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GEOGRAPHIC VARIATION IN THE REDBELLY TURTLE, *PSEUDEMYS RUBRIVENTRIS* (REPTILIA: TESTUDINES)

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ABSTRACT

Geographic variation in shell size and scute proportions in the redbelly turtle (*Pseudemys rubriventris*) was examined through univariate and multivariate analyses of separate male and female data sets. These analyses revealed the existence of clinal variation in some characters for males, but no obvious geographic patterns among females. No geographic population showed enough morphologic distinction to warrant subspecific status.

INTRODUCTION

The isolated population of the redbelly turtle, *Pseudemys rubriventris* (LeConte, 1830), in Massachusetts was described as a distinct subspecies (*P. r. bangsi*) by Babcock (1937), based on the turtles' supposedly higher carapace. However, only eight specimens from Massachusetts and twelve of the nominate form were apparently available for his study. Without further analysis some authors (Conant, 1951; Carr, 1952; Graham, 1969) have questioned the distinctiveness of the Massachusetts subspecies, and the question has recently become an issue because of the endangered status of the remaining population (Groombridge, 1982; U.S. Fish and Wildlife Service, 1985). We have examined morphological variation among populations from throughout the range of the species.

MATERIALS AND METHODS

Two hundred and nine *Pseudemys rubriventris* from throughout the range were examined. The following characters were measured (by TEG) to the nearest 0.1 mm on each specimen: maximum carapace length (not necessarily midline; CL), maximum carapace width (MCW), carapace width at level of pectoral-abdominal plastron seam (CW), maximum shell height (SH), maximum plastron length (MPL), plastron length at midline (PL), maximum plastron width (across hindlobe; MPW), plastron width at pectoral-abdominal seam (PW), intergular seam length (GL), interpectoral seam length (IP), interhumeral seam length (IH), interabdominal seam length (IAB), interfemoral seam length (IF), interanal seam length (IAN), bridge length (BL), length (tip to tip) of right axillary scute (AX), length (tip to tip) of right inguinal scute (ING), and distance from the anterior tip of the right axillary scute to the posterior tip of the right inguinal scute (AXIN). To reduce the effects of ontogenetic character variation, only turtles greater than 190 mm CL (76 males; 77 females) were included in the analysis.

For multivariate analysis, characters were standardized by dividing by CL. Despite the theoretical problems with using ratios in statistical analyses, their effectiveness in taxonomic studies of turtles has been clearly demonstrated (Berry, 1978; Iverson, 1981; Berry and Berry, 1985). For analysis, populations were grouped by drainage system (Fig. 1) as follows: Group 1) Massachusetts; Group 2) Delaware River basin eastward to the New Jersey coast (New Jersey and part of Pennsylvania); Group 3) Delmarva Peninsula (Delaware and parts of Maryland and Virginia); Group 4) Susquehanna River basin to, but not including, the Rappahannock River basin (including the Potomac, West Virginia,

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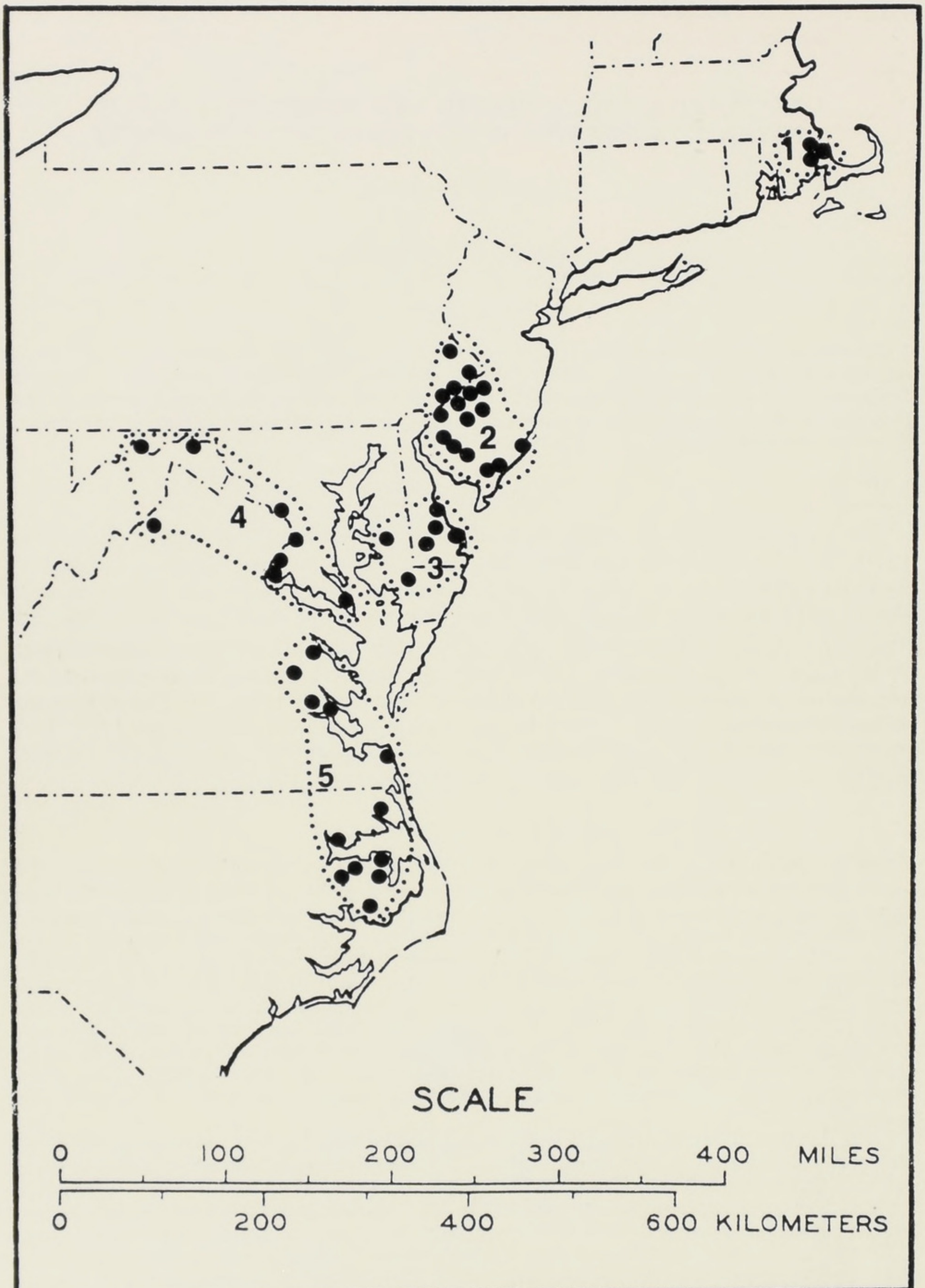

Fig. 1.—Distribution of the redbelly turtle *Pseudemys rubriventris* in the northeastern United States showing population groups 1–5 used for analysis. See text for group definitions.

Table 1.—*Sexual dimorphism in character ratios for redbelly turtles. Means are followed by ± one standard deviation. Only those characters different at P < 0.05 by t-test are listed.*

Character	Males (N = 76)		Females (N = 77)		P
	Mean ± 1 SD	Range	Mean ± 1 SD	Range	
CL	263.2 ± 26.8	194–312	289.3 ± 22.1	235–337	<0.0001
MPL	243.0 ± 28.5	137–291	276.3 ± 20.9	228–322	<0.0001
PL	235.0 ± 28.0	133–282	270.8 ± 20.7	220–310	<0.0001
SH/CL	0.375 ± 0.024	0.31–0.43	0.397 ± 0.027	0.32–0.46	<0.0001
MPL/CL	0.928 ± 0.021	0.88–0.98	0.955 ± 0.021	0.90–1.01	<0.0001
PL/CL	0.900 ± 0.024	0.83–0.94	0.931 ± 0.022	0.87–0.98	<0.0001
BL/CL	0.346 ± 0.016	0.29–0.39	0.366 ± 0.015	0.33–0.40	<0.0001
MPW/CL	0.460 ± 0.021	0.40–0.52	0.470 ± 0.022	0.41–0.52	0.006
PW/CL	0.546 ± 0.027	0.47–0.62	0.555 ± 0.026	0.45–0.61	0.044
GL/CL	0.155 ± 0.011	0.13–0.18	0.160 ± 0.012	0.13–0.19	0.004
IH/CL	0.075 ± 0.014	0.04–0.11	0.080 ± 0.013	0.05–0.11	0.036
IP/CL	0.141 ± 0.018	0.10–0.18	0.155 ± 0.018	0.11–0.20	<0.0001
IAB/CL	0.261 ± 0.018	0.22–0.29	0.274 ± 0.019	0.23–0.31	<0.0001
IF/CL	0.111 ± 0.018	0.07–0.17	0.105 ± 0.017	0.07–0.15	0.044
IAN/CL	0.181 ± 0.017	0.15–0.23	0.193 ± 0.021	0.12–0.25	<0.0001
AXIN/CL	0.461 ± 0.018	0.41–0.50	0.480 ± 0.016	0.45–0.52	<0.0001

and parts of Pennsylvania, Maryland, and Virginia); and Group 5) Rappahannock River and southward (North Carolina and part of Virginia).

Preliminary analysis revealed considerable sexual dimorphism in the characters examined (Table 1), and males and females were therefore analyzed separately. The data set was analyzed with One-way Analysis of Variance (ANOVA; comparing sample means for each character), Duncan's Multiple Range Test (as for the ANOVA; critical $P = 5\%$), discriminant analysis (DA; using the sample populations as groups), and cluster analysis (CA; using mean character ratios for the sample populations).

Table 2.—*Results of one-way ANOVA of character ratios by group for male and female redbelly turtles. F values and associated probabilities (P) of no significant variation across groups are indicated.*

	Males		Females	
	F	P	F	P
SH/CL	5.29	0.0009	6.79	0.0001
MCW/CL	3.71	0.0085	7.53	<0.0001
CW/CL	0.16	0.9600	0.29	0.8870
MPL/CL	2.75	0.0349	3.26	0.0162
PL/CL	5.33	0.0008	4.43	0.0030
MPW/CL	5.12	0.0011	1.72	0.1555
PW/CL	0.27	0.8960	0.37	0.8320
BL/CL	8.47	<0.0001	9.29	<0.0001
GL/CL	1.93	0.1154	3.71	0.0085
IH/CL	1.12	0.3548	1.24	0.3010
IP/CL	5.38	0.0008	8.02	<0.0001
IAB/CL	3.41	0.0132	1.19	0.3252
IF/CL	6.28	0.0002	5.24	0.0010
IAN/CL	3.87	0.0068	1.91	0.1190
AX/CL	0.85	0.5008	2.97	0.0249
ING/CL	8.43	<0.0001	5.93	0.0004
AXIN/CL	2.11	0.0896	1.35	0.2596

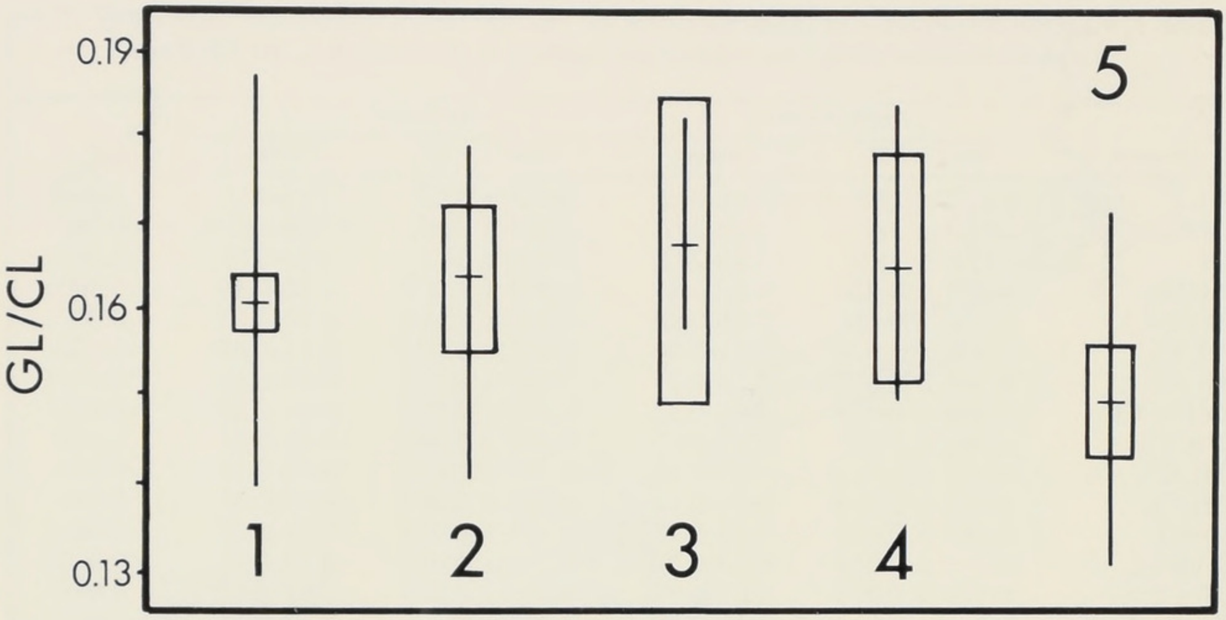

Fig. 2.—Plot of the sample means of gular length/maximum carapace length (GL/CL) for female redbelly turtles. Vertical lines represent ranges; horizontal lines indicate means; and boxes enclose two standard errors around the mean (95% confidence intervals for the mean). Numbers 1–5 indicate groups.

Specimens Examined

Museum acronyms follow Leviton et al. (1985), except TEG (collection of Terry E. Graham) and GRZ (collection of George R. Zug, USNM). DELAWARE (all Group 3): Kent Co. (AMNH 79133); Sussex Co. (AMNH 71293, 79132; ANSP 430). DISTRICT OF COLUMBIA (all Group 4): USNM 6587, 8710, 55606. MARYLAND (all Group 4, except Caroline and Wicomico cos.: Group 3): Allegany Co. (USNM 108971); Anne Arundel Co. (TEG 000); Caroline Co. (AMNH 76176); St. Marys Co. (USNM 98908); Wicomico Co. (AMNH 71284); "Potomac Basin" (USNM 12330–31, 103911). MASSACHUSETTS (all Group 1): Plymouth Co. (BSNH 1202; CM S8800; KU 40213–18; MCZ 16777–78, 76679, 157828; and 128 TEG field measured specimens). NEW JERSEY (all Group 2): Atlantic Co. (TEG 003); Burlington Co. (AMNH 71278–80, 71286, 76177); Camden Co. (AMNH 71281, 71287); Cape May Co. (USNM 7662); Cumberland Co. (AMNH 71288; USNM 66648–50); Gloucester Co. (ANSP 28096); Salem Co. (AMNH 71282–83, 71285). NORTH CAROLINA (all Group 5): Camden Co. (CM 53025–26); Chowan Co. (USNM 50875–76); Hyde Co. (AMNH 80219); Tyrrell Co. (AMNH 80218, 90640); Washington Co. (AMNH 90641–44). PENNSYLVANIA (all Group 2): Bucks Co. (ANSP 26308; CM 28969, 29400, 29457); Delaware Co. (AMNH 76175; CM 29502, 31244, 32651); Philadelphia Co. (ANSP 223; CM 27420). VIRGINIA (all Group 5, except Shenandoah Co.: Group 4): Essex Co. (AMNH 79134); King William Co. (AMNH 71276–77); New Kent Co. (CM 13262, 34409, 34531, 39672, 64113); Princess Anne Co. (CM 23136); Shenandoah Co. (USNM 203204); York Co. (GRZ 30086; USNM 52329); unknown county (USNM 11649). WEST VIRGINIA (Group 4): Morgan Co. (CM 26630). STATE UNKNOWN (Group 4): "CHESAPEAKE BAY" (ANSP 232); "POTOMAC RIVER" (USNM 02194).

Results

Sexual Dimorphism

Considerable sexual dimorphism exists in body size and scute proportions in *Pseudemys rubriventris* (Table 1). Females are larger, have a longer plastron, a higher shell, a wider bridge, and each plastral scute is relatively longer at the midline, except the femoral scute (slightly longer in males). Although Ernst and Barbour (1972:165) reported that males have narrower shells than females, relative carapace width was not significantly different in our samples (mean male MCW/CL = 0.721; mean female MCW/CL = 0.719; $t = 0.61$; $P = 0.54$).

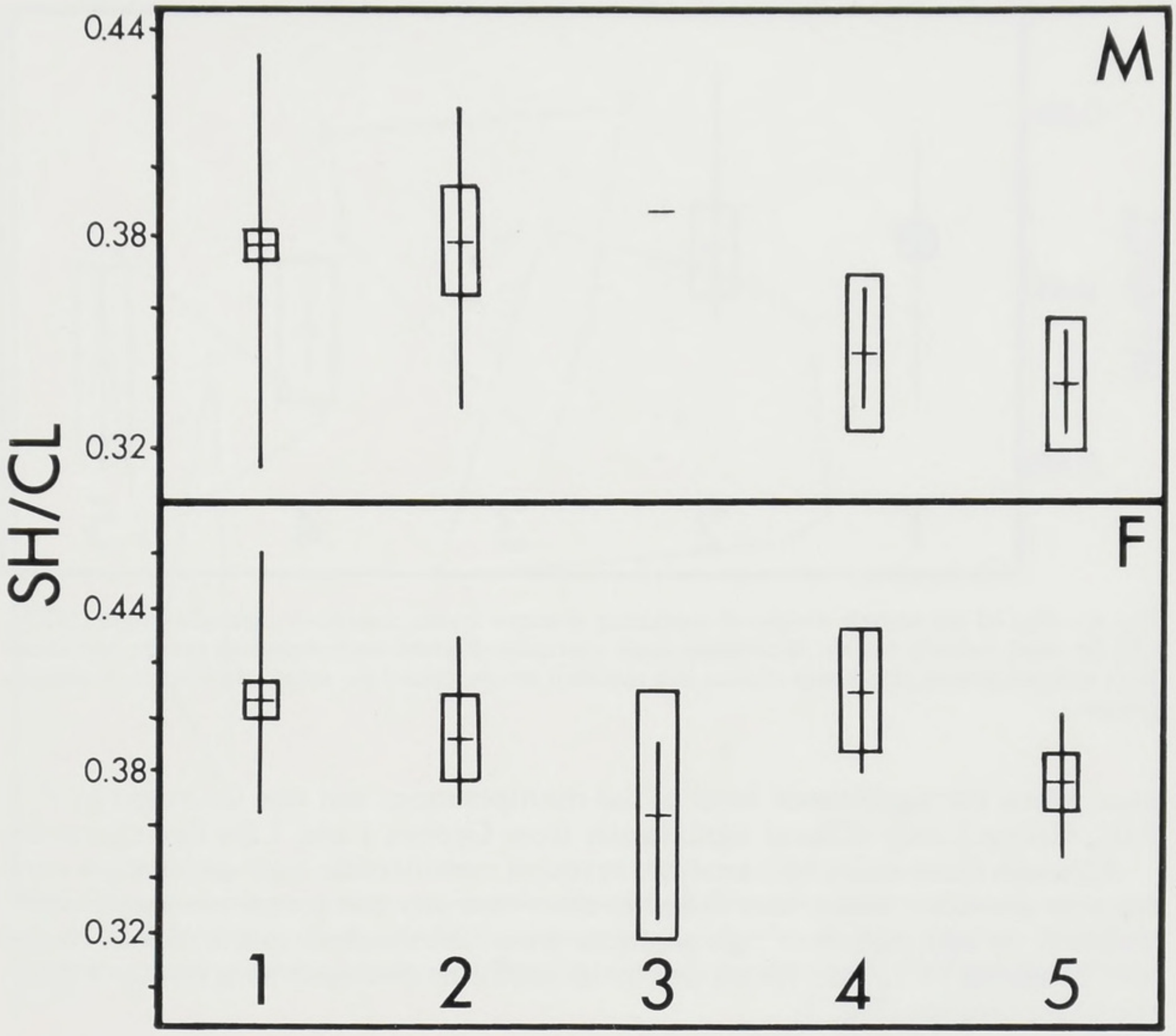

Fig. 3.—Plot of the sample means of shell height/maximum carapace length (SH/CL) for male (M) and female (F) redbelly turtles. Vertical lines represent ranges; horizontal lines indicate means; and boxes enclose two standard errors around the mean. Numbers 1–5 indicate groups.

Univariate Analysis of Variation

Separate one-way ANOVA of character ratios by group (Table 2) revealed that most of them varied highly significantly across groups. Group means of those characters that varied significantly across groups for both sexes at $P < 0.01$ are listed in Table 3. Character ratio means for Group 1 are maximum among all samples for both males and females for MCW/CL, BL/CL, ING/CL, IP/CL, and IF/CL, and for males only for PL/CL. However, a multiple range test of each character by group (sexes separately) revealed that the mean of Group 1 did not differ significantly from the means of all four of the other populations for any character; but, it did differ significantly (at $P < 0.05$) from three of the four other populations (groups 2, 4, and 5; except in one case) for MCW/CL in females, BL/CL in males and females, AXIN/CL in males, IP/CL in females, and ING/CL (from 2, 3, and 4) in females.

With one exception (Group 5 for GL/CL in females; Fig. 2), no group was significantly different (at $P < 0.05$) from all other groups for any character; how-

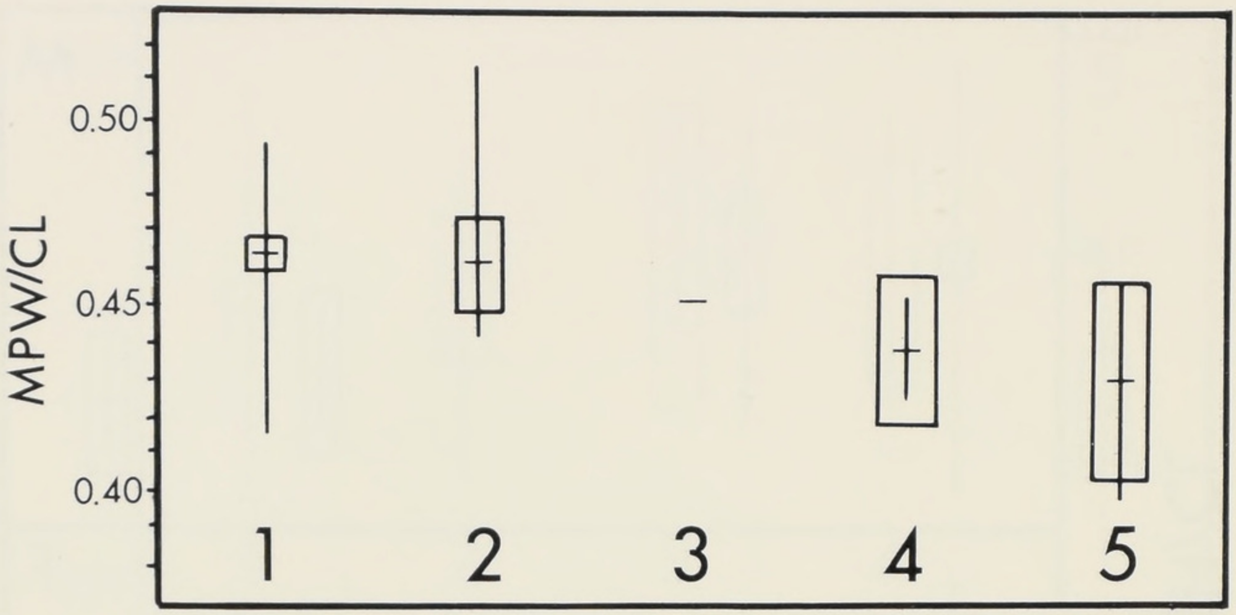

Fig. 4.—Plot of the sample means of maximum plastron width/maximum carapace length (MPW/CL) for male redbelly turtles, illustrating clinal variation. Vertical lines represent ranges; horizontal lines indicate means; and boxes enclose two standard errors around the mean. Numbers 1–5 indicate groups.

ever, when the significance level of the multiple range test was increased to $P < 0.01$, Group 5 only differed significantly from Groups 1 and 2 for that character.

Although these univariate analyses revealed considerable inter-population variation in character ratios, they failed to show that any one group was significantly different. In addition, the single character on which the description of *P. r. bangsi* was based (SH/CL) was found not to be useful in distinguishing Group 1 from the other Groups (Fig. 3)

Table 3.—*Group means of character ratios for redbelly turtles that varied significantly across groups for both sexes at least to $P < 0.01$. See Table 2 for results of ANOVA. Groups are delimited in text.*

		Group				
Character	Sex	1	2	3	4	5
N	M	54	12	1	4	5
	F	44	10	4	6	13
SH/CL	M	0.378	0.380	0.388	0.347	0.338
	F	0.406	0.392	0.364	0.410	0.377
MCW/CL	M	0.727	0.716	0.686	0.698	0.699
	F	0.730	0.700	0.708	0.708	0.702
PL/CL	M	0.906	0.895	0.870	0.877	0.867
	F	0.937	0.922	0.945	0.931	0.913
BL/CL	M	0.351	0.335	0.322	0.322	0.338
	F	0.372	0.355	0.367	0.345	0.361
ING/CL	M	0.178	0.161	0.159	0.146	0.145
	F	0.182	0.160	0.158	0.156	0.171
IP/CL	M	0.146	0.134	0.111	0.133	0.118
	F	0.163	0.143	0.158	0.146	0.141
IF/CL	M	0.111	0.099	0.108	0.128	0.138
	F	0.107	0.095	0.080	0.107	0.115

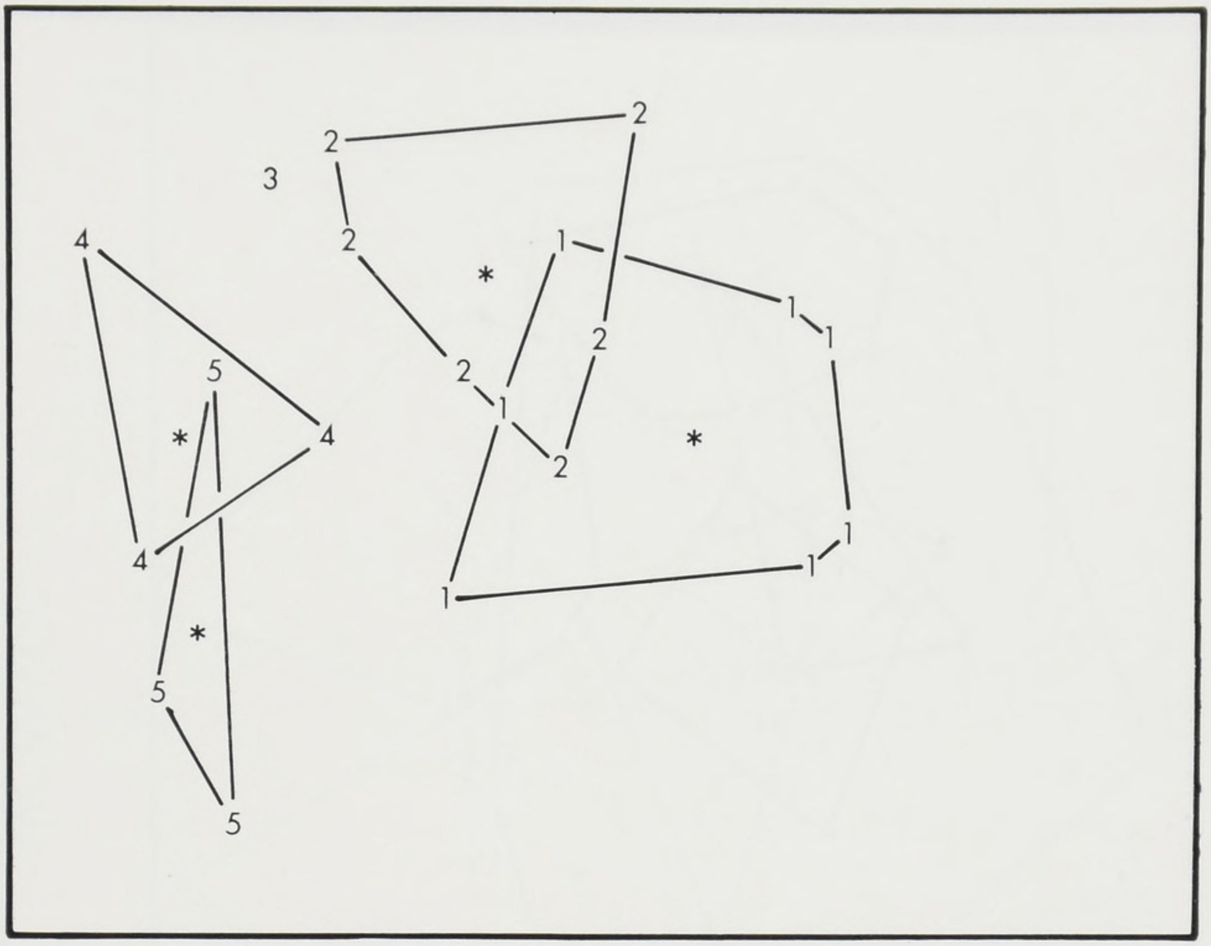

Fig. 5.—Canonical plot of male redbelly turtle data by group 1–5. Polygons indicate maximum dispersion around group means (asterisks). First canonical axis accounts for 70.4% of variation; second, 16.2%.

The univariate results suggest that clinal variation occurs in a few of the characters examined (e.g., see PL/CL in Table 3). For example, Group 1 has the highest or lowest mean for eight characters among males and six among females, and Group 5 has the highest or lowest sample mean for eight characters among males and six among females. Furthermore, for three of those characters among males (MPW/CL, ING/CL, and AXIN/CL), Groups 1 and 5 exhibited the extreme values of the means, and for two characters among females (MPW/CL and IP/CL), the same was true. The means of three characters (all for males; MPW/CL, AX/CL, and ING/CL) exhibited continuous clinal variation across the group means (Fig. 4)

Multivariate Analysis of Variation

The canonical plot produced by discriminant analysis (DA) of the male data set (Fig. 5) suggests that sample 1 (*P. r. bangsi*) is not distinct. The discriminant function using all 17 character ratios could correctly classify 90% of Group 1 males (100% of Groups 3, 4, and 5), but the dispersion pattern in Fig. 5 can best be explained as continuous clinal variation in shell size and scute measurements.

The canonical plot of the female DA (Fig. 6) suggests that each Group is distinctive. The female discriminant function was able to correctly classify 97% of Group 1 specimens (100% of Groups 2, 4, and 5).

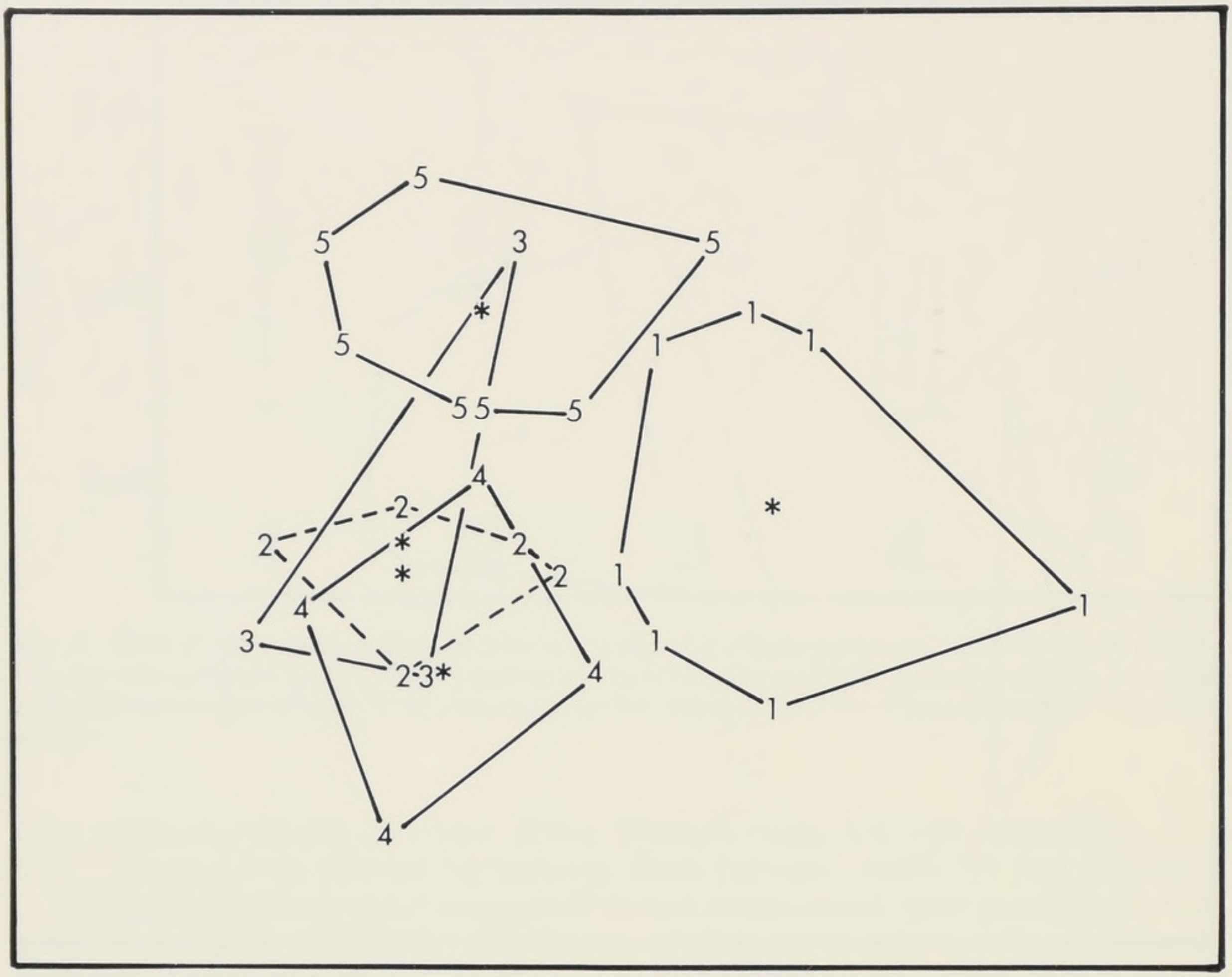

Fig. 6.—Canonical plot of female redbelly turtle data by group 1–5. Polygons indicate maximum dispersion around sample means (asterisks). First canonical axis accounts for 64.9% of variation; second, 20.2%.

The DA is sufficiently robust to discriminate among all five groups; however, it does not clearly indicate that any one (or more) group(s) is (are) consistently distinctive. Based solely on the results of the DA, one might argue that all five groups merit taxonomic recognition. However, we believe that this would be inappropriate for the following reasons. First, the level of discrimination probably would decrease with larger samples from the more southerly populations. Second, bivariate plots of the characters most important in the DA in discriminating among the groups (Fig. 7–10) reveal extensive overlap among groups. Only if many characters (10–15) were considered simultaneously could one confidently diagnose each of the five groups (for example, the DA required 17 characters to correctly assign 90–97% of the Massachusetts turtles). Finally, variation in several characters (Table 3) across groups appears to be clinal, with males in northern groups tending to have a wider carapace, longer bridges, longer inguinal scutes, and a longer and wider plastron than in southern groups, and females from northern groups tending to have a longer plastron, longer bridges, and a wider carapace than in southern groups.

Cluster analysis of group means (Fig. 11) for all 17 character ratios produced

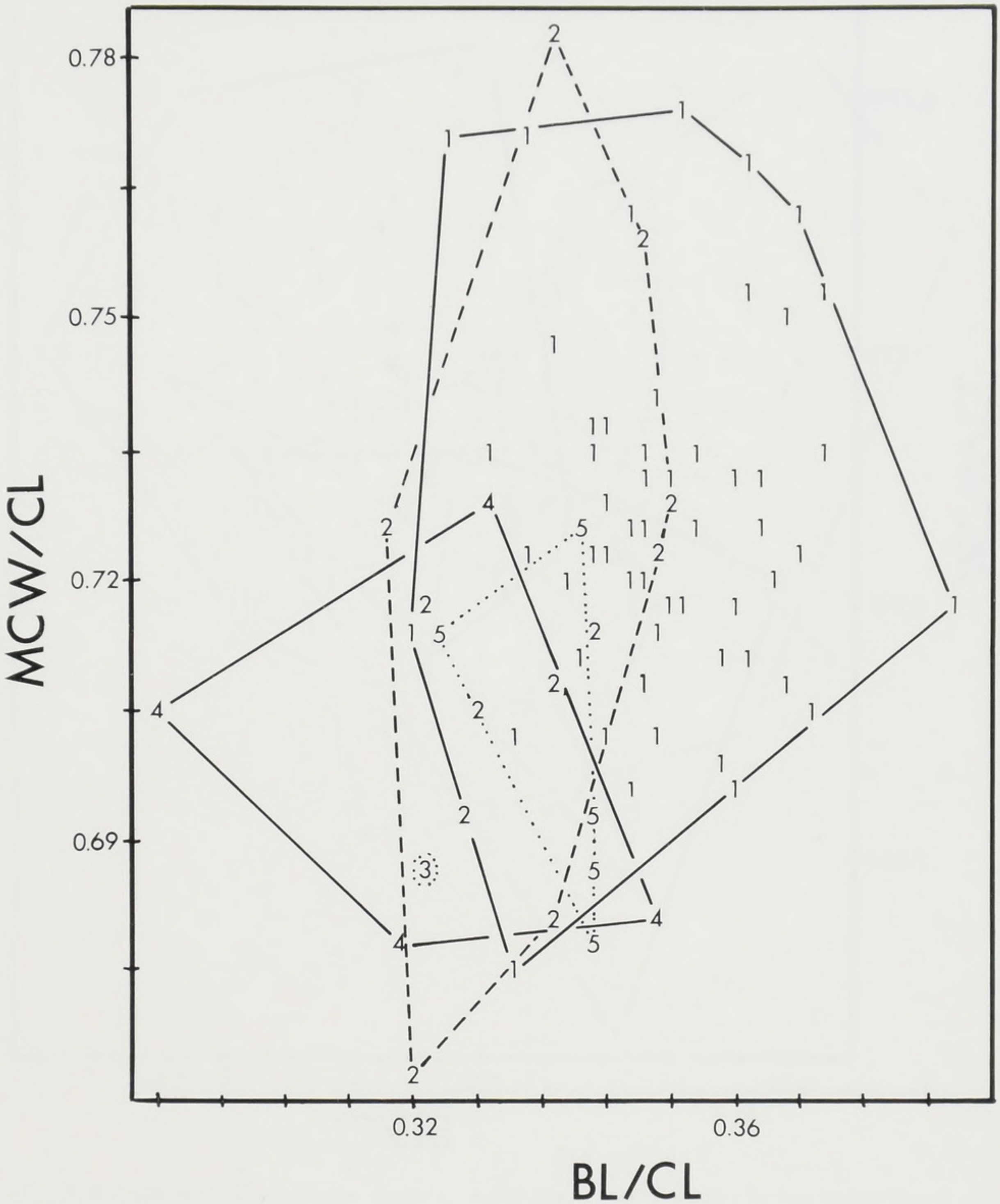

Fig. 7.—Bivariate plot of relative bridge length (BL/CL) versus relative carapace width (MCW/CL) for male redbelly turtles. Individual turtles are plotted by group number 1–5.

dendrograms (whether by average linkage, centroid, or median method) that offer little additional information. In the male analysis, the clinal relationship is apparent, and, for the females, Group 3 is most distinctive, though that is surely an artifact of the small sample size (N = 4).

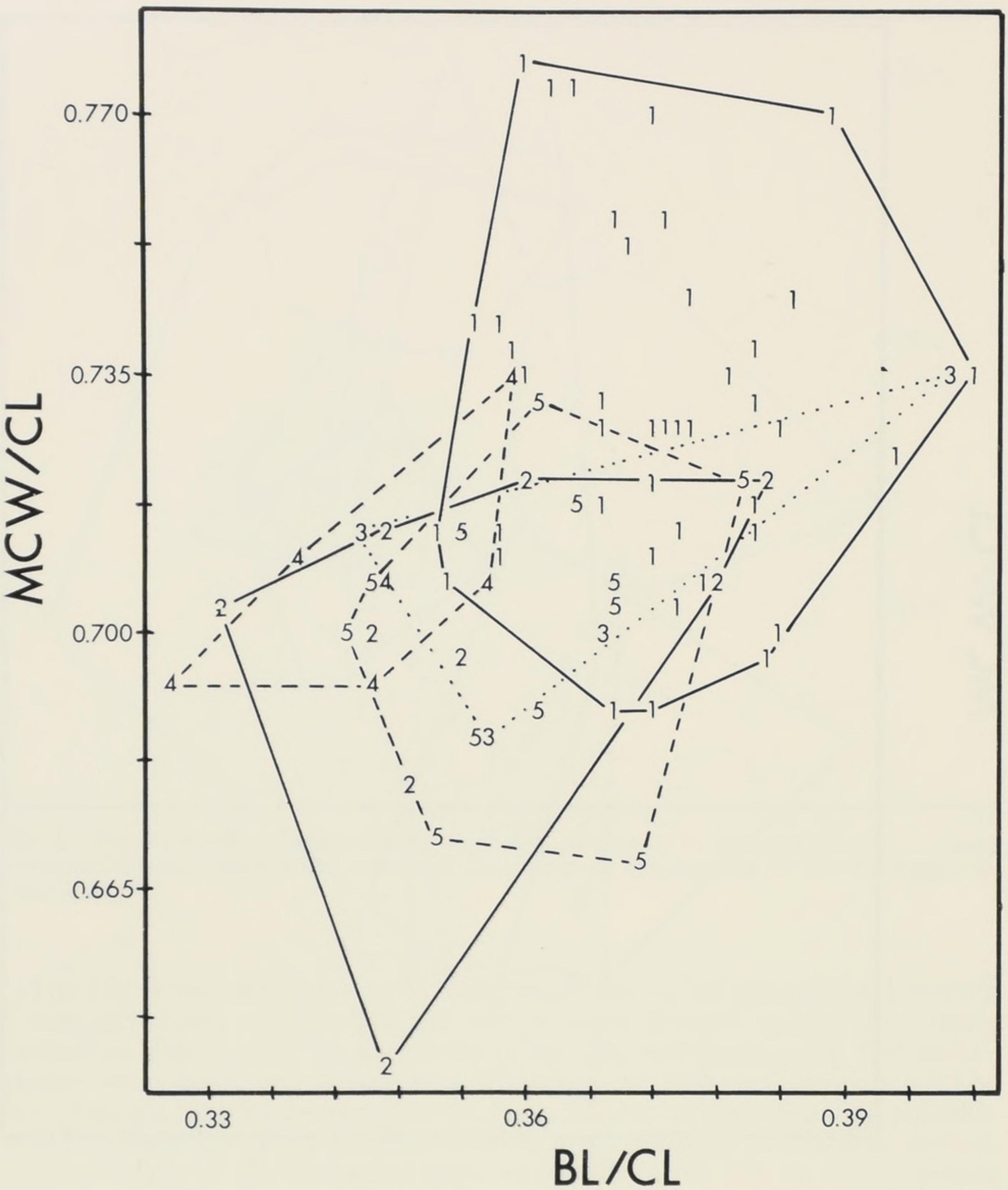

Fig. 8.—Bivariate plot of relative bridge length (BL/CL) versus relative carapace width (MCW/CL) for female redbelly turtles. Individual turtles are plotted by group number 1–5.

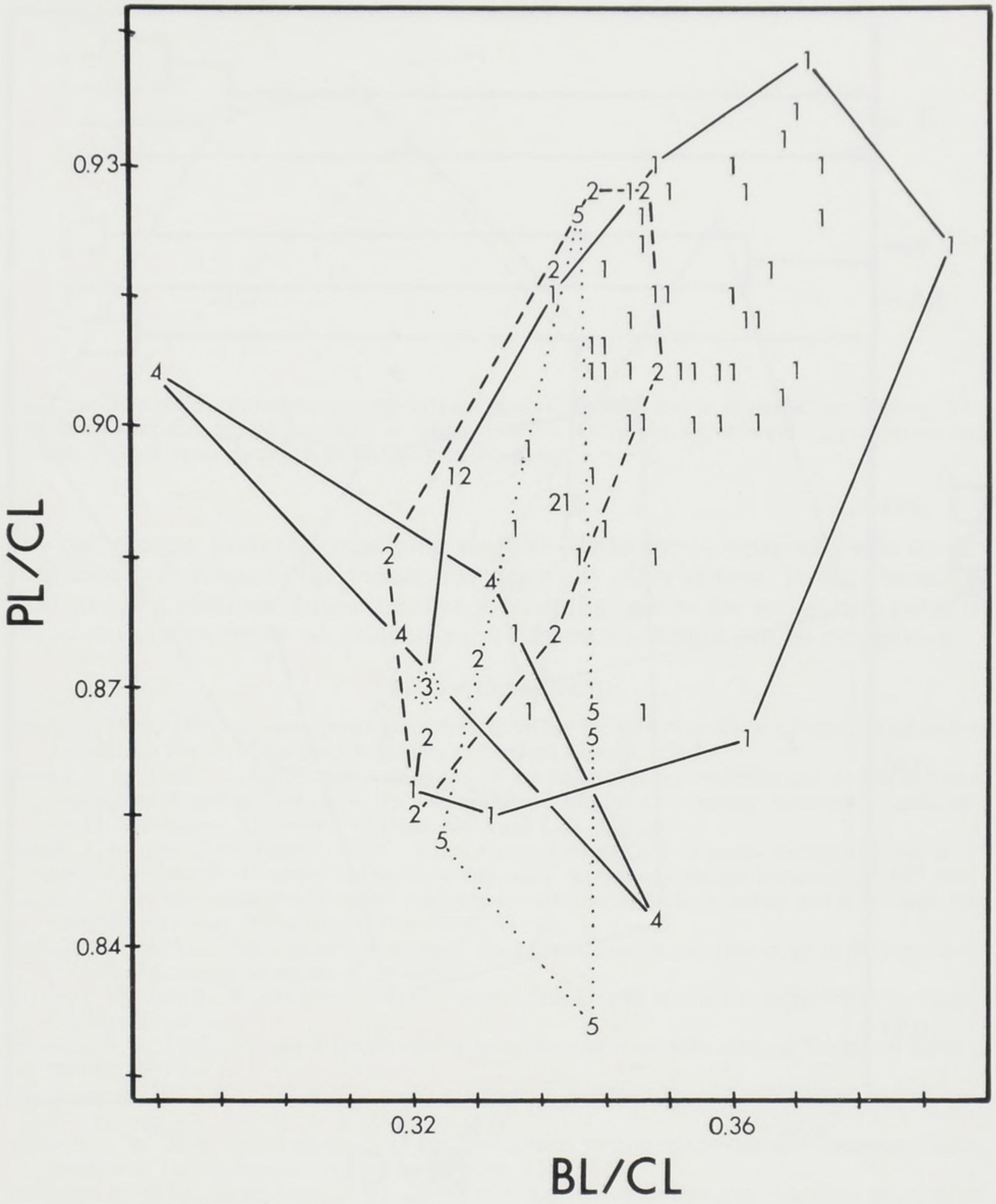

Fig. 9.—Bivariate plot of relative bridge length (BL/CL) versus relative plastron length (PL/CL) for male redbelly turtles. Individual turtles are plotted by group number 1–5.

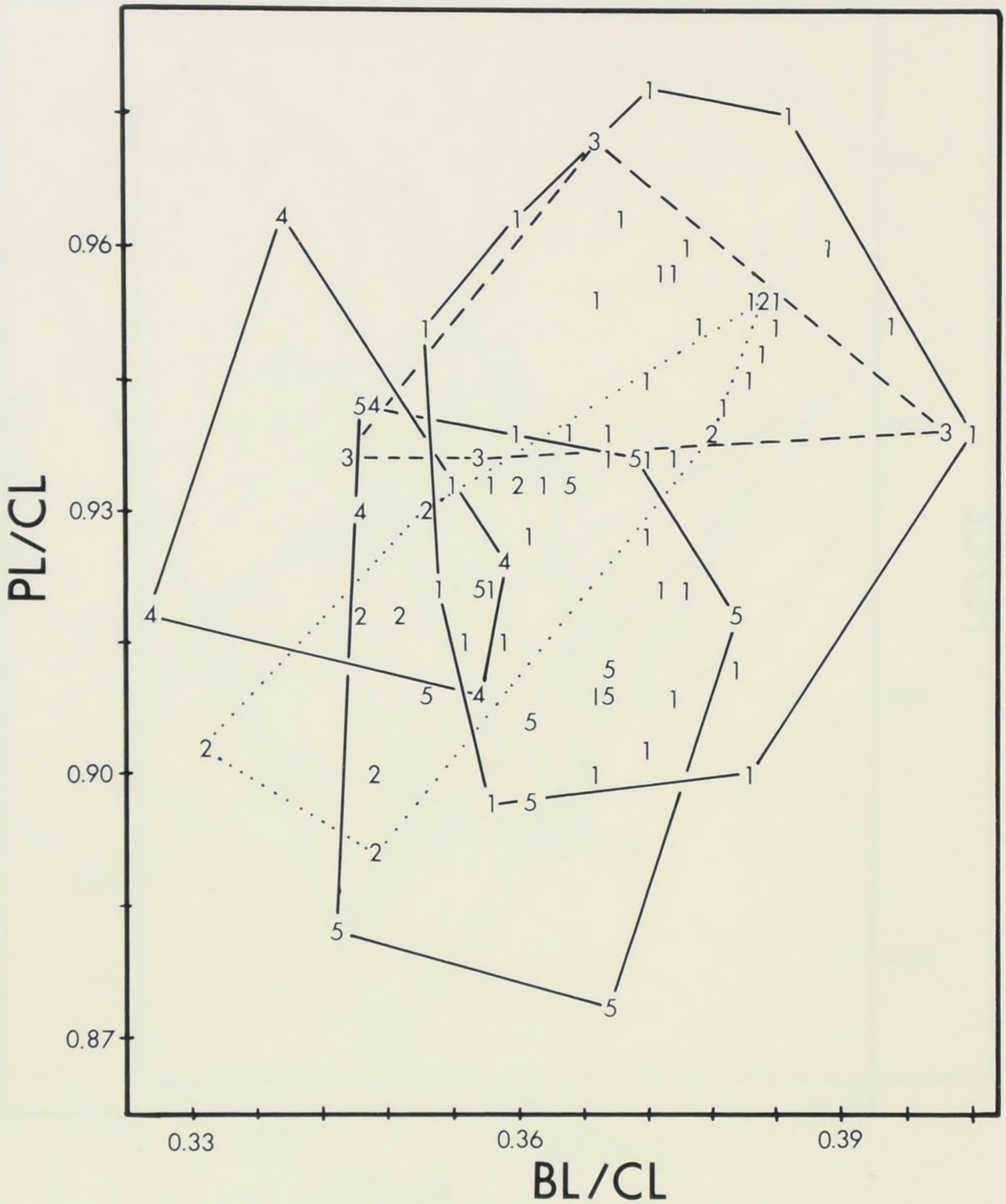

Fig. 10.—Bivariate plot of relative bridge length (BL/CL) versus relative plastron length (PL/CL) for female redbelly turtles. Individual turtles are plotted by group number 1–5.

CONCLUSIONS

The single character on which Babcock (1937) based his diagnosis of *Pseudemys rubriventris bangsi* (relative shell height; here SH/CL) is not significantly divergent in turtles from Massachusetts. There is considerable geographic variation in other characters, some of it apparently clinal. No single character reliably distinguishes

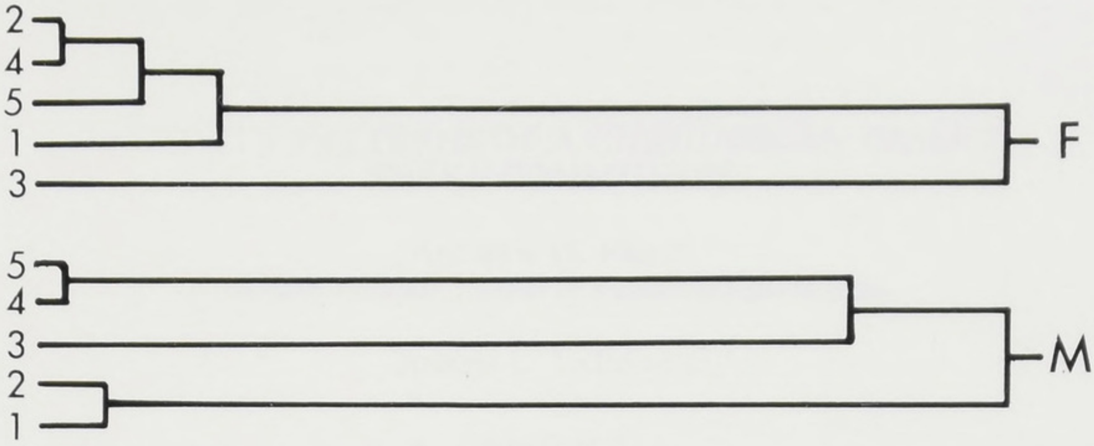

Fig. 11.—Distance dendrograms (average linkage method; females above, males below) relating character means for five groups (see text) of redbelly turtles. Other linkage methods (e.g. centroid and median) yielded dendrograms with the same topologies.

any one sample from the remaining samples. Bivariate comparisons also do not consistently distinguish the Massachusetts or any other sample. In the absence of evidence of significant discontinuities in variation across the geographic range of *Pseudemys rubriventris,* we conclude the subspecies should not be recognized.

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