Original Article

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Influence of sex and body size on selected morphometric traits of *Metopograpsus frontalis* (Miers, 1880) from Southern Vietnam

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ABSTRACT. A total of 167 specimens of *Metopograpsus frontalis* (105 males and 62 females) were collected monthly from intertidal mudflats in Ganh Hao, Ca Mau Province, Southern Vietnam, from July to October 2025. Selected morphometric traits, including carapace width from left to right ($CW_{L–R}$), carapace width from right to left ($CW_{R–L}$), manus width (MW2, MW3), pollex width (PW5), and dactyl width (DW7), were measured with a 0.01-mm vernier caliper. Generalized linear models were fitted to evaluate the effects of sex and body size, using Gaussian models for CW and Gamma models with a log link for MW, PW, and DW. We found no significant sex-related differences in $CW_{L–R}$ and $CW_{R–L}$ ($p > 0.05$), whereas MW2, MW3, PW5, and DW7 were significantly larger in males ($p < 0.001$). Sex coefficients ($\beta = 0.156–0.257$) corresponded to rate ratios (RR) of 1.17–1.29, indicating that male claws were 17–29% larger after adjusting for $CW_{L–R}$ and $CW_{R–L}$. Both CW variables had strong positive effects ($\beta = 0.054–0.070$; RR = 1.06–1.07; and $p < 0.001$). All Gamma models showed $\chi^2/df < 1$, confirming good model fit without overdispersion. These results provide quantitative evidence of sex-related variation in morphometric traits of *M. frontalis* and establish a morphometric baseline for future ecological and evolutionary studies of mangrove crabs in the Mekong Delta.

Keywords: *Metopograpsus frontalis*, Mekong Delta, morphometric traits, Generalized Linear Model, sex-related differences

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1. Introduction

Intertidal crabs are key components of macrobenthic communities in tropical and subtropical estuaries, functioning as ecosystem engineers and major trophic intermediates. Through bioturbation and feeding, they modify sediment composition (Botto and Iribarne, 1999; Escapa et al., 2004), regulate ecosystem productivity (Koch and Wolff, 2002; Werry and Lee, 2005), influence vegetation structure (Bosire et al., 2005) and faunal composition (Dye and Lasiak, 1986; Botto et al., 2000), and mediate energy flow across trophic levels (Wolff et al., 2000). Among estuarine brachyurans, the superfamilies Grapsoidea and Ocypodoidea dominate tropical mudflats (Lee, 2008; Nagelkerken et al., 2008). In Vietnam, the family Grapsidae is diverse and widespread, encompassing genera such as Sesarma, Metaplax, Neoeposesarma, and Metopograpsus (Nhuong, 2003).

Crab morphology reflects the combined effects of genetic, ecological, and sexual selection pressures (Parsons, 1992; Voje, 2016). For example, fiddler crabs (subfamily Gelasiminae), which are abundant in tropical and subtropical estuaries, rely heavily on visual communication strategies such as claw waving and body posturing (Zeil and Hemmi, 2006; How et al., 2008). In these species, sex-related differences are extreme, with males possessing one enlarged chela while females have two smaller claws of similar size. Such morphological divergence has received considerable attention in behavioral and ecological studies (Valiela et al., 1974; Oliveira and Custodio, 1998; Allen and Levinton, 2007).

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Within the family Grapsidae, *Metopograpsus frontalis* (Miers, 1880) is an ecologically important mangrove crab species. It is an opportunistic omnivore with strong predatory capabilities and plays a crucial role in estuarine food webs (Poon et al., 2010). Morphologically, the chelae and walking legs of *M. frontalis* contain low calcium levels but are enriched with halogens such as chlorine and bromine, while the carapace is highly calcified (Cribb et al., 2009). Previous research has addressed various aspects of this species, including taxonomy and phylogenetic relationships (Guan et al., 2018), molecular identification (Paransa et al., 2024), feeding ecology (Poon et al., 2010), and population structure (Poon, 2004; Vermeiren et al., 2021).

However, in the Mekong Delta, particularly in Ca Mau Province, information on *M. frontalis* remains limited, especially regarding its morphological characteristics and how these vary with sex and body size. The findings of this study provide baseline morphometric data that may support future ecological, evolutionary, and population-level assessments in the mangrove ecosystems of Southern Vietnam.

2. Materials and methods

2.1. Sample collection and analysis

Specimens of *Metopograpsus frontalis* (Fig. 1) were collected manually during daylight hours from intertidal mudflats along riverbanks at low tide. Sampling was conducted monthly from July to October 2025 in the Ganh Hao area, Ca Mau Province, Southern Vietnam (Fig. 2). Approximately 30 individuals were collected per month. Crabs were captured by hand or using baited traps and fixed in 70% ethanol for transport to the laboratory.

In the laboratory, specimens were identified based on morphological descriptions provided by Miers (1880). The following morphometric parameters were measured using a vernier caliper with a precision of 0.01 mm: carapace width from left to right ($CW_{L–R}$), carapace width from right to left ($CW_{R–L}$), manus width (MW2 and MW3), pollex width (PW5), and dactyl width (DW7) (Fig. 3).

Each specimen was sexed by examination of abdominal morphology: males possess a narrow, triangular abdomen, whereas females have a broader, rounded abdomen. Morphological features characteristic of *M. frontalis* include a smooth and glossy carapace, dark brown coloration, and two chelae of similar size, with males typically having larger and more robust claws than females.

2.2. Data analysis

Before model fitting, the normality of each morphometric variable was assessed using the Shapiro–Wilk test. $CW_{L–R}$ and $CW_{R–L}$ were normally distributed ($p > 0.05$), whereas MW2, MW3, PW5, and DW7 deviated from normality ($p < 0.05$). Consequently, CW variables were analyzed using generalized linear models (GLMs) with a Gaussian distribution, while MW, PW, and DW variables were analyzed using GLMs with a Gamma distribution and a log-link function.

Separate models were fitted for each dependent variable using the general structure: $Y \sim Sex + CW_{L–R}/CW_{R–L}$, where Y represents MW2, MW3, PW5, or DW7, and Sex is a categorical factor (male or female). Covariates were mean-centered before analysis. Model outputs included: regression coefficients ($\beta \pm SE$), Wald z-values, p-values, rate ratios ($RR = e^{\beta}$), and fit indices (AIC, BIC, Deviance, χ^2/df). Significant p-values (< 0.05) for Sex indicated sex-related differences in trait size. Positive β(CW) values signified that the trait increased with body size. For Gamma models, $\chi^2/df < 1$ denotes adequate fit and no overdispersion.

Statistical analyses were performed using jamovi v2.6.44 (The jamovi project, 2024), with the GAMLj module. Descriptive values ($Mean \pm SE$) were obtained from the Estimated Marginal Means (EMMs) derived from GLMs rather than raw data averages for interpretability.

3. Results

Descriptive statistics and normality

The Shapiro–Wilk test indicated that both carapace-width variables, $CW_{L–R}$ and $CW_{R–L}$, followed a normal distribution ($p = 0.517$ and $p = 0.854$, respectively), whereas MW2, MW3, PW5, and DW7 deviated significantly from normality ($p < 0.01$). Accordingly, Gaussian GLMs were applied for $CW_{L–R}$ and $CW_{R–L}$, and Gamma–log GLMs were used for MW2, MW3, PW5, and DW7 (measurement scheme in Fig. 3).

Fig.1. *Metopograpsus frontalis* (A: Dorsal view; B: Frontal view).

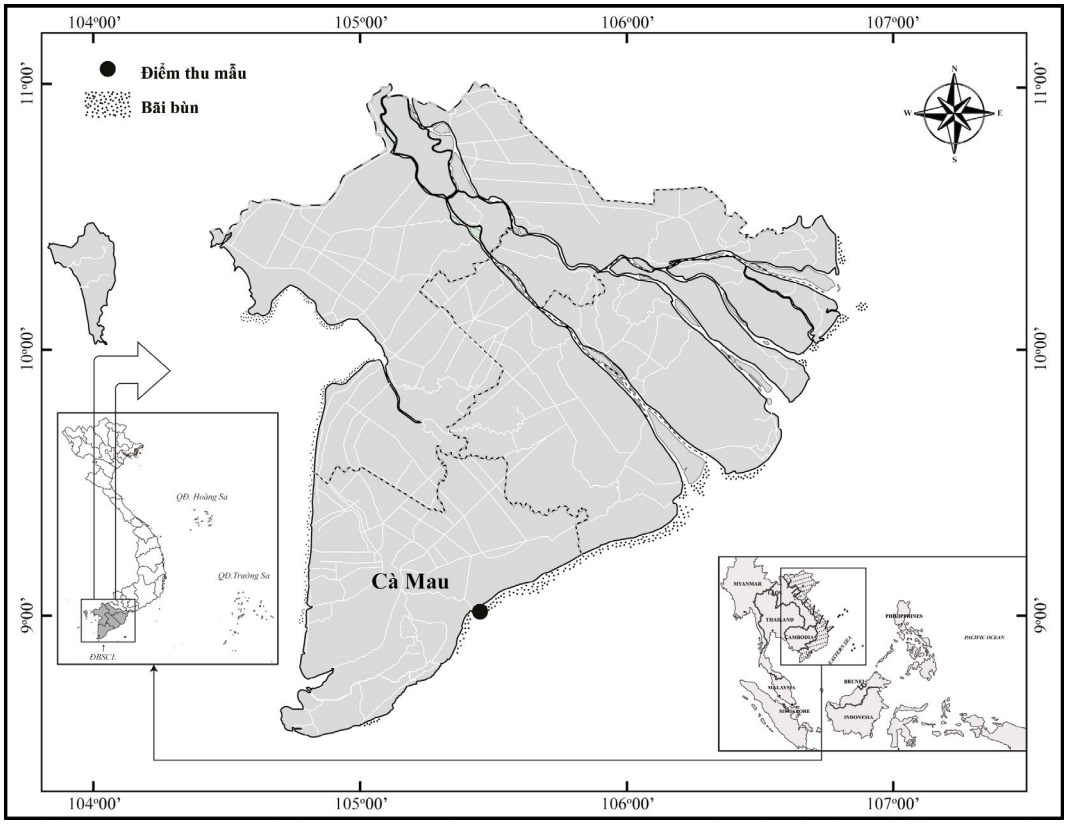

Fig.2. Sampling map in Ca Mau, Vietnam (● Sampling sites: Ganh Hao, Ca Mau; source: Dinh (2018)).

Carapace width ($CW_{L–R}$ and $CW_{R–L}$)

No significant sex-related differences were detected in either $CW_{L–R}$ ($\beta = 0.280 \pm 0.526$, $p = 0.594$) or $CW_{R–L}$ ($\beta = 0.175 \pm 0.515$, $p = 0.734$). Estimated marginal means (EMMs) were nearly identical between males and females (Table 1), indicating comparable overall body size. The overlapping confidence intervals and p-values > 0.05 confirm the absence of sex effects on carapace width.

Functional morphometric traits (MW2, MW3, PW5, and DW7)

Gamma–log GLMs showed strong effects of sex on all cheliped-related traits after accounting for carapace width. We fitted two models for each trait with $CW_{L–R}$ and $CW_{R–L}$ entered separately as covariates; conclusions were consistent (Table 2).

Sex coefficients varied, $\beta = 0.156–0.257$ (all $p < 0.001$), corresponding to RR = 1.17–1.29, i.e., male traits were 17–29% larger than female traits at a given carapace width. Both CW covariates positively affected all traits ($\beta = 0.054–0.070$; RR ≈ 1.06–1.07; and $p < 0.001$), indicating a ~6–7% increase in trait size per 1-mm increase in $CW_{L–R}$ and $CW_{R–L}$. All Gamma models showed $\chi^2/df < 1$, indicating a good fit without overdispersion.

Mean ± SE values (EMMs) for each sex and trait are summarized below (Table 3). These results demonstrate a clear and consistent pattern of sexual differentiation in chela components, whereas the carapace width remains similar between sexes.

Table 1. Estimated marginal means of carapace width (mm) by sex from Gaussian GLMs

Parameter	Sex	n	Mean ± SE	p
$CW_{L–R}$ (mm)	Female	62	22.10 ± 0.38	0.594
	Male	105	22.38 ± 0.35	
$CW_{R–L}$ (mm)	Female	62	22.04 ± 0.38	0.734
	Male	105	22.22 ± 0.33	

Note: Carapace width from left to right ($CW_{L–R}$), carapace width from right to left ($CW_{R–L}$)

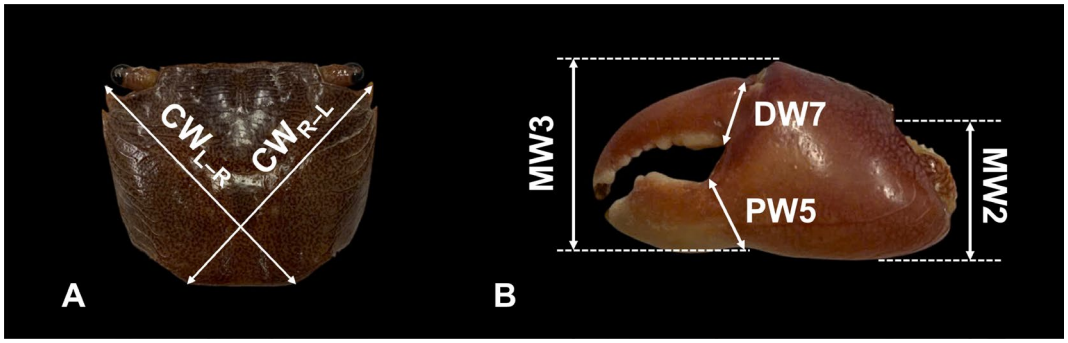

Fig.3. Illustration of morphological measurement parameters of *Metopograpsus frontalis* (A: carapace width from left to right ($CW_{L–R}$), carapace width from right to left ($CW_{R–L}$); B: manus width (MW2, MW3), pollex width (PW5), and dactyl width (DW7).

Table 2. Gamma–log GLM results for effects of sex and carapace width on functional traits

Parameter	Controlled variable	β (sex) ± SE	z	p	RR	Sex effect	β	p	AIC	BIC
MW2	$CW_{L–R}$	0.156 ± 0.039	3.99	< 0.001	1.17	♂ 17 % larger	0.054	< 0.001	550.98	563.45
	$CW_{R–L}$	0.162 ± 0.039	4.12	< 0.001	1.18	♂ 18 % larger	0.055	< 0.001	551.26	563.74
MW3	$CW_{L–R}$	0.230 ± 0.031	7.44	< 0.001	1.26	♂ 26 % larger	0.065	< 0.001	557.52	569.99
	$CW_{R–L}$	0.237 ± 0.031	7.69	< 0.001	1.27	♂ 27 % larger	0.067	< 0.001	554.38	566.85
PW5	$CW_{L–R}$	0.251 ± 0.035	7.27	< 0.001	1.29	♂ 29 % larger	0.059	< 0.001	312.35	324.82
	$CW_{R–L}$	0.257 ± 0.034	7.49	< 0.001	1.29	♂ 29 % larger	0.060	< 0.001	309.86	322.33
DW7	$CW_{L–R}$	0.203 ± 0.038	5.34	< 0.001	1.23	♂ 23 % larger	0.068	< 0.001	312.19	324.67
	$CW_{R–L}$	0.211 ± 0.038	5.62	< 0.001	1.24	♂ 24 % larger	0.070	< 0.001	308.41	320.89

Note: Carapace width from left to right ($CW_{L–R}$), carapace width from right to left ($CW_{R–L}$); manus width (MW2, MW3), pollex width (PW5), and dactyl width (DW7)

4. Discussion

The present analysis provides quantitative evidence of sex-related morphometric differences in *Metopograpsus frontalis* from Southern Vietnam. Although overall body size ($CW_{L–R}$ and $CW_{R–L}$) did not differ significantly between sexes, all functional claw components (MW2, MW3, PW5, and DW7) were markedly larger in males. The rate ratios (RR = 1.17–1.29) demonstrate that, after controlling for carapace width, males possess 17–29% larger claw dimensions than females. This pattern remained consistent regardless of the carapace-width covariate used ($CW_{L–R}$ or $CW_{R–L}$), confirming the robustness of the observed sex effect.

The strong positive allometric slopes for both CW variables (β = 0.054–0.070; RR ≈ 1.06–1.07) indicate that each 1-mm increase in the carapace width corresponds to a proportional 6–7% increase in claw trait size, emphasizing the importance of size scaling in the species. However, the absence of a sexual difference in the carapace width suggests that dimorphism is localized to the chelae rather than generalized body enlargement. This pattern of functional rather than overall dimorphism was reported in several grapsoid and ocypodoid crabs (Chatterjee and Chakraborty, 2015; Vermeiren et al., 2021).

In *M. frontalis*, enlarged male claws likely provide advantages during courtship, territorial defense, and intraspecific competition, consistent with findings in other species (Aldea et al., 2025). Females, by contrast, display smaller, more slender claws, possibly reflecting an energetic trade-off favoring reproduction, feeding efficiency, and burrow maintenance. The magnitude of sexual disparity (17–29%) observed here parallels reports for M. latifrons and Parasesarma longicristatum, where male chelae exceeded those of females by approximately 15–33% (Vermeiren et al., 2021; Aldea et al., 2025).

Overall, the results confirm that *M. frontalis* exhibits sex-linked allometric differentiation, characterized by disproportionate investment in cheliped growth relative to carapace size. Such differentiation likely reflects the combined influence of sexual selection and functional specialization, allowing males to enhance their signaling and competitive performance, while females prioritize their reproductive roles. This adaptive divergence highlights the ecological and evolutionary significance of claw morphology in mangrove crabs inhabiting dynamic estuarine environments.

Table 3. Estimated marginal means of functional traits (mm) by sex from Gamma–log GLMs

Parameter	Sex	Mean ± SE
MW2	Female	4.57 ± 0.14
	Male	5.34 ± 0.13
MW3	Female	5.66 ± 0.14
	Male	7.13 ± 0.13
PW5	Female	2.45 ± 0.07
	Male	3.16 ± 0.07
DW7	Female	2.23 ± 0.07
	Male	2.75 ± 0.06

Note: Manus width (MW2, MW3), pollex width (PW5), and dactyl width (DW7)

5. Conclusion

This study provides quantitative evidence of sex-related differences in *Metopograpsus frontalis* from the Ganh Hao estuary, Ca Mau Province. Although males and females exhibit similar carapace widths, males possess significantly larger functional morphometric traits (MW2, MW3, PW5, and DW7), being 17–29% greater after controlling for body size. The positive effect of CW_{L-R} and CW_{R-L} on all traits confirms that growth scaling influences these differences but does not entirely explain. The results provide baseline morphometric data that will support future ecological and evolutionary studies on sex-related variation in mangrove crabs of Southern Vietnam.

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Conflict of interest

The authors declare no conflicts of interest.

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