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BRIEF NOTE

MORPHOLOGICAL VARIATIONS OF *CAMBARUS (CAMBARUS) BARTONII CAVATUS* (DECAPODA:CAMBARIDAE) FROM OHIO, WITH A DIAGNOSIS OF THE OHIO FORM[1]

RAYMOND F. JEZERINAC, Department of Zoology, The Ohio State University, University Drive, Newark, OH 43055

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The original description of *Cambarus (Cambarus) bartonii cavatus* (Hay 1902) is very brief, and investigators (Rhoades 1944, Jezerinac and Thoma 1984) have stated that the Ohio form (called *C. b. laevis* and *C. b. bartonii* by Rhoades 1944) exhibits considerable morphological variation; however, they presented no data to substantiate this claim. This note provides the missing data, suggests some reasons for the observed variations, and presents a diagnosis of the Ohio form.

More than 300 individuals were examined during this study, but only 140 specimens were selected for quantitative analysis because the other material was either immature, damaged, or possessed regenerated chelae. Three meristic and 10 morphometric structures were studied (table 1). Measurements were made to the nearest 0.05 mm with a vernier caliper (Mitutoya Model No. 505-633) following the techniques of Fitzpatrick (1967) for six structures. The other four measurements were as follows: carapace width, the greatest width of the carapace without compression; postorbital ridge width, the distance between the two ridges with the caliper set in the lateral groove; chela thickness, the greatest thickness of the palmar region of the chela; and palm length, the distance from the dactyl joint to the proximal bend of the palm of the chela. Two structures, rostral length and width, are not included because they were incorrectly measured. All specimens examined are either in the collection of The Ohio State University Museum of Zoology, Columbus, Ohio, or the Smithsonian Institution, Washington, D.C.

The data were analyzed statistically using the Instructional and Research Computer Center facilities at The Ohio State University and SAS (Statistical Analysis System, release 79.3A) statistical programs. Pearson correlation analysis indicated a very strong relationship ($r = 0.9039 - 0.9923$) between 10 of the structures examined and carapace length. Tubercles on the mesial margin of the palm were not analyzed. Only areola width ($r = 0.5107 - 0.7592$) and the number of punctations across the narrowest part of the areola ($r = -0.3165 - 0.1566$) were poorly correlated with carapace length. Correlation analyses of all chela measurements with chela length were also very strong ($r = 0.9308 - 0.9958$). Multiple correlation analysis (R^2 – coefficient of determination) is presented in table 2. Because strong linear relationships exist between the structures measured and carapace and chela length, linear regression analyses were performed to estimate the parameters of the equations using carapace and chela lengths as the independent variables. These equations are presented so different size specimens can be compared with one another, and because the slopes of the regression lines are the average ratio of the body part to carapace or

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chela length, ratios that are helpful in comparing the body measurements of different species. The resulting equations are as follows: Structure = Intercept ± S.E. + (Slope ± S.E. × Carapace Length/Chela Length). Statistical significance ($p \leq 0.05$) of the data was determined by using a Student's *t*-test, linear regression, and/or analysis of covariance.

First form males are larger, statistically, than second form males and females in all chela measurements and have a greater postorbital ridge width than second form males (table 1). When first form males are compared with females, the males have five structures that are initially larger (intercept of the regression line) and four structures of the chela that increase in length or width more rapidly (slope of the regression line) in relation to carapace length (table 2 — top) than those of the females. A comparison of chela structures with chela length between first form males and females indicate that the males have a dactyl length that is initially longer and increases more rapidly in length than those of the females (table 2 — bottom). These data indicate that a sexual dimorphism exists in this taxon, and that this dimorphism is most evident in the chelae. Chelae dimorphism in crayfishes has been noted in the genus *Orconectes* (Stein 1976, Weagle and Ozburn 1970) and has been frequently illustrated (Villalobos 1955(1983) and Hobbs 1981) in members of the genera *Procambarus* and *Cambarellus*. This dimorphism is a result of hetergonic growth in males and Stein (1976) has commented upon the behavioral significance of this dimorphism in populations of *Orconectes propinquus* (Girard).

Second form males exhibit more variation, as measured by the standard error of the mean (table 1), than first form males and females in the following: carapace length, carapace width, postorbital ridge width, areola length, chela width, chela thickness, and number of tubercles on the mesial surface of the palm of the chela. The only differences, however, that are significant, statistically, are measurements of the chelae. Second form males have smaller chelae than do first form males. Most interestingly, second form males do not differ statistically from females in any structures that were counted or measured. These variations indicate a very heterogenous assemblage of individuals that probably includes males that have never been first form and those that have attained first

TABLE 1

Measurements (mm) and counts of parameters of Cambarus (C.) b. cavatus *from Ohio.*

	Female			First Form Male			Second Form Male		
	N	$\bar{X}$ ± S.E.	Range	N	$\bar{X}$ ± S.E.	Range	N	$\bar{X}$ ± S.E.	Range
Carapace length	80	36.5 ± 0.67	26.8–54.0	23	37.7 ± 0.91	30.7–48.9	37	35.6 ± 0.94	26.1–46.8
Carapace width	80	19.3 ± 0.37	14.3–28.9	23	20.3 ± 0.49	16.1–25.3	37	18.9 ± 0.57	12.8–25.7
Postorbital ridge width[2]	80	7.9 ± 0.13	6.0–11.4	23	8.2 ± 0.15	6.9–10.0	37	7.7 ± 0.18	5.6– 9.8
Areola length	80	14.2 ± 0.28	10.1–21.9	23	14.8 ± 0.37	11.6–19.3	37	13.9 ± 0.39	10.0–18.5
Areola width	79	1.8 ± 0.04	1.2– 2.8	23	1.8 ± 0.06	1.3– 2.4	37	1.8 ± 0.04	1.2– 2.2
Areola punctations	79	2.7 ± 0.08	2– 4	23	2.8 ± 0.12	2– 4	37	2.9 ± 0.11	2– 5
Chela length[1,2]	80	27.7 ± 0.69	18.0–47.3	23	35.8 ± 1.31	26.3–49.5	37	28.9 ± 1.19	16.8–43.3
Chela width[1,2]	80	12.8 ± 0.33	8.2–21.1	23	16.5 ± 0.58	12.4–21.8	37	13.3 ± 0.59	7.3–20.1
Chela thickness[1,2]	79	7.7 ± 0.17	5.1–12.0	23	9.4 ± 0.31	7.1–12.9	37	7.9 ± 0.31	4.6–11.3
Dactyl length[1,2]	80	17.9 ± 0.46	11.4–31.4	23	24.1 ± 1.17	17.0–38.8	37	18.6 ± 0.78	11.0–27.7
Palm length[1,2]	80	8.3 ± 0.20	5.5–13.4	23	10.5 ± 0.39	7.8–14.9	37	8.6 ± 0.34	4.8–12.4
Tubercles; mesial	80	6.6 ± 0.08	5– 9	23	6.7 ± 0.13	6– 8	37	6.9 ± 0.14	5– 9
Tubercles; 2nd row	80	4.1 ± 0.12	0– 7	23	4.1 ± 0.13	3– 5	37	4.3 ± 0.20	2– 7

Significant difference ($P \leq 0.05$) between [1]Female and First Form Male and [2]First Form Male and Second Form Male using a *t*-test.

TABLE 2

Regression analysis of Cambarus (C.) b. cavatus *from Ohio.*

Dependent Variable	Females N	Females Inter. ± S.E.	Females Slope ± S.E.	Females R^2	First Form Male N	First Form Male Inter. ± S.E.	First Form Male Slope ± S.E.	First Form Male R^2
Independent Variable—Carapace Length								
Carapace width	80	0.003 ± 0.485	0.529 ± 0.013	0.96	23	0.252 ± 0.860	0.531 ± 0.023	0.96
Postorbital ridge width[1]	80	1.116 ± 0.207	0.185 ± 0.006	0.94	23	2.213 ± 0.409	0.159 ± 0.011	0.92
Areola length	80	−0.915 ± 0.318	0.413 ± 0.009	0.97	23	−0.246 ± 0.479	0.399 ± 0.013	0.98
Areola width	80	0.252 ± 0.153	0.042 ± 0.004	0.58	23	0.553 ± 0.469	0.034 ± 0.012	0.26
Chela length[1,2]	80	−8.513 ± 1.068	0.992 ± 0.029	0.94	23	−15.290 ± 3.930	1.354 ± 0.104	0.89
Chela width[2]	80	−4.368 ± 0.466	0.472 ± 0.013	0.95	23	−6.007 ± 1.844	0.597 ± 0.049	0.88
Chela thickness[1]	80	−1.401 ± 0.258	0.248 ± 0.007	0.94	23	−2.867 ± 0.986	0.325 ± 0.026	0.88
Dactyl length[1,2]	80	−6.059 ± 0.764	0.656 ± 0.021	0.93	23	−19.735 ± 4.558	1.163 ± 0.120	0.82
Palm length[1,2]	80	−2.427 ± 0.321	0.293 ± 0.009	0.94	23	−4.315 ± 1.396	0.392 ± 0.037	0.84
Independent Variable—Chela Length								
Dactyl length[1,2]	80	−0.365 ± 0.270	0.659 ± 0.010	0.98	23	−5.730 ± 2.597	0.835 ± 0.072	0.87
Palm length	80	0.189 ± 0.158	0.292 ± 0.006	0.97	23	0.036 ± 0.465	0.291 ± 0.013	0.96
Chela width	80	−0.015 ± 0.314	0.464 ± 0.011	0.96	23	0.936 ± 0.688	0.436 ± 0.019	0.96
Chela thickness	80	0.939 ± 0.199	0.242 ± 0.007	0.94	23	1.003 ± 0.455	0.234 ± 0.013	0.94

Significant difference ($P \leq 0.05$) in [1]intercepts using a *t*-test and [2]slopes using analysis of covariance.

form but have molted back to second form, and, in so doing, increase in body size but not in chelae size. Based upon these variations in the second form males, first form males and females are to be preferred in recognizing members of this subspecies.

Areola width of all forms is similar (table 1). This measurement, however, has the lowest R^2 value (table 2), indicating that its correlation with carapace length is less than that of any other measurement recorded. Jezerinac (Jezerinac and Thoma 1984) has suggested that the width of the areola is correlated with the environment in which an individual is found; those individuals occurring in burrows usually have narrower areolae. This idea is consistent with the statements of Hobbs (1969) regarding burrowing adaptations of crayfishes.

Diagnosis of the Ohio form of *C.* (*C.*) *b. cavatus:* Body subovate, dorsally depressed in region of cervical groove; body pigmented, dorsal and lateral surfaces brownish-green, ventral surface, chelae, and base of legs cream, lateral margin of chelae with orange stripe; eyes normal size with pigment; rostrum rectangular, dorsal surface flat to slightly excavate, with parallel to slightly convergent margins of uniform thickness lacking spines or tubercles; anterior rostral margins bending abruptly mesially, ending in short upturned acumen; postorbital ridges short with lateral groove but lacking upturned spines or knobs; suborbital angle strong and acute; branchiostegal spine reduced to small knob; carapace without hepatic spines, cervical spine reduced to small tubercle or absent, dorsal surface of carapace with shallow punctations, granules in hepatic area larger than those in branchiostegal region; areola 5.5 to 11.9 ($\bar{x}$ = 8.1) times longer than broad, constituting 35.0 to 41.6% ($\bar{x}$ = 38.9%) of total length of carapace, bearing 2 to 5 ($\bar{x}$ = 2.8) punctations across narrowest part; chelae broadly triangular with well-defined dorsal longitudinal ridges, moderate lateral impression at base of propodus, fingers not gaping, never with tufts of setae at base of opposable margins of fingers; 2nd or 3rd tubercle from base on opposable surface of propodal (or fixed) finger enlarged; mesial margin of palm of chelae with two, non-cristiform, rows of tubercles, first row usually with six-seven well-developed tubercles, second row usually with four greatly adpressed tubercles; first pleopod of first form male with corneous central projection recurved at approximately 110° to axis of main shaft, tapered distally, with distinct subterminal notch, and extending caudally beyond tip of mesial process; mesial process inflated, directed caudolaterally and somewhat proximally, terminating in a simple tip; ischial hooks of males on third pereiopods only; annulus ventralis of female asymmetrical, sinus usually not deep; sexual dimorphism evident between first form males and females in lengths and widths of all chela structures compared with carapace length, first form males significantly larger.

The Ohio form of *C.* (*C.*) *b. cavatus* differs most conspicuously from the syntypes in the depth of excavation of the rostrum. Syntypes and topotypes have very deeply excavated rostrums. Drawings of the typical form can be found in Hobbs (1974) and the carapace of the Ohio form in Jezerinac and Thoma (1984).

Range: Disjunct. The typical form of *C.* (*C.*) *b. cavatus* occurs in the smaller tributaries (< 10 m wide), especially those flowing from caves, of the Tennessee, Clinch, and Powell rivers from northwestern Georgia (Dade Co., Hobbs 1981) to southwestern Virginia (Lee Co.). The Ohio form occurs in small streams (< 10 m wide), especially if watercress (*Nasturtium officinale L.*) is present, of the Ohio River drainage in southeastern Indiana, northern Kentucky, western West Virginia, and throughout Ohio except in those streams of the Flushing Escarpment north of Barnes' Run (Monroe Co.) and the Mahoning River drainage in the northeastern part of the state. The Ohio form has also been captured in tributaries to Lake Erie from the Chagrin River (Geauga Co.) westward to the Sandusky River (Sandusky Co.) and in the headwaters of the Maumee River (Auglaize Co.).

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