

SIZE DIMORPHISM OF *CALLINECTES AMNICOLA* DE ROCHEBRUNE, 1881 (DECAPODA, PORTUNIDAE) IN THE IVORIAN LAGOONS.

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Abstract

Size dimorphism is a common phenomenon in crabs species. This study was undertaken to investigate size dimorphism of populations of *Callinectes amnicola* in the Ivorian Lagoons. Data on eleven morphological characters; body weight, carapace width, carapace length, right and left propodus length, right and left merus length, right and left carp length and right and left dactylus length, were taken from 585 specimens comprising 314 males and 271 females. In both 585 specimens, heterochely showed that 51.12 percent had long claw to left and 48.88 percent had to right. Concerning size dimorphism index, in six localities, we found that four populations had males who weighter than females. However, we remarked that degree dimorphism (SD) is low between males and females for chelipeds length (1% to 11%). The cases of homochely were found for four characters.

Keywords: Size dimorphism, Degree dimorphism, Heterochely, *Callinectes amnicola*, Morphological.

INTRODUCTION

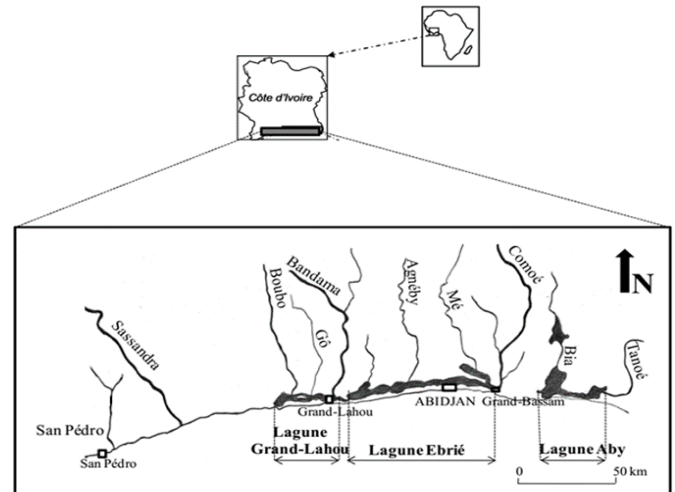
The morphometric and allometric analyses or relationship among various parts of the body is functionally important in biology (Sinha, 2014). Moreover variation in body size, or sexual size dimorphism, is common in animals, and has a variety of ecological and life-history implications (Promislow 1992; Fairbairn 1997; Fairbairn *et al.*, 2007). Also, the size and growth of crabs are important ecological indicators. The ranges of their significant sizes expose the richness of the habitat with nutrient (Schlacher *et al.*, 2011). During ontogeny, crabs undergo morphological changes as well as alterations in the relative size and these changes in morphology have been used by many authors to estimate maturity (Le Foll, 1993; Le Foll *et al.*, 1993; Sampedro *et al.*,

1999). Thus, evolutionary change in morphology is determined by the interaction of the timing of selection and the distribution of ontogenetic variation. More researchers have used comparative studies to examine morphology in species and populations. One approach used for these reserchers is the comparison of phenotypic selection on the sexes and variation in sexual dimorphism in different populations (Powell and King 1997; Wikelski and Trillmich 1997). Sexual dimorphism is generally interpreted as being the outcome of sexual selection. Knowledge of these distinguishing characters and size relationships in individuals is of particular importance in the study of commercially valuable crustaceans. The aim of this study was to gather large datasets of morphometric values of *Callinectes amnicola* on heterochely and sexual dimorphism with regard to body size, cheliped size, and asymmetric index.

METHODOLOGY

Sampling and data collection

A total of 585 specimens were collected in the lagoons of Aby, Ebrié and Grand-Lahou (Figure 1). All samples were collected from commercial fishing. Linear measurements were always taken by the same person. Body weight was measured with an electronic balance. Sex was recognised by abdomen characteristic. The morphometric measures of the carapace, the left (L) and right (R) chelipeds were taken using image analysis software Imagej.



Fig(1) Sample differents lagoon of Côte d'Ivoire

Data analysis

Data on eleven morphologic characters (Figure 2); body weight (w), carapace length (LC), carapace wide (CW), right and left cheliped length (RCL & LCL), right and left cheliped propodus length (RCPL & LCPL), right and left cheliped merus length (RCML & LCML) and right and left cheliped carp length (RCaL & LCaL) were taken. The difference in female and male body parameters was analysed by applying either independent sample t-tests, in the case of parametric data, or Mann-Whitney tests. Shapiro-Wilk tests for analysing normality of data as well as Levene's tests for analysing homogeneity of variances were applied to test whether data was parametric. All statistical analyses were carried out with STATISTICA software (release 7.1, StatSoft, 2005).

Standardisation of morphologic characters

Due to variations in size of crab from different areas, only morphometric data were statistically adjusted to permit comparative analysis of shape independently of size (Thorpe, 1976). To remove the effect of size and in order to achieve a size and shape independent comparison of the size of the cheliped parameters between females and males, all morphometric characters were

standardized according to the equation (Thorpe, 1976; Ihssen *et al.*, 1981; Hurlbut and Clay, 1998 ; Leonart *et al.*, 2000).

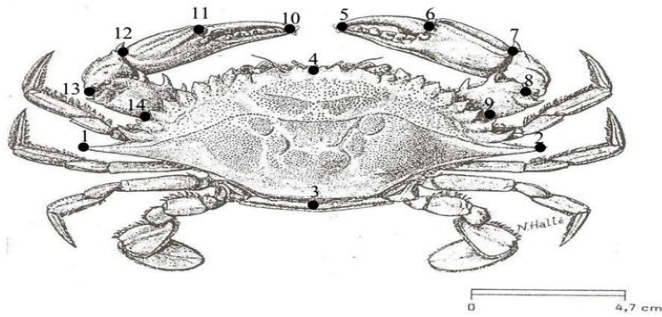


Figure 2: Location of the 14 anatomical landmarks of *Callinectes ornicola* : (1) edge of the left lateral thorn; (2) edge of the right lateral thorn; (3) middle of carapace base ; (4) middle of front ; (5) tip of right dactylus ; (6) posterior tip of right dactylus ; (7) posterior edge of right propodus ; (8) anterior tip of right merus, (9) posterior edge of right merus ; (10) tip of left dactylus ; (11) anterior edge of left palm ; (12) posterior tip of left propodus ; (13) posterior edge of left carap ; (14) posterior tip of left merus.

$$M_s = M_0 \left(\frac{L_s}{L_0} \right)^b$$

M_s is the standardized measurements, M_0 is the length of measured character, L_s is the arithmetic mean of the standard length (carapace length) for all shrimp from all samples in each analysis and L_0 is the standard length of each specimen. The value of the parameter b was estimated for each character from the observed data by allometric growth equation $M = aL^b$. Coefficient b was evaluated as the slope of regression of $\log_{10}M_0$ on $\log_{10}L_0$ using all crab in each group (Leonart *et al.*, 2000; Ferrito *et al.*, 2007).

Dimensions of body parameters

Size dimorphism index (SDI) representing the ratio of male to female (De Marchi *et al.*, 2012). The means of female and male body parameters were used to calculate a compressed size dimorphism index (SDI). The SDI is calculated by dividing the mean size of the larger sex by the mean size of the smaller sex (Anagnostou et Schubart, 2014). Size dimorphism index was calculated as:

$$SDI = \left(\frac{X_l}{X_s} \right) - 1$$

With X_l is the mean size of the larger sex, X_s is the mean size of the smaller sex.

According to Anagnostou et Schubart (2014), the resulting value of SDI renders a negative value when males are larger than females, and a positive value when females are larger than males.

Dimensions of cheliped parameters and heterochely

To facilitate comparisons with other studies, for each characters of chelipeds we report standardized differences between sexes. The heterochely is the difference in size of the chelipeds. The degree of heterochely in both females and males was described by calculating an asymmetry index (AI) as proposed by Van Valen (1962):

$$AI = \frac{(R-L)}{(R+L)}$$

with R and L representing the standardised values of the measured parameters of the right (R) and left (L) chelipeds. The values of AI range between -1 and $+1$. If AI is 0, there is no difference in the measured dimension between the right and left cheliped parameter (perfect homochely). If AI is smaller than 0, the dimension of the left

cheliped parameter is larger than that of the right cheliped parameter (heterochely). If AI is larger than 0, the dimension of the left cheliped parameter is smaller than that of the right cheliped parameter (heterochely) (Anagnostou & Schubart, 2014).

RESULTS

Degree and size dimorphism index

Populations strongly differed in sexual dimorphism (Table 1). For this study, five characters were considered. It is the weight (w), carapace length (L_c), carapace width (CW), right cheliped length (RCL) and left length cheliped (LCL). The results are shown in the table (xx). Homogeneity of all parameters was tested to see if they followed normal distribution within each population.

In Adjouan, males had the highest values for the five characters. T test indicates a significant difference ($p < 0.001$) between males and females of this locality for weight (w) (154.5 ± 19.19 g) $>$ 104.5 ± 9.95 g), carapace width (cw) (109.83 ± 5.77 mm) $>$ 93.06 ± 5.35 mm) and carapace length (CL) (54.92 ± 2.82 mm) $>$ 46.12 ± 2.82 mm). Index (SDI) and degree (SD) size dimorphism showed dimorphism pronounced in males. It were more important in weight (SD = 47%). As length chelipeds (RCL and LCL), Mann-Whitney test revealed significant difference ($p < 0.001$) between males and females of this population. Values recorded for these characters (RCL and LCL) were respectively 91.55 ± 6.6 mm for males and 82.06 ± 13.2 mm for females, 91.67 ± 6.62 mm in males and 82.17 ± 13.3 for females. For these characters, size dimorphism is marked into male (SDI = 0.11 and SD = 11%).

In Adiaké, highest values founded both in females than males. However, the weight (w) and carapace width (CW) was greater in males. It is 149.5 ± 14.57 in males against 99.5 ± 14.57 in females. The value measured at the carapace width (cw) was 103.8 ± 7.79 respectively males and 79.41 ± 6.93 in females. Females Carapace length was higher (49.71 ± 3.68) than males (37.85 ± 4.96). Statistical analysis of these values showed a significant difference (t-test, $p < 0.001$) between males and females for these characters. Index (SDI) and degree of dimorphism (SD) recorded: weight (SDI = - 0.50; SD = 50%), carapace width (SDI = -0.31, SD = 31%) and carapace length (SDI = 0.31; SD = 31%). Size dimorphism index is 50% in weight and 31% L_c and L_c . As chelipeds length (RCL and LCL) t-test showed no significant difference ($p > 0.001$) between males and females. In addition to the index and the degree dimorphism was very low (RCL : SDI = 0.006; SD = 0.06 and LCL : SDI = 0.005, SD = 0.05) but marked in females.

This study showed that at Moossou, size dimorphism was more pronounced in females. Indeed, the highest values of the characters examined was observed in them. T test indicated significant difference ($p < 0.001$) between male and female characters for weight (w) (F: 184.5 ± 14.57 and M: 128 ± 18.33), CW (F: 124.77 ± 6.32 and M: 106.65 ± 7.11) and LC (F: 62.22 ± 2.96 , and M: 52.8 ± 4.27). The results showed that females weighed more than males (SD = 44%) while for CW and LC , the degree of dimorphism was approximately equal (SD: $CW = 17\%$ and $L_c = 18\%$). Unlike the other three characters, the statistical analysis of RCL values (F: 92.5 ± 17.67 and M: 89.15 ± 13.83) and LCL (F: 92.53 ± 17.79 and M: 89.06 ± 13.81) by the t-test showed no significant differences between males and females. For SDI and SD, these two characters had the same values (SDI and SD = 0.04 = 4%).

Overall, the specimens from Layo had a size dimorphism pronounced in males for all characters. The test results indicated significant difference ($p < 0.001$) for characters W (M: 165 ± 19.9 g

Table 1: results of size and degree dimorphism index

Variables	Moossou		Layo		Grand-lahou		Fresco		Adjouan		Adiaké		
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
W	Valeur	128±18,3	184,5±14,5	165±19,9	95±21,1	138,33±48,9	264,58±82,1	121,38±24,1	101,64±17,7	154,5±19,19	104,5±9,9	149,5±14,5	99,5±14,5
	SDI	0,44		- 0,73		0,91		-0,19		-0,47		-0,50	
	SD	44		73		91		19		47		50	
CW	Valeur	106,65±7,1	124,77±6,3	123,69±12,46	81,9±17,1	60,21±7,9	80,65±15,1	108,35±12,2	109,44±16,5	109,83±5,77	93,06±5,3	103,8±7,7	79,41±6,9
	SDI	0,17		-0,51		0,34		0,01		-0,18		-0,31	
	SD	17		51		34		1		18		31	
LC	Valeur	52,8±4,2*	62,22±2,9*	59,15±5,81	40,42±8,2	27,22±3,1	39,76±5,4	52,43±8,2	48,6±5,9	54,92±2,82	46,12±2,8	37,85±4,96	49,71±3,6
	SDI	0,18		-0,46		0,46		-0,08		-0,19		0,31	
	SD	18		46		46		8		19		31	
RCL	Valeur	89,15±13,8	92,5±17,6	91,23±10,3	85,38±9,1	93,15±5,6	94,38±8,8	96,61±13,9	94,42±13,1	91,55±6,6	82,06±13,2	94,98±4,01	95,57±3,5
	SDI	0,04		-0,07		0,01		-0,02		-0,11		0,006	
	SD	4		7		1		2		11		0,6	
LCL	Valeur	89,06±13,8	92,53±17,8	91,31±10,3	85,52±8,1	93,08±5,6	94,43±9,6	96,1±13,8	94,71±12,9	91,67±6,6	82,17±13,3	94,96±4	95,52±3,6
	SDI	0,04		-0,07		0,01		-0,02		-0,11		0,005	
	SD	4		7		1		2		11		0,5	

(w: weight ; CW : carapace width ; Lc : carapace length ; RCL : right cheliped length ; LCL : left cheliped length ; SDI : size dimorphism index ; SD : degree dimorphism)

and F: 95 ± 21.1 g), CW (M: 123.69 ± 12.46 mm F: 81.9 ± 17.1 mm) and LC (M: 59.15 ± 5.81 mm and F: 40.42 ± 8.2 mm). However, no significant difference was founded between males and females for characters (RCL and LCL). The degree of dimorphism (SD) of 71% P, 51% Lc, 46% for Lc and 7% for RCL and LCL characters. Specimens from Grand-lahou exhibit size dimorphism in females. T test revealed significant difference ($p < 0.001$) between males and females for W, CW and LC. The respective values of these characters are W (M: 138.33 ± 48.9 g and F: 264.58 ± 82.1 g) CW (M: 60.21 ± 7.9 mm and F: 80.65 ± 15.1 mm) and LC (M: 27.22 ± 3.1 mm F: 39.76 ± 5.4 mm). As for length right and left chelipeds (RCL and LCL), the Mann-Whitney U test denoted no significant difference between the values of males and females. Size dimorphism in weight is very important (SD = 91%) as against to the length of the chelipeds, it was small (SD = 1%). In Fresco, the size dimorphism marked for almost every character in males except for Lc character. Indeed, the respective SDI to the weight (w), LC, RCL and LCL are: -0.19, -0.08 and -0.02 and CW (0.01). These results obtained were low. T test indicated no significant difference between females and males characters for CW, CL, RCL and LCL. However, Mann-Whitney test revealed significant difference between the weight of females (101.64 ± 17.7 g) and males (121.38 ± 24.1 g).

Study of index asymmetry

Heterochely by sex and populations

In total, 585 specimens of *Callinectes amnicola*, 286 crabs had long cheliped positioned to right (48.88%), while 299 crabs have long cheliped to left (51.12%) (Table 2). The results by gender, showed that the highest percentage is found among females Adjouan where 64.71% of the specimens had their long to left. The smallest percentage (35.29%) was obtained in males of this town who have long cheliped right. In Moossou, majority of males (53.96%) and females (52%) had their long claw to right. This same result was observed in Fresco with 51.61% for females and 50.79% for males. For Layo, long claw positioned to left with 61.76% for males and 58.34% in females. Regarding Grand-Lahou, long cheliped is both the left (54.17% in females) and right (52.77% males). However Adiaké there as long cheliped to right or left (50% in both sexes).

(H D : Righth heterochely ; H G : left heterochely ; F : female ; M : male ; n : number)

Asymmetry index of chelipeds characters

For this study, six characters have been taken into account. This is the propodus length (PL), the carpus length (caL), palm length (pL), dactylus length (dL), merus length (mL) and finally the cheliped length (CL) (Table 3).

Four homochely (H; AI = 0) were obtain at propodus length (PL), dactylus length (Ld), merus length (Lm) and chelipeds length of the (LP). Most of these results were observed in respective female Moossou (pL), Grand-Lahou (dL) and Fresco (mL) except cheliped length (CL) where males displayed a homochely in Fresco. As regards propodus length (PL), heterochely is much stronger on the left except in Layo and Adjouan males. For carp length (caL), heterochely varied by gender in Moossou. In males of this population, heterochely were right (0.01) against females had left heterochely (-0.002). Other people have either left or right heterochely for both sexes. Populations with right heterochely were males and females Adiaké, Layo and Grand-Lahou. As for males and females of Fresco

and Adjouan, heterochely was left. The asymmetry index showed that palm length (pL) was right heterochely for both sexes of Adjouan, Layo and left for Adiaké specimens. For populations of Fresco and Grand-Lahou, it was right for females while left of males. On contrary, in the population of Moossou besides having a homochely (AI = 0) in females, she had right heterochely to males (0.005). The results observed for dactylus given left heterochely for both sexes in Adiaké and Fresco and right (Adjouan). For dL, females displayed left heterochely for the populations of Layo and Moossou. As males of these two populations, they had right heterochely. Males of Grand-Lahou, had the longest left dactylus (AI = -0.003). High values of merus length (mL) were on the left side in females of all populations except Fresco where there was a homochely. In males, it were position to right for all populations except those Moossou and Grand-

Table(2) Heterochely rate of chelipeds length in both sexes

Localities	Sex	n	H D	(%)	H G	(%)
Moossou	F	50	26	52	24	48
	M	63	34	53,96	29	46,04
Layo	F	36	15	41,66	21	58,34
	M	34	13	38,23	21	61,76
Adiaké	F	50	25	50	25	50
	M	50	25	50	25	50
Adjouan	F	34	12	35,29	22	64,71
	M	66	36	54,54	30	45,46
Fresco	F	31	16	51,61	15	48,39
	M	63	32	50,79	31	49,21
Grd-Lahou	F	72	33	45,83	39	54,17
	M	36	19	52,77	17	47,23
Total		585	286	48,88	299	51,12

lahou where she left. Finally, long claw were mostly left in females of all populations except Adiaké. By against males, three populations (Moossou, Adiaké and Grand-Lahou) have their long pliers right, other people have left except to Fresco where there was homochely in males.

DISCUSSION

Distinguishing the sex of individuals is an essential part of most studies of animal species. Dimorphism in at least some body measurements. Since considerable overlap exists between male and female measurements in single characters, differences between sexes are of a statistical nature (Weidinger and van Franeker, 1998). Our results showed that according to characters, populations strongly differed in sexual dimorphism. Among the six localities, males of four populations had growth than females. Differences between sexes of growth respond to environmental variation and selection during ontogeny (Badyaev *et al.*, 2001). Male size also seems to determine the particular reproductive behaviour of an individual (Contreras-Garduno and Cordoba-Aguilar, 2006). Additional slower growth of females in relation to males can be attributed to the former directing their potential energy principally to reproductive processes (Conan, 1985 ; Díaz and Conde, 1989). Regarding to CL, CW, RCL and LCL, in three localities, males had highest mean than females. Our findings indicated that SDI was marked in males which is line with the study of Anagnostou & Schubart (2014).

Table(3) Asymmetry index of differents characters

Localities	Sex	RPL	LPL	AI	H	RcaL	LcaL	AI	H	LpR	LpL	AI	H	RdL	LdL	AI	H	RmL	LmL	AI	H	RCL	LCL	AI	H
Adjouan	F	42,06	42,10	-0,000	G	16,29	16,41	-0,003	G	20,05	19,83	0,005	D	22,8	22,38	0,009	D	25,75	25,78	-0,00	G	82,06	82,17	-0,00	G
	M	43,45	43,22	0,002	D	16,84	16,85	-0,000	G	19,96	19,74	0,005	D	24,05	23,9	0,003	D	26,48	26,08	0,007	D	91,55	91,67	-0,00	G
Adiaké	F	39,88	39,99	-0,001	G	16,95	16,91	0,001	D	21,27	21,34	-0,001	G	18,97	19,05	-0,002	G	33,78	33,96	-0,002	G	95,57	95,52	0,00	D
	M	43,45	43,22	-0,002	G	16,83	16,84	0,000	D	19,96	19,74	-0,00	G	24,05	23,09	-0,003	G	26,48	26,08	0,000	D	94,98	94,96	0,00	D
Layo	F	38,29	38,39	-0,001	G	14,34	14,31	0,001	D	21,15	21,13	0,000	D	17,46	17,55	-0,002	G	32,36	32,44	-0,001	G	85,38	85,52	-0,00	G
	M	46,49	46,26	0,002	D	14,59	14,49	0,003	D	26,37	25,88	0,009	D	20,88	20,86	0,000	D	32,61	32,57	0,000	D	91,23	91,31	-0,00	G
Moossou	F	43,44	43,51	-0,00	G	20,06	20,16	-0,002	G	19,9	19,9	0	h	23,63	23,64	-0,00	G	17,17	17,41	-0,006	G	92,5	92,53	-0,00	G
	M	42,37	42,45	-0,000	G	17,66	17,28	0,01	D	19,03	18,83	0,005	D	23,56	23,52	0,000	D	28,13	28,14	-0,000	G	89,15	89,06	0,00	D
Fresco	F	40,69	41,1	-0,005	G	18,92	19,78	-0,022	G	20,21	20,77	0,013	D	19,53	21,08	-0,038	G	31,82	31,82	0	h	94,42	94,71	-0,001	G
	M	42,88	40,09	-0,002	G	17,21	17,73	-0,014	G	22,36	21,77	-0,013	G	21,85	21,21	-0,008	G	31,84	31,62	0,002	D	96,61	96,61	0	h
Grd-Lahou	F	42,3	42,85	-0,006	G	15,07	14,78	0,009	D	22,83	22,82	0,000	D	19,5	19,5	0	h	29,61	29,88	-0,004	G	94,38	94,43	-0,000	G
	M	39,72	39,99	-0,003	G	14,49	14,46	0,001	D	21,6	21,86	-0,005	G	18,49	18,63	-0,003	G	29,01	29,18	-0,002	G	93,15	93,08	0,000	D

(AI : asymmetry index value ; H : heterochely ; D : righth ; G : left ; h : homochely ; RPL : righth propodus length ; LPL : left propodus length ; RcaL : righth carp length ; LcaL : left carp length ; LpR : righth palm length ; LpL : left palm length ; RdL : righth dactylus length ; LdL : left dactylus length ; RmL : righth merus length ; LmL : left merus length ; RCL : righth cheliped length ; LCL : left cheliped length)

According to Contreras-Garduño and Cordoba-Aguilar (2006), the reason is possibly, because male size is related to female choice, male–male competition and/or sexual conflict. Also, in many species, males are larger than females (Mantelatto and Martinelli, 2001; Litulo, 2005; Litulo and Tudge, 2005; Turra, 2005). Nevertheless, our study shows that for the same characters, SDI is accentuated to females in the other localities. That be able to due to environmental conditions.

The larger cheliped can be located on the left or right side of the body (Akin-Oriola *et al.* 2005). This study showed that heterochely in all specimens resulted in a slight tendency towards left-handedness (51.12 %). This result is disagree with Akin-Oriola *et al.* (2005) study of *Callinectes pallidus*. But for *Cardisoma armatum* species, our work is agree of the same authors. However, our study is according to Sinha (2014) who founded 86.16 % of males and 84.89 % of females with Left handed.

In both sexes, the position of large chelipeds differed. According to Fumis *et al.* (2007), the presence of a larger cheliped is especially important for males. The larger cheliped had procure an advantage during the breeding season, when males compete with each other for females (Pinheiro and Fransozo, 1993; Lee, 1995).

Regarding the individuals characters investigated in our study, heterochely was significantly more pronounced in females compared to males. Index asymmetry showed that the dimensions of females chelae were largest than males. Our findings is not agree with study of Anagnostou & Schubart (2014). This study indicated three cases of perfect homochely.

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Declaration of conflicting of interests

Authors declared that there is no conflict of interest concerning this manuscript.

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