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Shell selection in the estuarine hermit crab *Clibanarius longitarsus* (De Haan)

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Abstract. In the laboratory, under choice situation, *C. longitarsus* preferred shells with greater shell width and shell weight. The correlation coefficient values calculated between the crab and shell parameters in the laboratory sample showed that this hermit crab selects a shell of suitable dimension for its occupation. In the multiple regression equations calculated with carapace length against the three shell variables aperture width, shell width and shell weight which are deemed to be important for hermit crabs, the regression coefficient of the variables varied much. The unscaled first principal component explained 84·9% of the total variability of the shell parameters and scaled first principal component explained 95·8% of shell parameters. The scaled first principal component was found to be a reliable estimator of shell size and the hermit crab, if given a choice, selected a shell of suitable dimension which fits its body quite closely.

Keywords. *Clibanarius longitarsus* ; shell selection in laboratory ; multivariate analysis.

1. Introduction

Empty gastropod shells constitute an important resource for hermit crabs and a hermit crab in order to protect itself from the environment and from its predators must enter a gastropod shell. This behaviour of hermit crabs living in empty gastropod shells intrigued naturalists down through the ages from Aristotle (Reese 1963) to the present (Ajmal Khan *et al* 1980). Hermit crabs do not enter gastropod shells at random but prefer shells according to shape, shell covering, dimension and weight (Grant and Ulmer 1974). Under choice situation, the shell factors influencing the estuarine hermit crab *Clibanarius longitarsus* in shell selection were studied presently through multivariate analysis.

2. Materials and methods

Five measures of the gastropod shells, i.e., shell length, shell width, aperture length, aperture width and shell weight and three measures of hermit crabs, i.e., carapace length, dactylus length of second left walking leg and weight of the crab were used in the present study. The length of the shell was measured from the tip of spire to the other end of the shell, the shell width was the greatest distance at right angles to the length of the shell, aperture length was measured parallel to shell length and the aperture width was the greatest distance from the margin of the outer lip of the inner wall of the inner lip at 90° to aperture length (parietal callosities were excluded from aperture width). The shells were completely dried before weighing. Carapace length of the crab was measured from the tip of the rostrum to the posterior notch and the live body weight was taken after blotting the specimen dry with a blotting paper. Correlation coefficient values between crab and shell variables were calculated for 50 specimens collected from the field and for 50 specimens of hermit crabs allowed to select shells of their choice in the laboratory. For shell selection experiments in the laboratory, the crabs were divided into 4 size groups (I group 4–6·9 mm, II group 7–10 mm, III group 10·1–14·9 mm and IV group 15 mm and above) and the gastropod shells inhabited in the field by crabs in each length were identified and the empty gastropod shells represented in each length group were collected and used in the shell selection experiments. Percentage distribution of molluscan shell types, occupied by the crabs of the four size groups is given elsewhere (Ajmal Khan and Natarajan 1981). Shell selection experiments in the laboratory were done following Grant and Ulmer (1974).

3. Results

Shell preference of the hermit crab was found to vary from one size group to another. While the first size group crabs showed preference for the shells of *Nassa jacksoniana*, second, third and fourth size groups showed preference for the shells of *Nassa dorsata*, *Babylonia spirata* and *Bursa spinosa* respectively.

The mean values of carapace lengths of crabs and variables of gastropod shells occupied by the hermit crabs in the field and selected in the laboratory experiments, are given in table 1. Since the standard errors of the shells selected in the laboratory were noticeably larger than the corresponding values in field sample, a modified form of the t test, the statistic d (Bailey 1959) was used to determine if the carapace length and shell parameters of the two categories were significantly different from each other. It was found that the carapace length of hermit crabs in the above two situations were not significantly different. In the same way among the shell variables, the aperture width in these two categories was not significantly different but the shell width and shell weight differed significantly.

The correlation coefficient values calculated between the crabs and shell parameters in field samples and laboratory selected samples are given in table 2. It was found that there was no large scale difference in the r values of aperture width and shell width calculated against carapace length in the two situations and in both the cases the values were highly significant ($P < \cdot 001$). Eventhough the r values in the first category (field sample) were statistically significant in all cases except one (carapace length/shell length), the r values in the second category were highly significant. By looking at the r values in the second situation, it could be inferred that a single factor alone was not influencing this hermit crab in shell selection and this hermit crab normally selected a shell suitable in general dimension. But the difficulty in putting forward the above inference only by looking

Table 1. Results of crab carapace lengths and shell variables of shells occupied and shell selected by *C. longitarsus*. Table values are means ± standard errors. The "*d*" values are those given from the formula of Bailey (1959) for comparing two means. *P* : Probability.

Variable	Shells occupied	Shells selected	*d* value	*P*
Carapace length	13·13 mm ±0·91	13·12 mm ±0·99	0·01	>0·10
Shell width	20·98 mm ±0·66	28·26 mm ±2·39	2·94	<0·01
Aperture width	9·68 mm ±0·29	12·04 mm ±1·10	1·90	>0·05
Shell weight	8·88 mm ±0·78	18·31 mm ±3·12	2·93	<0·01

Table 2. Correlation coefficient values between the crab and shell parameters of shells occupied and shells selected by *C. longitarsus*. *P* : Probability ; Number of sample 50 each.

Parameters	*r* value in field sample	*P*	*r* value calculated after shell selection experiment in the laboratory.	*p*
Carapace length/Aperture length	+0·413	<0·01	+0·960	<0·001
Carapace length/Aperture width	+0·636	<0·001	+0·890	<0·001
Carapace length/Shell length	+1·356 (Spurious)	..	+0·922	<0·001
Carapace length/Shell width	+0·464	<0·001	+0·962	<0·001
Carapace length/Shell weight	+0·397	<0·01	+0·819	<0·001
Dactylus length/Aperture length	+0·301	<0·05	0·924	<0·001
Dactylus length/Aperture width	+0·331	<0·02	+0·902	<0·001
Dactylus length/Shell length	+0·318	<0·05	+0·904	<0·001
Dactylus length/Shell width	+0·326	<0·02	+0·962	<0·001
Dactylus length/Shell weight	+0·328	<0·02	+0·837	<0·001
Crab body weight/Shell weight	+0·352	<0·02	+0·815	<0·001

at the *r* values was that shell variables are interrelated with each other and simple regression and correlation techniques fail to show the individual influence of a shell parameter during selection. So, for this type of study multivariate analysis seems to be preferable.

Table 3. Results of multiple regression of carapace length (Y) against aperture width (x_1), shell width (x_2) and shell weight (x_3) of gastropod shells occupied in the field and selected in the laboratory by *C. longitarsus*.

	Regression equation	Coefficient of variation of shell parameters
Shells occupied in the field	$Y-\bar{Y}=0.012\,(x_1-\bar{x}_1)$ $+0.343\,(x_2-\bar{x}_2)$ $+0.023\,(x_3-\bar{x}_3)$	$x_1=63.07$ $x_2=60.08$ $x_3=56.78$
Shells selected in the laboratory	$Y-\bar{Y}=0.395\,(x_1-\bar{x}_4)$ $+0.351\,(x_2-\bar{x}_2)$ $+(-0.073)\,(x_3-\bar{x}_3)$	$x_1=64.87$ $x_2=59.76$ $x_3=82.96$

Through studies on the shell selection behaviour of hermit crabs, it became clear that, among different shell variables, three variables, viz., shell volume, shell aperture width and shell weight were more important. The volume of shell interior is certainly of prime importance to hermit crabs, but volume estimate is difficult time consuming and often inaccurate and imprecise (Kuris and Brody 1976). So a change of shell var iable was made and instead of shell volume, shell width in addition to the other two variables was used in the multivariate analysis of the present study.

The multiple regression equation of carapace length against the three shell variables in the field situation and by choice in the laboratory are given in table 3. The coefficient of variation in both the equations for aperture and shell widths did not differ widely, but the coefficient of variation for shell weight differed widely. Moreover, in the laboratory choice situation, even though the r values used in the multiple regression equation did not vary much, regression coefficient for weight differed widely from the other two. The main problem in using multiple regression to distinguish the effects of separate parameters was that there was high correlation between the three shell variables which obscured their separate effects. To overcome this difficulty principal component analysis was used.

For principal component analysis all the shell variables have to be expressed in the same units. Here the shell width and aperture width were measured in millimeters and shell weight in grams. To overcome this defect caused by the three shell variables measured in different units, scaling of shell variables has to be done and both the unscaled and scaled principal component analyses have to be compared. Scaling can be done by dividing the shell parameters by the square root of the sums of squares of their deviation (Mitchell 1976). Logarithmic transformation of the variables also approximately satisfies these conditions (Kuris and Brody 1976). In the present study scaling was done by the second method. The results of the unscaled and scaled principal component analyses are given in tables 4 and 5 respectively. Multiple regression equation of the carapace length of the crabs against the unscaled and scaled principal components are given in table 6.

The first principal component in the unscaled situation explained 84·9% of the total variability of the shell parameters. The second component explained only

Table 4. Principal components of shells selected by *C. longitarsus* in the laboratory. No Scaling has been performed on them.

x_1—Aperture width ; x_2—shell width and x_3—shell weight.

Principal components		Percentage contributions to total variability of shell parameters
I Component	$1 \cdot 000000x_1$ $+0 \cdot 964919x_2$ $+0 \cdot 887572x_3$	84·9
II Component	$-0 \cdot 139600x_1$ $+0 \cdot 666600x_2$ $+1 \cdot 000000x_3$	1·5

Table 5. Principal components of shells selected by *C. longitarsus* in the laboratory. Scaling was performed by logarithmic transformation of shell and crab variables. x_1-aperture width ; x_2—shell width and x_3—shell weight.

Principal components		Percentage contributions to total variability of shell parameters
I Component	$1 \cdot 000000\ x_1$ $+0 \cdot 999043\ x_2$ $+0 \cdot 992294\ x_3$	95·800
II Component	$1 \cdot 000000\ x_1$ $+-0 \cdot 500000\ x_2$ $+0 \cdot 500000\ x_3$	0·013

Table 6. Regression equations of carapace length against unscaled and scaled principal components for shells selected in the laboratory by *C. longitarsus*. Y—carapace length ; x_1—I principal component ; x_2—II principal component.

Regression equation		Coefficient of variation of principal components
Unscaled	$Y-\bar{Y} = 0 \cdot 054\ (x_1-\bar{x}_1)$ $+7 \cdot 550\ (x_2-\bar{x}_2)$	$x_1 = 77 \cdot 11$ $x_2 = 74 \cdot 01$
Scaled	$Y-\bar{Y} = 0 \cdot 154\ (x_1-\bar{x}_1)$ $+0 \cdot 005\ (x_2-\bar{x}_2)$	$x_1 = 61 \cdot 39$ $x_2 =$ negligible

1·5% of the total variability. In scaled component analysis, the results were still more significant; the first principal component explained 95·8% of the total variability while the percentage of variability of the shell parameters explained by the second component was very low (0·013%). Moreover both in unscaled and scaled first principal components, the values attached to the three variables were nearly equal; in the scaled first principal component the values were more or less the same. This indicates that in the first principal component the three shell variables play equal roles in shell selection. The coefficient of variation of the first and second principal components in the unscaled situation was very close to the multiple regression equation. But in the scaled situation the coefficient of variation of second principal component was negligible.

4. Discussion

The first principal component seems to be a more reliable estimator of shell size for hermit crabs than selection by multiple regression of the best pair of shell and crab size correlates (Kuris and Brody 1976). In the present study also, both in scaled and unscaled conditions, the variability of the shell parameters could be mostly explained by the first principal component. Similar results were also reported by Mitchell (1976). When a multiple regression equation was calculated, with first principal component and second principal component against carapace length, the coefficient of variation of the two components in unscaled situation was more or less equal. In scaled condition, the coefficient of variation for first principal component was high and it was negligible in the case of second component. It therefore seems to be advisable to look at the scaled analysis and interpret the first principal component as the main guideline which influences *C. longitarsus* to select its shell. In *Pagurus bernhardus*, the percentage contributions to the total variability of the shell parameters of the first principal component was slightly less in the case of scaled analysis than in the unscaled analysis (Mitchell 1976). Even then, the percentage of variation in crab weight explained by the scaled first principal component was more than that of unscaled first principal component. But in the present study, the percentage contribution to the total variability of shell parameters was more in the scaled first principal component than in the unscaled first principal component. So it is probable that the scaled first principal component will explain more percentage of variation in crab length than the second principal component. This first principal component can be very easily interpreted, as, in all the cases, the length concerned with all the three shell variables is almost equal. This means that all the three shell variables play equally important roles in the selection of a shell.

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