* Known from Idaho

(Based on Adults)

1. Shell with posteroventral projection 2
   Shell without posteroventral projection 3
2. Posteroventral projection arising anterior to posteriormost margin of shell .... ***U. thektura*** Hart, 1965
   Posteroventral projection arising at posteriormost margin of shell .... ***C. cassiensis*** Hart, 1965
3. Clasping apparatus C-shaped .... ***U. occidentalis*** (Kozloff and Whitman, 1954)

Clasping apparatus not C-shaped, having distinct horizontal and vertical rami 4

4. Peniferal cleft almost closed ventrally by posterior curve of anterior spine . . . . ***U. ericksoni*** (Kozloff, 1955)

Peniferal cleft not almost closed ventrally . . . . ***U. holti*** Hart, 1965

Ostracod Growth Stages

IMMATURE STAGES OF ENTOCYTHERID OSTRACODS, A SUMMARY.—Each molt of an ostracod apparently presents an animal differing in some respect from that of the previous stage (Kesling, 1951:94; Hart et al., 1967:5), and when new appendages are added the structures of the previous appendages are often changed. Marshall (1903:134, 135, fig. 7), in describing the first entocytherid ostracod, *Entocythere cambaria* (subfamily Entocytheridae), illustrated the "youngest stage" that he observed, but neither discussed subsequent development in depth nor recorded observations on the number of instars. Paris (1920:479–491, figs. 1, 19–22, 42, 43) first described a series of entocytherid instars—figuring an adult plus seven instars for *Sphaeromicola topsenti* Paris (subfamily Sphaeromicolinae). Rioja (1940:606, 607, pl. II: figs. 4–11) described the first four instars of *Entocythere heterodonta* (= *Ankylocythere heterodonta*), referred to them as "estados larvarios," but did not state specifically how many additional instars he observed. The next stage that he discussed was the biunguis female—an instar that he knew to be penultimate—which seemed to imply that he recognized five instars plus the adult form. Hart et al. (1967:5–10, figs. 8–17) described the instars of *Microsyssitria indica* Hart, Nair, and Hart (subfamily Microsyssitrinae), and observed only six instars plus adults. This latter pattern apparently holds also for *Uncinocythere occidentalis* (Kozloff and Whitman), the instars of which are described below.

IMMATURE STAGES OF *Uncinocythere occidentalis*.—*First Instar* (Figure 2*a*, Tables 1 and 2): Reflecting the elliptical shape of the egg from which it emerges, the shell of the newly hatched ostracod is also elliptical. For our sample of 12 ostracods determined to be in the first instar stage, the mean length (Figure 4) was 193.3 μm, with a standard deviation of 10.7 μm, while the mean shell height was 109.2 μm with a standard deviation of 9.9 μm. The range was 170–210 μm for the length and 90–120 μm for height.

The eyespot may or may not be observable at this time. Four pairs of appendages, or their anlagen, are evident—the antennules, the antennae, the mandibles, and the first pair of walking legs (Table 1).

(In the literature, the first pair of walking legs in instars 1 and 2 are referred to in various ways. They are the "prolegs" of Marshall (1903:135),

TABLE 1.—Order of appearance of appendages of *Uncinocythere occidentalis* (Al = antennule; An = antenna; Md = mandible; ( ) = anlagen; * = incomplete; Mx = maxilla; L1 = first thoracic leg; L2 = second thoracic leg; L3 = third thoracic leg; Gn = genitalia; P1 = first pair of walking legs; Ps = Posteroventral seta).

Instar	Appendages								
1	Al*	An*	Md*	Mx*	P1	–	–	–	–	Ps
2	Al*	An*	Md*	Mx*	P1	–	–	–	–	Ps
3	Al*	An*	Md	Mx*	–	L1*	(L2)	–	–	Ps
4	Al	An*	Md	Mx	–	cL1*	L2*	(L3)	–	Ps
5	Al	An	Md	Mx	–	L1	L2	L3*	(Gn)	–
6	Al	An	Md	Mx	–	L1	L2	L3	Gn*	–
7	Al	An	Md	Mx	–	L1	L2	L3	Gn	–

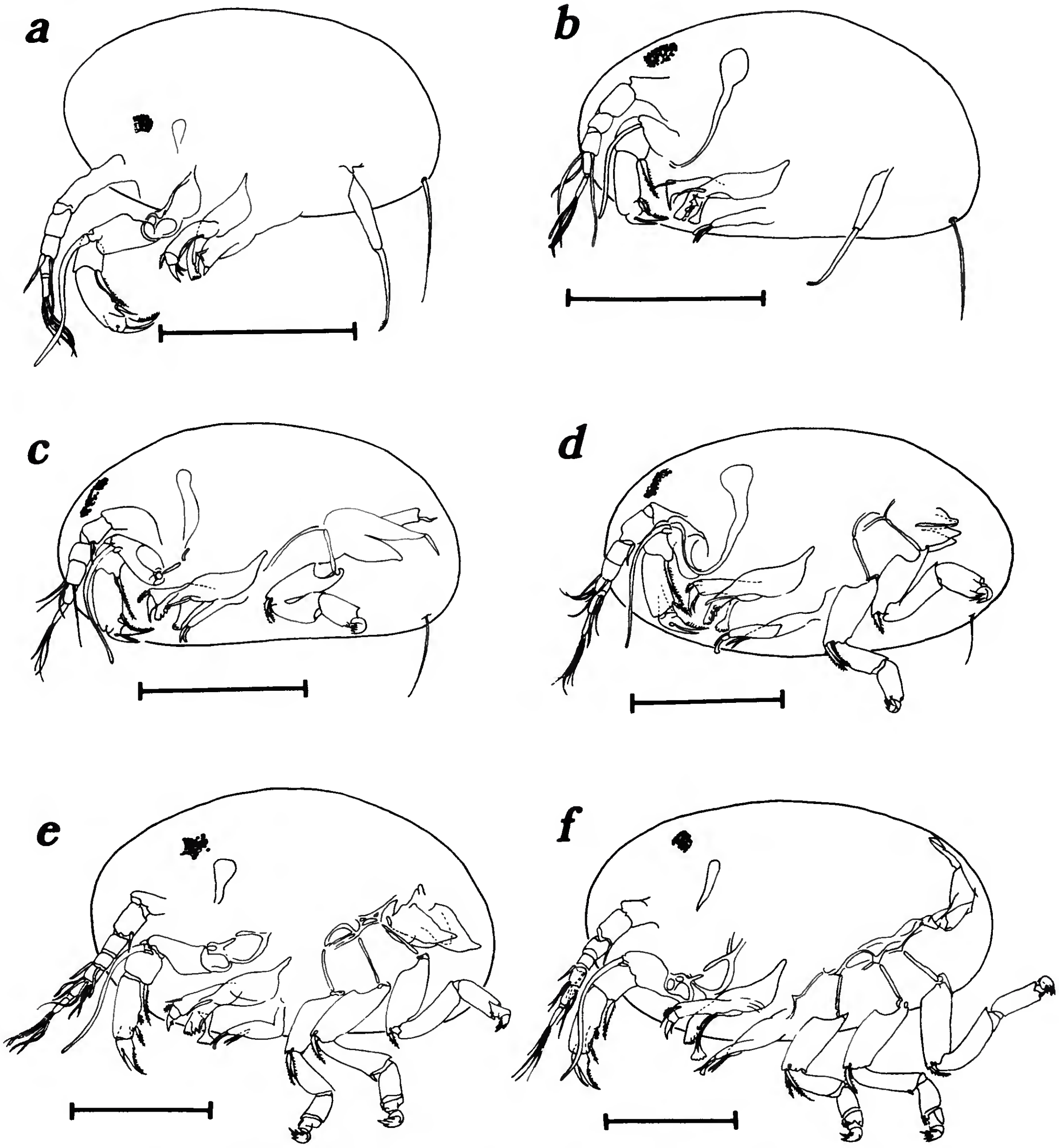

FIGURE 2.—*Uncinocythere occidentalis: a,* instar 1; *b,* instar 2; *c,* instar 3; *d,* instar 4; *e,* instar 5 ♂; *f,* instar 5 ♀. Scale bar = 100 μm.

the "maxillipedes" of Paris (1920:484), the "patas larvarias" of Rioja (1940:606), the "anlagen of the walking legs" of Hart et al. (1967:5), and the "larval feet" of Hobbs (1971:6)).

The antennule consists of five podomeres and a terminal brush of fine setae; the antenna comprises three podomeres, two terminal claws, and a well-developed exopodite; the mandible is well developed; the maxilla does not appear to be present. The antennules, antennae, and mandibles of *Uncinocythere occidentalis, Ankylocythere heterodonta, Entocythere cambaria,* and *Sphaeromicola topsenti* are better developed in the first instar than are those of *Microsyssitria indica* (Table 2).

The antennal gland is present, situated posterior to the eyespot and immediately dorsal to the base of the antenna.

As in all first instar entocytherids that have been studied, anlagen of the first walking legs of *U. occidentalis* differ greatly from the legs of the adults, each styliform appendage having only two discernible podomeres—the terminal one of which tapers to a point and bears a row of short fine setae along its anterodistal margin (Figure 2*a*).

Paris (1920:483, figs. 21, 43) illustrated the shell outline of this stage of *S. topsenti* and referred to it (and the next two instars) as "metanaupliens." This stage was also illustrated by Marshall (1903:141) for *E. cambaria,* showing well-developed antennules, antennae, and mandibles as well as a pair of "prolegs." He was uncertain whether the prolegs disappeared in subsequent instars or became changed into the first pair of permanent legs, noting (page 135) that "their position on the body is not so far forward as that of the first pair of legs." Hart et al. (1967, fig. 8) also figured this stage for *Microsyssitria indica,* and it is our present belief that these "prolegs" disappear and do not become changed into the first pair of permanent legs.

Second Instar (Figure 2*b*, Table 1): Forty-four ostracods were found to be in the second instar on the crayfish examined. These exhibited a statistically significant ($p<.01$) increase in mean length (30.1 μm) and mean height (11.9 μm) over the first instar ostracods. For these second instar ostracods the mean shell length was 223.4±7.1 μm; the mean shell height was 121.1±9.5 μm. Lengths ranged from 210 to 240 μm; heights from 100 to 140 μm. The antennules develop a sixth podomere, there appears to be little change in the structure of the antennae, and the maxillae appear for the first time. The "prolegs" remain similar to those of the first instar. The eyespot was present in all of the specimens examined, as it was throughout the remaining instars. As in the first instar, a pair of long, ventrally directed setae are present on the posteroventral margin of the shells.

Lacking legs with terminal claws adapted for holding onto the host, the method by which this and the previous instar remain attached to the crayfish is unknown. Hart et al. (1967:7, fig. 14)

TABLE 2.—A comparison of certain first instar characteristics in five entocytherid ostracod species.

Species	Antennule	Antenna	Mandible	Maxilla	Size range	Reference
ENTOCYTHERINAE						
Uncinocythere occidentalis	5 podomeres	3 podomeres 2 terminal claws	well developed	absent	170–210 μm	Kozloff and Whitman, 1954
Ankylocythere heterodonta	5 podomeres	3 podomeres 2 terminal claws	weakly developed	present	?	Rioja, 1940
Entocythere cambaria	5 podomeres	4? podomeres 2 terminal claws	well developed	absent	?	Marshall, 1903
SPHAEROMICOLINAE						
Sphaeromicola topsenti	5? podomeres	3 podomeres 2 terminal claws	well developed	present	170–180 μm	Paris, 1920
MICROSYSSITRINAE						
Microsyssitria indica	3 podomeres	2 podomeres 1 terminal claw	developed	absent	110–120 μm	Hart et al., 1967

figured a gelatinous sheath or strand encasing the "prolegs" of the first instar of *Microsyssitria indica*, and observed that such strands probably suffice to prevent loss of ostracods during the first two instars. Such strands have not been observed in other ostracods, but it seems possible that this might be due to the method by which they were initially preserved.

Third Instar (Figure 2*c*, Table 1): The third instar shows a statistically significant ($p<.01$) increase in average length of 27.3 μm and in height of 22.5 μm over the second stage. Of the 101 third instar ostracods, the mean shell length was 250.7±7.7 μm and the mean shell height was 143.6±8.2 μm—with length and height ranges of 230–280 μm and 120–160 μm, respectively. The most striking change over the previous instar is the disappearance of the prolegs and appearance of the first walking legs. These legs show adult entocytherid characteristics, notably the terminal claws that are apparently adapted for holding onto the setae of the host. At this stage, the first legs consist of three podomeres, as compared with four in instars 5 through 7. Also visible are anlagen of the second pair of walking legs, which appear in the fourth instar. These anlagen are unlike those of the first walking legs, appearing as undifferentiated "buds" immediately posterior to the first pair of walking legs.

The pair of ventrally directed setae on the posteroventral margins of the shells are present, as they were in the first two instars.

Fourth Instar (Figure 2*d*, Table 1): At the molt initiating this instar the 86 ostracods studied were an average of 30.4 μm longer than those in the previous instar (mean length, 281.1±9.7 μm). The average height increased by 17.1 μm (to 160.7±9.8 μm). These increases represented statistically significant growth ($p<.01$) in both dimensions over the prior stage. The range for shell length was 260–300 μm; and for shell height 140–180 μm. The antennule develops its seventh, and final, podomere. The second pair of walking legs appear at this time, and undifferentiated anlagen of the third pair may be seen immediately posterior to their bases.

As in the first three instars, a pair of ventrally directed setae are present on the posteroventral margins of the shells.

Fifth Instar (Figure 2*e,f*, Table 1): Sexual differentiation, including differential growth rates between instars for both sexes, becomes apparent at this stage.

Male: Undifferentiated anlagen of the copulatory apparatus are usually present posterior to the walking legs in the male (Figure 2*e*). Between the sexually undifferentiated fourth instar and the male fifth instar, a statistically significant ($p<.01$) amount of growth takes place. In our sample of 39 specimens there was an increase in length of 25.3 μm (to an average length of 306.4±10.1 μm) and an increase in height of 16.2 μm (to an average height of 176.0±10.0). Lengths ranged from 290 to 330 μm; heights from 160 to 200 μm.

Female: A precursor of an amiculum appears to be present in many female specimens at this stage (Figure 2*f*). Between the fourth undifferentiated instar and the recognizable female fifth instar there is also a statistically significant ($p<.01$) amount of growth. For the 26 specimens measured, an increase of 45.8 μm in length and 27.4 μm in height was observed. At this stage the average shell length and height for the females were 326.9±8.8 μm and 188.1±10.6 μm, respectively.

These data represent not only significant growth over the fourth instar, but our first indication of a statistically significant ($p<.01$) differentiation between the sexes in both shell dimensions. The range for male and female shell lengths was found to be 290–330 μm and 310–340 μm, respectively. These values for the height were 160–200 μm and 170–220 μm, which show the female to be consistently larger.

Sixth Instar (Figure 3*a,b*, Table 1): As with *Microsyssitria indica*, the greatest overall growth (64.3 μm in length; 37.3 μm in height) apparently takes place with the molt to this instar.

Male: The average length for males is 353.8±8.1 μm, based upon a sample size of 34. This is an increase of 47.4 μm from the fifth instar males. For the shell height there is an increase of

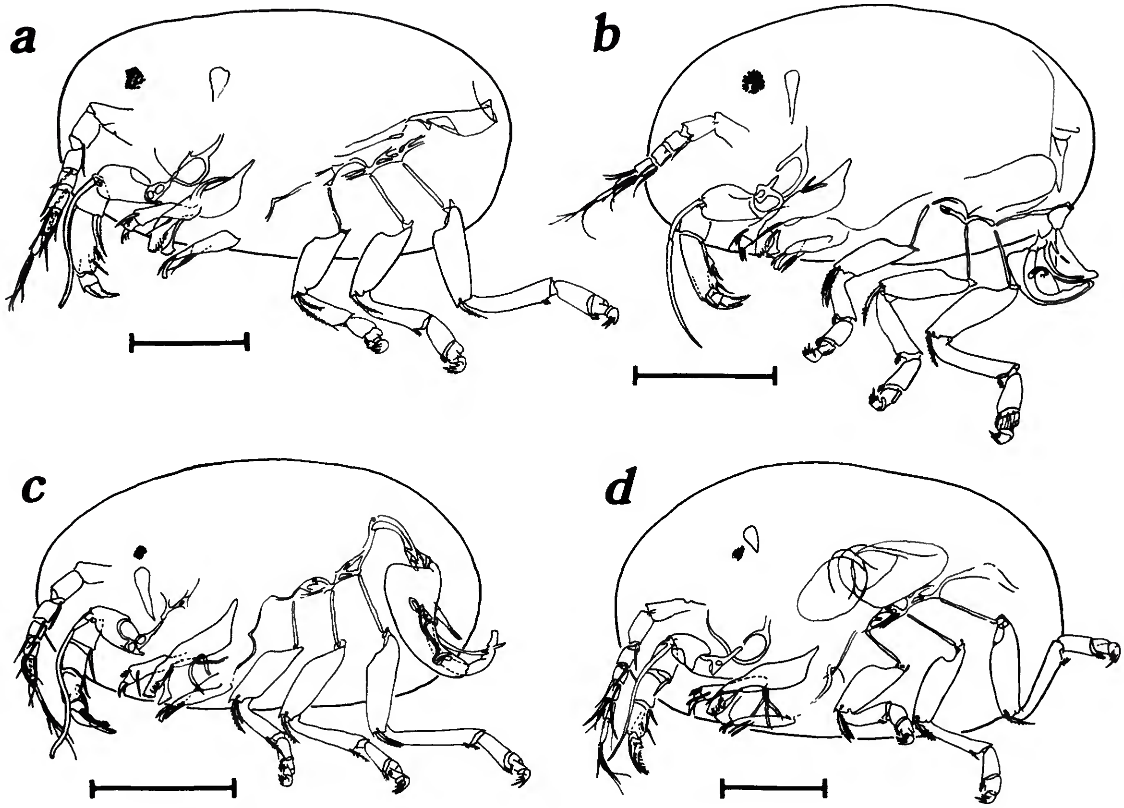

FIGURE 3.—*Uncinocythere occidentalis: a,* instar 6 ♂; *b,* instar 6 ♀; *c,* adult ♂; *d,* adult ♀. Horizontal measurement-line = 100 μm.

29.6 μm to an average of 206.5±9.2 μm. The range for shell length and height is 340–370 μm and 190–220 μm, respectively.

At this stage, the structure of the male copulatory apparatus is usually revealed as paired and partially developed clasping apparatus, peniferum, and associated fingers—apparently contained within the sheath-like anlagen "bud" that appeared in the fifth instar (Figure 3*a*).

Female: At this stage the females still have significantly (p<.01) larger shell dimensions than the males (Figure 3*b*). Based on the sample of 48 females, they attained an average shell length of 396.7±12.9 μm and an average shell height of 227.3±10.7 μm. This represents an increase of 69.8 μm in length and 39.2 μm in height. Lengths ranged from 360 to 420 μm; heights from 210 to 250 μm.

ADULT STAGE OF *Uncinocythere occidentalis.*—*Seventh Instar* (Figure 3*c,d*): *Uncinocythere occidentalis* attains its adult form in the seventh instar. For the 112 adult males in the sample, the average shell length of 388.3±9.6 μm represented a statistically significant (p<.01) increase of 34.5 μm over those males in instar 6. For the height, the average was 221.7±8.3 μm, which is a statistically significant (p<.01) increase of 15.2 μm. Lengths ranged from 370 to 410 μm; heights from 200 to 240 μm.

While it is conventional to illustrate only one half of the copulatory apparatus (as in Figure 3*c*), it should be understood that each part exists in duplicate (Hart and Hart, 1969:155–163) and serves to raise, lower, and position its integral organs of sperm transfer so that they are able to introduce sperm into the female. When the male ostracod is not concerning himself with copulation, the apparatus is held high within the shell and between the bases of the last pair of legs (Figure 4). When copulation is contemplated, the apparatus is lowered so that its distal portion extends beyond the shell (Figure 5). Then, before copulation can take place the entire apparatus is positioned further caudad so that the peniferums can clear the legs, and both swing through 180° lateral arcs. In this series of moves the apparatus reverses its non-copulatory position and makes it possible for the organs of sperm transfer to face anteriorly. The pivotal points for these maneuvers are shown in Figure 6, and the probable angular motions are indicated by appropriate arrows.

Female: The average shell length of the 59 adult females observed in this instar was 465.4± 15.2 μm; the average height was 281.2±12.6 μm. These measurements reflect a statistically significant ($p<.01$) increase over the dimensions of the sixth instar females, and show a growth of 68.7 μm in length and 53.9 μm in height. Shell lengths ranged from 430 to 500 μm; heights from 250 to 310 μm.

The adult females are, on the average, significantly larger than the males ($t_{169} = 37.1$ $p<.01$). The adult female of *Uncinocythere occidentalis* does not possess an obvious genital apparatus—as do adult females of the entocytherid genus *Dactylocythere*.

Ostracod Growth Patterns

Figure 7 is a diagrammatic representation of the growth pattern of *Uncinocythere occidentalis*. Each of instars 1 through 4 resulted in significantly ($p<.01$) larger shell dimensions. For the sub-adult specimens (instars 5 and 6), the sexes differ significantly in dimensions, with instar 5 females approximately 7% longer than males and instar 6 females approximately 12% longer than males. The corresponding percentages for shell height were 6% and 10%.

For adult *U. occidentalis* (instar 7), the same relationship held, with females larger than males by 20% in length and 27% in height. Thus, a comparison of adults with instar 6 individuals by sex shows the adult males to be significantly longer (18%) and higher (16%), while females are larger by 25% and 32%, respectively.

Ostracods and Their Crayfish Hosts

Because the methods by which the crayfish were collected varied and were therefore not consistent among the collections, a meaningful statistical analysis of growth patterns of the host crayfish used in this study cannot be made.

However, the total number of ostracods found on each of the 45 crayfish ranged from 12 to 935, with a median of 176 and a mean of 225.8± 205.7. Table 8 provides a breakdown of these data by season; Tables 3–7 summarize the crayfish/ostracod relationships by ostracod instar and intervals of crayfish postorbital carapace length. Overall, the majority of the ostracod population infests larger crayfish hosts. This is in keeping with the results of Young (1971). For instars 3 through 7, the larger the crayfish the greater the number of commensal ostracods found infesting it.

There appeared to be no correlation between crayfish size and the number of ostracods found in the first two molts. Although we have no proof, it seems likely that many ostracods of the smaller instars are lost between the time the crayfish hosts are collected and final mounting on slides; they may not be recovered from the detritus from which they are extracted, and they may become lost during dehydration, clearing, and mounting.

Most ostracod populations inhabiting individual crayfish appear to be composed predominantly of immature individuals. However, this percentage does not increase with increasing crayfish size. Also, crayfish with dense populations of ostracods do not have a higher incidence

FIGURE 4.—Posterior portion of entocytherid ostracod showing copulatory apparatus held up inside shell in non-copulatory position. (From Hart and Hart, 1969:159.)

FIGURE 5.—Three-dimensional drawing of copulatory apparatus and adjacent legs, with copulatory apparatus lowered to extend beyond shell. (From Hart and Hart, 1969:160.)

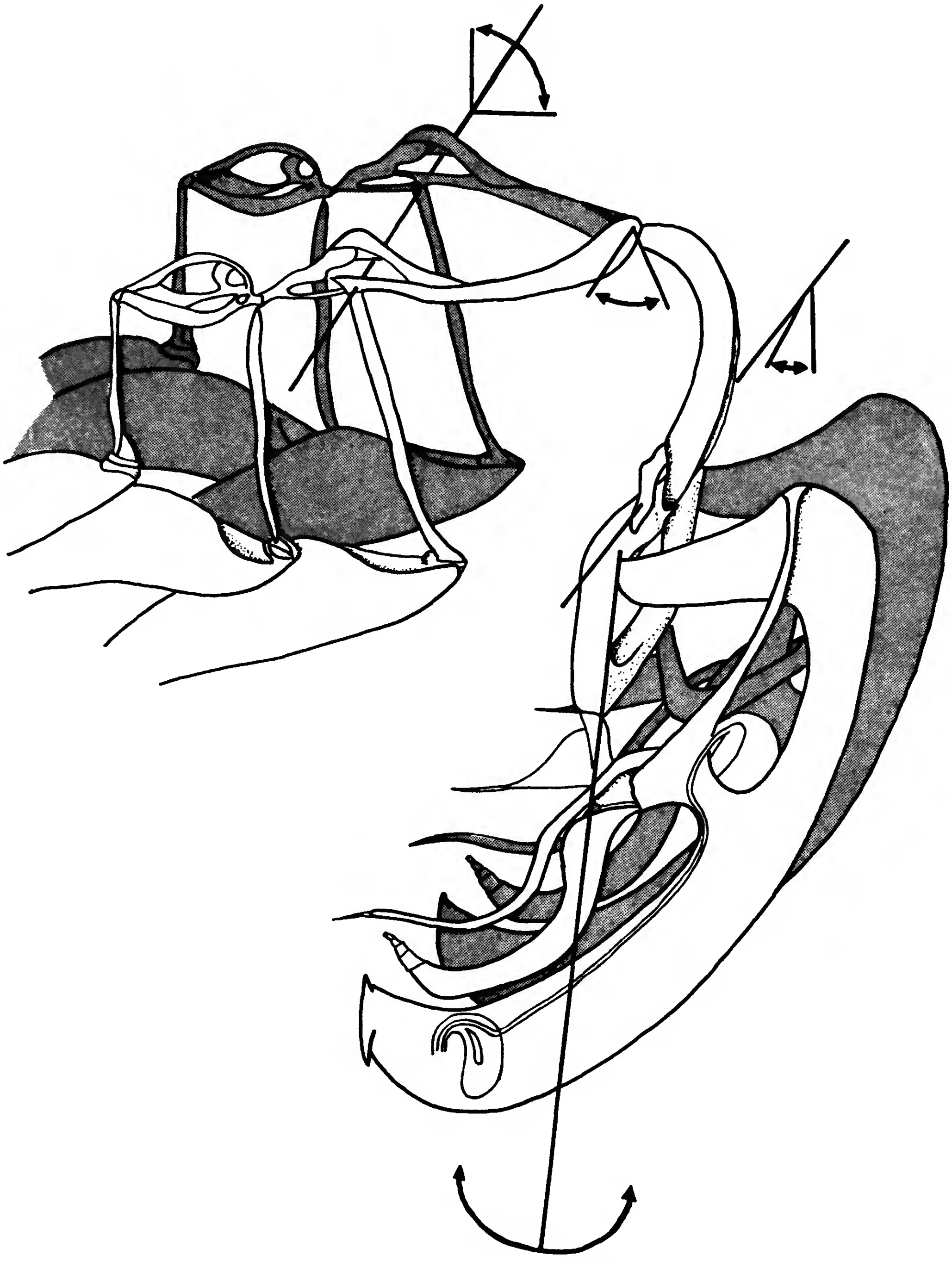

FIGURE 6.—Three-dimensional drawing of copulatory apparatus with copulatory apparatus lowered and peniferum swung through 180° into copulatory position. (From Hart and Hart, 1969:162.)

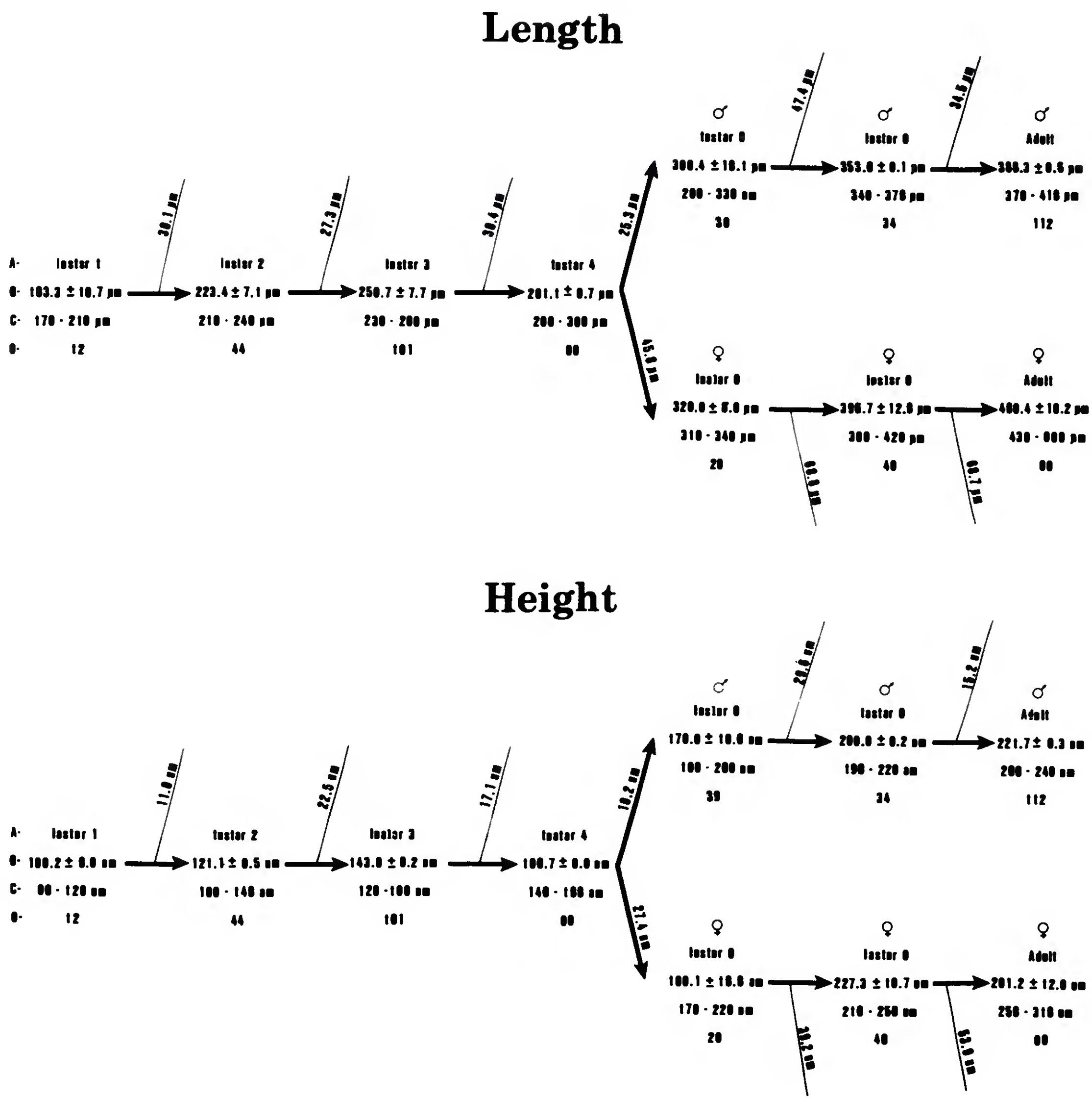

FIGURE 7.—Diagrammatic representations of the sizes and growth patterns of the instars of *Uncinocythere occidentalis,* based on measurements of 561 individuals. A = instar number; B = mean shell lengths or heights and standard deviation; C = range of shell lengths or heights; D = sample sizes. Numbers on diagonal lines represent average growth between instars.

of immature forms than those with less dense populations.

In crayfish hosts having postorbital lengths greater than approximately 3.0 cm, the trend across instars is similar—i.e., there is a slight increase in number of ostracods per individual crayfish as the ostracods progress from instar 1 through instar 6, followed by a larger increase for instar 7 individuals.

Regardless of crayfish size, the ratio of immature male to adult male ostracods was approximately 1 :: 2. However, the female ratio of im-

TABLE 3.—Total number of ostracods on 45 crayfish of various size ranges taken in all seasons (percentages of totals in parentheses; section A shows sexes of instars 5–7 combined; section B shows them separated).

Instar	Intervals of crayfish postorbital carapace length (in cm)					Total
	2.0–2.5	2.51–3.0	3.01–3.5	3.51–4.0	4.01–4.5	
A						
1	–	68(8.4)	49(4.7)	96(6.3)	343(5.1)	556(5.5)
2	–	138(17.1)	182(17.4)	138(9.1)	705(10.4)	1163(11.4)
3	2(11.8)	124(15.3)	102(9.8)	177(11.7)	814(12.0)	1219(12.0)
4	2(11.8)	117(14.5)	125(12.0)	169(11.2)	878(12.9)	1291(12.7)
5	4(23.5)	79(9.8)	165(15.8)	170(11.2)	849(12.5)	1267(12.5)
6	1(5.9)	91(11.3)	146(14.0)	234(15.5)	1011(14.9)	1483(14.6)
7	8(47.1)	191(23.6)	275(26.3)	529(35.0)	2191(32.3)	3194(31.4)
Total	17(0.1)	808(7.9)	1044(10.3)	1513(14.9)	6791(66.8)	10,173
B						
5♂	2(11.8)	29(3.6)	60(5.7)	65(4.2)	357(5.3)	513(5.0)
5♀	2(11.8)	50(6.2)	105(10.1)	105(6.9)	492(7.2)	754(7.4)
6♂	–	27(3.3)	54(5.2)	81(5.4)	361(5.3)	523(5.1)
6♀	1(5.9)	64(7.9)	92(8.8)	153(10.1)	650(10.0)	960(9.4)
7♂	6(35.3)	107(13.2)	162(15.5)	333(22.0)	1310(19.3)	1918(18.9)
7♀	2(11.8)	84(10.4)	113(10.8)	196(13.0)	881(13.0)	1276(12.6)

TABLE 4.—Total number of ostracods on 10 crayfish of various size ranges in *fall* (percentages of totals in parentheses; section A shows sexes of instars 5–7 combined; section B shows them separated).

Instar	Intervals of crayfish postorbital carapace length (in cm)					Total
	2.0–2.5	2.51–3.0	3.01–3.5	3.51–4.0	4.01–4.5	
A						
1	–	37(17.5)	21(5.0)	77(11.6)	200(7.8)	335(8.7
2	–	70(33.2)	76(18.0)	73(11.0)	229(8.9)	448(11.6)
3	–	35(16.6)	15(3.6)	104(15.7)	257(10.0)	411(10.7)
4	–	21(10.0)	65(15.4)	88(13.3)	252(9.8)	426(11.0)
5	–	20(9.5)	105(24.9)	76(11.5)	345(13.5)	546(14.2)
6	–	12(5.7)	55(13.0)	94(14.2)	448(17.5)	609(15.8)
7	–	16(7.6)	85(20.1)	150(22.7)	830(32.4)	11081(28.0)
Total	–	211(5.5)	422(10.9)	662(17.2)	2561(66.4)	3856
B						
5♂	–	6(2.8)	43(10.2)	37(5.9)	184(7.2)	270(7.0)
5♀	–	14(6.6)	62(14.7)	39(5.9)	161(6.3)	276(7.2)
6♂	–	5(2.4)	17(4.0)	35(5.3)	175(6.8)	232(6.0)
6♀	–	7(3.3)	38(9.0)	59(8.9)	273(10.7)	377(9.8)
7♂	–	11(5.2)	49(11.6)	120(18.1)	482(18.8)	662(17.2)
7♀	–	5(2.4)	36(8.5)	30(4.5)	348(13.6)	419(10.9)

TABLE 5.—Total number of ostracods on 10 crayfish of various size ranges in *winter* (percentages of totals in parentheses; section A shows sexes of instars 5–7 combined; section B shows them separated).

Instar	Intervals of crayfish postorbital carapace length (in cm)					Total
	2.0–2.5	2.51–3.0	3.01–3.5	3.51–4.0	4.01–4.5	
A						
1	–	12(5.4)	12(5.5)	5(2.6)	44(2.5)	73(3.0)
2	–	22(9.8)	43(19.5)	6(3.1)	147(8.2)	218(9.0)
3	–	37(16.5)	44(20.0)	10(5.2)	296(16.5)	387(15.9)
4	–	35(15.6)	30(13.6)	18(9.3)	323(18.0)	406(16.7)
5	–	13(5.8)	10(4.5)	17(8.8)	233(13.0)	273(11.2)
6	–	35(15.6)	27(12.3)	21(10.8)	196(0.9)	279(11.5)
7	–	70(31.3)	54(24.5)	117(60.3)	555(30.1)	796(32.7)
Total	–	224(9.2)	220(9.0)	194(8.0)	1794(73.8)	2432
B						
5♂	–	7(3.1)	3(1.4)	11(5.7)	97(5.4)	118(4.9)
5♀	–	6(2.7)	7(3.2)	6(3.1)	136(7.6)	155(6.4)
6♂	–	14(6.3)	8(3.6)	5(2.6)	61(3.4)	88(3.6)
6♀	–	21(9.4)	19(8.6)	16(8.2)	135(7.5)	191(7.9)
7♂	–	37(16.5)	34(15.5)	66(34.0)	335(18.7)	472(19.4)
7♀	–	33(14.7)	20(9.1)	51(26.3)	220(1.4)	324(13.3)

TABLE 6.—Total number of ostracods on 15 crayfish of various size ranges in *spring* (percentages of totals in parentheses; section A shows sexes of instars 5–7 combined; section B shows them separated).

Instar	Intervals of crayfish postorbital carapace length (in cm)					Total
	2.0–2.5	2.51–3.0	3.01–3.5	3.51–4.0	4.01–4.5	
A						
1	–	–	4(2.1)	3(0.7)	48(2.2)	55(1.9)
2	–	10(7.8)	36(18.8)	29(6.9)	241(11.1)	316(10.8)
3	2(11.8)	15(11.7)	33(17.3)	36(8.6)	216(9.9)	302(10.3)
4	2(11.8)	28(21.9)	19(9.9)	37(8.9)	287(13.2)	373(12.7)
5	4(23.5)	16(12.5)	21(11.0)	56(13.4)	262(12.0)	359(12.3)
6	1(5.9)	18(14.1)	29(15.2)	90(21.5)	353(16.2)	491(16.8)
7	8(47.1)	41(32.0)	49(25.7)	167(40.0)	769(35.3)	1034(35.3)
Total	17(0.6)	128(4.4)	191(6.5)	418(14.3)	2176(74.3)	2930
B						
5♂	2(11.8)	2(1.6)	6(3.1)	12(2.9)	73(3.4)	95(3.2)
5♀	2(11.8)	14(10.9)	15(7.9)	44(10.5)	189(8.7)	264(9.0)
6♂	–	1(0.8)	14(7.3)	30(7.2)	123(5.7)	168(5.7)
6♀	1(5.9)	17(13.3)	15(7.9)	60(14.4)	230(10.6)	323(11.0)
7♂	6(35.3)	27(21.1)	30(15.7)	99(23.7)	462(21.2)	624(21.3)
7♀	2(11.8)	14(10.9)	19(9.9)	68(16.3)	307(14.1)	410(14.0)

TABLE 7.—Total number of ostracods on 10 crayfish of various size ranges in *summer* (percentages of totals in parentheses; section A shows sexes of instars 5–7 combined; section B shows them separated).

Instar	Intervals of crayfish postorbital carapace length (in cm)					Total
	2.0–2.5	2.51–3.0	3.01–3.5	3.51–4.0	4.01–4.5	
A						
1	–	19(7.8)	12(5.0)	11(4.6)	51(19.6)	93(9.7)
2	–	36(14.7)	27(11.3)	30(12.6)	88(33.8)	181(19.0)
3	–	37(15.1)	10(4.2)	27(11.3)	45(17.3)	119(12.5)
4	–	33(13.5)	11(4.6)	26(10.9)	16(6.2)	86(9.0)
5	–	30(12.2)	29(12.1)	21(8.8)	9(3.5)	89(9.3)
6	–	26(10.6)	35(14.6)	29(12.1)	14(5.4)	104(10.9)
7	–	64(26.1)	87(36.4)	95(39.7)	37(14.2)	283(29.6)
Total	–	245(25.7)	211(22.1)	239(25.0)	260(27.2)	955
B						
5♂	–	14(5.7)	8(3.8)	5(2.1)	3(1.2)	30(3.1)
5♀	–	16(6.5)	21(10.0)	16(6.7)	6(2.3)	59(6.2)
6♂	–	7(2.9)	15(7.1)	11(4.6)	2(0.8)	35(3.7)
6♀	–	19(7.8)	20(9.5)	18(7.5)	12(4.6)	69(7.2)
7♂	–	32(13.1)	49(23.2)	48(20.1)	31(11.9)	160(16.8)
7♀	–	32(13.1)	38(18.0)	47(19.7)	6(2.3)	123(12.9)

TABLE 8.—Numbers of ostracods from 45 crayfish of various sizes, by season.

Season	Number of crayfish	Numbers of ostracods						
		Total	Mean	SD	CV	Max.	Min.	Median
Fall	10	3856	384.60	273.06	70.98	935	151	248.50
Winter	10	2432	243.20	168.21	69.17	532	29	192.50
Spring	15	2930 (1953)*	195.33	180.12	92.21	575	17	111.00
Summer	10	955	95.50	68.87	73.16	260	12	84.50

* Number proportionally corrected for 10 crayfish instead of 15.

mature to adult was always greater than 1. There does not appear to be a trend with crayfish size for either ostracod sex.

Population Densities

The numbers of *U. occidentalis* ranged from 12 to 935 specimens on a host animal (Table 8). Densities in relation to sex of the host were considered, but no significant differences were found between the average number of ostracods commensal on male and female crayfish. Also, there were no differences by instar or by season on male vs female hosts.

Of the 116 female crayfish collected, seven were found to be gravid. The detailed study sample of 45 crayfish included ostracod counts on 21 females, 6 of which were gravid.

Tables 4–7 present seasonal summaries of ostracod populations in relation to size of the crayfish host, and Table 8 contains the total seasonal counts from samples that indicate possible seasonal differences to be tested.

A comparison of the total numbers shows the pattern of counts to be similar for all seasons except summer. During spring, fall, and winter, approximately 70% of all ostracods in each sample were found on the larger host specimens, while in the summer the distribution of these commensals was approximately uniform over all hosts, regardless of size. The total number of ostracods was also significantly less in the summer and maximal in the fall. Tests of these seasonal totals by instar indicate that this fall/summer discrepancy is consistent for all stages except instars 1 and 7. A test for monthly fluctuations indicates that September and May/June figures account for these differences for instars 2–6. There is a lack of variation in adult counts for the monthly values as well as for the seasonal.

When examined by sex of the host, the seasonal variability in the counts disappears. That is, 56 hypothesis tests were constructed to ascertain whether the number of ostracods in each separate instar found on male or female crayfish were the same, and no statistical significance was detected (i.e., each hypothesis was accepted). In addition, the number of ostracods found only on female crayfish did not vary significantly across seasons. However, for male crayfish it appears that a maximum number of adult ostracods was observed in fall and a minimum in summer. For juveniles, no seasonal differences were found.

The observed ostracod population structure shows a majority of immature individuals, but in a proportion to adults that does not increase with crayfish size. Table 9 shows the immature/adult ratios by season and host size interval. Since seasonal variation in the populations is clear, tests were performed but no trend over seasons or season by host size was detected for these numbers. The ratios of immature to adult is maintained approximately throughout these intervals. Figure 8 is a computer-generated graphic representation of the seasonal variations in the relative numbers of ostracods of various instars.

The percentages of gravid ostracods varied from 6.3% in November to 68.3% in May (Table 10), and appeared to be, in part, inversely related to total number of females present.

Over all seasons, larger numbers of subadult females than males of instars 5 and 6 were found, but considerably more adult males than females (instar 7).

Water Quality

The chemical, physical, and bacteriological characteristics of Eagle Drain, as conditions existed there between 15 November 1977 and 19 September 1978, are given in Table 11. Comparative data for the Boise River stations are given in Idaho Department of Health and Welfare (1980). The relatively warm temperature ($\bar{x}$=13.7°C) probably indicates the presence of water of artesian origin as well as ground water; it does not freeze. The dissolved oxygen (DO) levels are relatively high ($\bar{x}$=10.4 mg/l) and the pH range of 7.35 to 8.2 is typical of the area (Idaho Department of Health and Welfare, 1980). The Drain was usually clear (mean turbidity 2.2 FTU) and had a mean flow of about 30 cfs.

TABLE 9.—Percentages of immature ostracods (instars 1–6) versus adult ostracods (instar 7) by season and host crayfish postorbital carapace length. (Total = percentages for entire seasonal sample.)

Carapace interval (cm)	Spring	Summer	Fall	Winter
2.0–2.5	52.9/47.1	0.0/0.0	0.0/0.0	0.0/0.0
2.51–3.0	68.0/32.0	73.9/26.1	92.4/7.6	68.7/31.3
3.01–3.5	74.3/25.7	63.6/36.4	79.9/20.1	75.5/24.5
3.51–4.0	60.0/40.0	60.3/39.7	77.3/22.7	39.7/60.3
4.01–4.5	64.7/35.3	85.8/14.2	67.6/32.4	69.9/30.1
Total	64.7/35.3	70.4/29.6	72.0/28.0	67.3/32.7

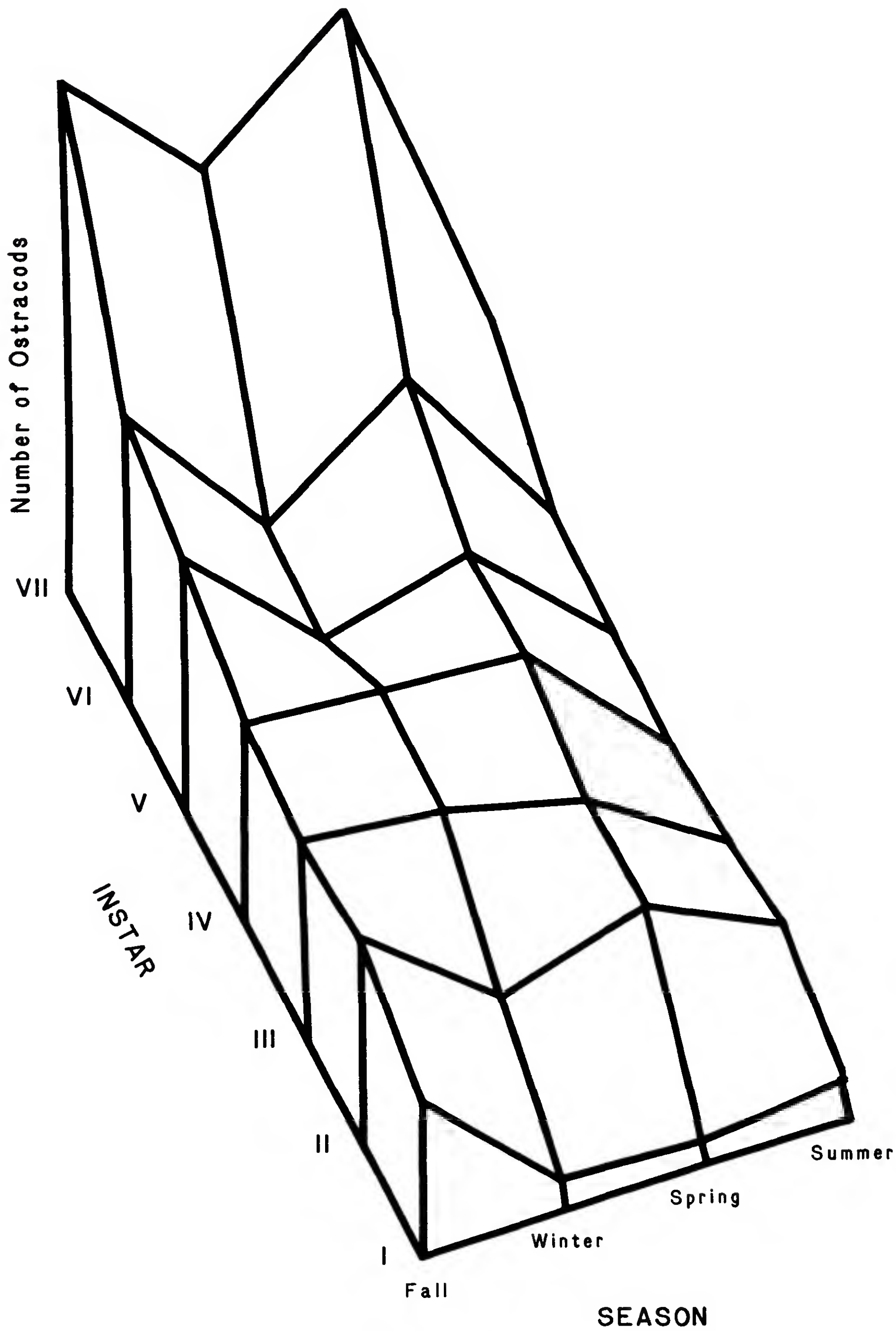

FIGURE 8.—Computer-generated diagram of relative numbers of ostracods of various instars found on 45 crayfish taken in fall, winter, spring, and summer.

TABLE 10.—Monthly counts of gravid ostracods as percentages of total number of adult females found on five crayfish during each of nine months.

Month	No. of gravid females	Total no. females	Percent gravid
November	15	238	6.3
December	67	152	44.1
January	33	172	19.2
March	113	167	67.7
April	94	202	46.5
May	28	41	68.3
June	39	74	52.7
July	14	49	28.6
September	80	181	44.2

The Drain appeared to have a moderate nutrient load, above the 0.3 mg/l level for total inorganic nitrogen ($NH_3 + NO_2 + NO_3$) indicated as necessary for algal bloom potential by Tangarone and Bogue (1975). The mean total inorganic nitrogen concentration was 1.4 mg/l. Soluble reactive phosphorus (orthophosphate) levels in the Drain averaged 0.2 mg/l, which is well above the level (0.01 mg/l) considered to be critical for algal bloom potential by Sawyer (1947).

Concentrations of arsenic, cadmium, chromium, copper, lead, silver, and nickel were below

TABLE 11.—Chemical, physical, and bacteriological characteristics of Eagle Drain, Ada Co., Idaho, 1977–1978 (unless noted, values are in milligrams per liter).

Characteristics	Nov 15	Jan 25	Mar 22	Jun 20	Sep 19	Mean
Temperature (°C)	13.5	7.5	14.0	18.0	15.5	13.7
Dissolved oxygen	8.9	10.4	13.2	10.0	9.4	10.4
pH	7.35	7.6	8.2	7.6	7.8	7.7
Flow (cfs)	21.	20.	20.	40.	40.	28.2
BOD_5	<0.1	0.1	3.4	0.6	0.2	0.88
COD	7.1	5.7	4.5	12.	6.9	7.24
Ammonia -N	0.046	0.041	0.009	0.026	0.018	0.03
Nitrate -N, total	1.13	1.8	1.84	1.1	0.67	1.3
Nitrite -N, total	0.03	0.015	0.021	0.011	0.009	0.086
Kjeldahl nitrogen N, total	1.0	1.12	1.1	0.72	0.67	0.92
Ortho phosphate -P	0.168	0.096	0.14	0.097	0.12	0.124
Phosphorus -P, total	0.26	0.22	0.16	0.15	0.22	0.2
Specific conductivity (μmhos/cm)	–	303.	354.	223.	222.	275.5
Turbidity (FTU)	–	2.2	2.2	3.8	2.8	2.8
Suspended solids	<2.	8.	<2.	10.	12.	6.8
Residue, total	245.	217.	225.	160.	165.	202.4
Alkalinity, total ($CaCO_3$)	131.	129.	139.	92.	97.	117.6
Alkalinity, bicarbonate ($CaCO_3$)	131.	129.	139.	92.	97.	117.6
Chloride	–	6.	17.	3.	6.	8.
Fluoride, total	0.72	0.71	0.89	0.41	0.42	0.63
Iron, total (μg/l)	140.	130.	100.	130.	180.	136.
Zinc, total (μg/l)	3.	6.	<1.	2.	3.	3.
Mercury, total (μg/l)	<0.5	<0.5	<0.5	<0.5	0.7	0.7
Aluminum, total (μg/l)	<100.	200.	100.	300.	200.	180.
Boron, total (μg/l)	–	<200.	240.	50.	100.	118.
Bacteria, total coliform per 100 ml	730.	550.	230.	220.	950.	
Bacteria, fecal coliform per 100 ml	68.	30.	30.	160.	1180.	
Bacteria, fecal strep per 100 ml	98.	180.	20.	80.	70.	

detectable limits for samples taken on all dates.

The fecal coliform/fecal streptococci ratio of less than 0.7, found on most dates, indicates that bacterial contamination was probably primarily of livestock origin (Clausen et al., 1977). Some human influence was indicated, however, when, on 19 September 1978, a fecal coliform density of 1180/100 ml was found.

The water quality data are within the tolerances reported for crayfish (Hobbs and Hall, 1976). Except for the data presented herein, little is known of the water quality tolerances of entocytherid ostracods.

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Review of manuscripts and art by the Press for requirements of series format and style, completeness and clarity of copy, and arrangement of all material, as outlined below, will govern, within the judgment of the Press, acceptance or rejection of manuscripts and art.

Copy must be prepared on typewriter or word processor, double-spaced, on one side of standard white bond paper (not erasable), with 1¼" margins, submitted as ribbon copy (not carbon or xerox), in loose sheets (not stapled or bound), and accompanied by original art. Minimum acceptable length is 30 pages.

Front matter (preceding the text) should include: **title page** with only title and author and no other information; **abstract** page with author, title, series, etc., following the established format; table of **contents** with indents reflecting the hierarchy of heads in the paper; also, **foreword** and/or **preface**, if appropriate.

First page of text should carry the title and author at the top of the page; **second page** should have only the author's name and professional mailing address, to be used as an unnumbered footnote on the first page of printed text.

Center heads of whatever level should be typed with initial caps of major words, with extra space above and below the head, but with no other preparation (such as all caps or underline, except for the underline necessary for generic and specific epithets). Run-in paragraph heads should use period/dashes or colons as necessary.

Tabulations within text (lists of data, often in parallel columns) can be typed on the text page where they occur, but they should not contain rules or numbered table captions.

Formal tables (numbered, with captions, boxheads, stubs, rules) should be submitted as carefully typed, double-spaced copy separate from the text; they will be typeset unless otherwise requested. If camera-copy use is anticipated, do not draw rules on manuscript copy.

Taxonomic keys in natural history papers should use the aligned-couplet form for zoology and may use the multi-level indent form for botany. If cross referencing is required between key and text, do not include page references within the key, but number the keyed-out taxa, using the same numbers with their corresponding heads in the text.

Synonymy in zoology must use the short form (taxon, author, year:page), with full reference at the end of the paper under "Literature Cited." For botany, the long form (taxon, author, abbreviated journal or book title, volume, page, year, with no reference in "Literature Cited") is optional.

Text-reference system (author, year:page used within the text, with full citation in "Literature Cited" at the end of the text) must be used in place of bibliographic footnotes in all Contributions Series and is strongly recommended in the Studies Series: "(Jones, 1910:122)" or ". . . Jones (1910:122)." If bibliographic footnotes are required, use the short form (author, brief title, page) with the full citation in the bibliography.

Footnotes, when few in number, whether annotative or bibliographic, should be typed on separate sheets and inserted immediately after the text pages on which the references occur. Extensive notes must be gathered together and placed at the end of the text in a notes section.

Bibliography, depending upon use, is termed "Literature Cited," "References," or "Bibliography." Spell out titles of books, articles, journals, and monographic series. For book and article titles use sentence-style capitalization according to the rules of the language employed (exception: capitalize all major words in English). For journal and series titles, capitalize the initial word and all subsequent words except articles, conjunctions, and prepositions. Transliterate languages that use a non-Roman alphabet according to the Library of Congress system. Underline (for italics) titles of journals and series and titles of books that are not part of a series. Use the parentheses/colon system for volume(number):pagination: "10(2):5–9." For alignment and arrangement of elements, follow the format of recent publications in the series for which the manuscript is intended. Guidelines for preparing bibliography may be secured from Series Section, SI Press.

Legends for illustrations must be submitted at the end of the manuscript, with as many legends typed, double-spaced, to a page as convenient.

Illustrations must be submitted as original art (not copies) accompanying, but separate from, the manuscript. Guidelines for preparing art may be secured from Series Section, SI Press. All types of illustrations (photographs, line drawings, maps, etc.) may be intermixed throughout the printed text. They should be termed **Figures** and should be numbered consecutively as they will appear in the monograph. If several illustrations are treated as components of a single composite figure, they should be designated by lowercase italic letters on the illustration; also, in the legend and in text references the italic letters (underlined in copy) should be used: "Figure 9b." Illustrations that are intended to follow the printed text may be termed **Plates**, and any components should be similarly lettered and referenced: "Plate 9b." Keys to any symbols within an illustration should appear on the art rather than in the legend.

Some points of style: Do not use periods after such abbreviations as "mm, ft, USNM, NNE." Spell out numbers "one" through "nine" in expository text, but use digits in all other cases if possible. Use of the metric system of measurement is preferable; where use of the English system is unavoidable, supply metric equivalents in parentheses. Use the decimal system for precise measurements and relationships, common fractions for approximations. Use day/month/year sequence for dates: "9 April 1976." For months in tabular listings or data sections, use three-letter abbreviations with no periods: "Jan, Mar, Jun," etc. Omit space between initials of a personal name: "J.B. Jones."

Arrange and paginate sequentially every sheet of manuscript in the following order: (1) title page, (2) abstract, (3) contents, (4) foreword and/or preface, (5) text, (6) appendixes, (7) notes section, (8) glossary, (9) bibliography, (10) legends, (11) tables. Index copy may be submitted at page proof stage, but plans for an index should be indicated when manuscript is submitted.