Operationalizing Mud Crab (*Scylla* spp.) Length–Weight in a Micro-Site Data-Limited Ecotourism Fishery

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ABSTRACT

Urban mangrove fisheries and ecotourism need micro-site, data-limited baselines to guide low-cost gear management. This study establishes the size structure and length–weight scaling (Carapace Width–weight Relationship (CWR) and Carapace Length-weight Relationship (LWR)) of mud crabs (*Scylla serrata*, *S. olivacea*) as practical inputs for monitoring and trap guidance. Foldable traps (3 stations × 3 traps) were deployed during September and November of 2024 and 15 individuals (5 females, 10 males) were measured for Carapace Width (CW, mm) and body weight (W, g). We summarized CW distributions and fitted $W = \alpha L^b$ in log–log space by OLS to assess association strength and test isometry (b=3). CW spanned from 49.00 to 85.00 mm and mass from 15.81 to 102.47 g. CW–W relationships were strong, and growth was positively allometric (females, males, pooled), indicating mass increases faster than width. Results should be interpreted cautiously, given the narrow spatial scope, sampling dates, and small female sample. The findings provide a reproducible baseline for cross-estuary comparison and can be operationalized without additional analyses into an auditable workflow for ecotourism co-management, consisting of publishing a site-specific minimum-size concept, recording CW at landings, tuning entrances/mesh so smaller crabs escape, and monthly auditing using the existing indicators.

Keywords-allometry; carapace width; size-structure; sex; mangrove ecosystem

I. INTRODUCTION

Mangrove ecosystems buffer shorelines, store blue carbon, improve water quality, and provide nursery habitats while supporting urban nature-based tourism and education. In Surabaya's Wonorejo Ecotourism area, planning for conservation and visitor use needs to reflect ecological status and site-management requirements [1]. At broader scales, mangrove condition and species composition vary along climatic and hydrological gradients, and can recover with effective restoration of tidal exchange. In addition, shoreline change and sediment dynamics can modify habitat extent and sampling accessibility, underscoring the value of site-specific baselines [2]. Mud crabs (*Scylla* spp.) are both economically valuable and functionally important in mangrove food webs. Their physiology and population performance track habitat quality, making them informative indicators in data-limited settings [3]. Basic biometrics, such as size structure and the CWR and LWR, are widely used to infer growth via the allometric exponent b and to summarize conditions.

This study addresses the challenges of generating reliable biological information with limited data, including only 15 individuals taken in two sampling dates. This constraint is common in micro-site ecotourism fisheries, where mud crab availability is seasonal and influenced by the lunar cycle. Therefore, this study aims to establish a site-specific biometric baseline that is auditable and readily applicable despite the limited available data. A site-specific biometric baseline for *Scylla* spp. is established, valid only within the Wonorejo Mangrove Ecotourism area (Surabaya) by (i) quantifying size structure (CW, mm; W, g), (ii) estimating the standard CWR power $W = \alpha L^b$ in log–log space and testing isometry, and (iii) interpreting growth pattern from b. The results aim to inform conservation and urban ecotourism management and to support comparisons with other East Java estuaries [4]. Although the results are based on a limited sample size, they can already be translated into a simple and low-cost protocol: set a minimum harvestable size and adjust trap entrances so smaller crabs can escape. This provides managers with straightforward and auditable rules that can be applied immediately, while future studies can broaden the temporal coverage and include environmental factors.

II. MATERIAL AND METHODS

A. Study Site

This study was conducted in September and November 2024 at the Wonorejo Mangrove Ecotourism area, Surabaya, East Java, Indonesia (7°17'13" S; 112°41'18" E). The Wonorejo mangrove covers 64.83 ha, representing part of Surabaya's 133.98 ha mangrove estate [5]. Wonorejo functions as both a conservation and ecotourism site, with built visitor facilities and boardwalk access. Sampling stations were selected purposively to represent contrasting microhabitats and levels of human use (Figure 1 [6]): (i) near the estuary, (ii) around the gazebo area, and (iii) along the tracking bridge [3, 5]. Each station was equipped with three folding traps (see below).

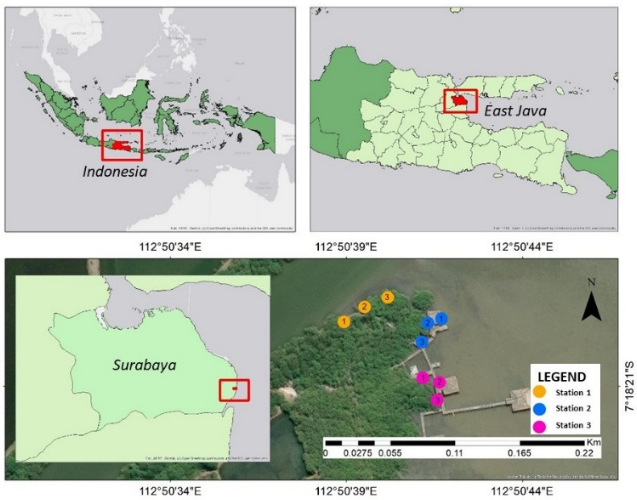

Fig. 1. Study site location.

B. Sampling Design

Mangrove crabs were sampled in Wonorejo Mangrove Ecotourism site using 40 × 29 × 15 cm folding traps baited with wideng or *Sesarma* spp. offcuts (Figure 2(b)). Nine traps (3 stations × 3 traps) were deployed purposively across representative microhabitats on 7–8 September and 15 November 2024 Each trap was set for ~5 h (08:30–14:00) from rising to low tide, following the common practice for *Scylla* sampling in Indonesian estuaries [5]. This study intentionally focuses on a micro-site with two sampling dates and modest catch numbers. This micro-site design (three stations, two sampling dates, modest catch) provides a preliminary baseline for low-cost, easily audited monitoring under data-limited conditions.

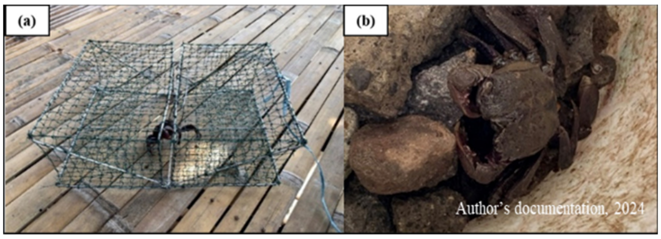

Fig. 2. (a) folding trap and (b) *wideng*.

After retrieval, crabs were identified to species level using the WWF Indonesia BMP key [7]. For each individual, CW (mm), W (g), and sex were recorded in situ. Instruments (Sigmat caliper, 0.05-mm resolution; Kenko balance, 500-g capacity, 0.01-g readability) were calibrated at the start of each sampling day, and metadata (CW, weight, sex, station, soak time: ~5 h from 08:30 rising tide to 14:00 low tide) were logged to ensure reproducibility. The field measurements were conducted in situ at the natural mangrove habitat under the permission of the Wonorejo Mangrove Ecotourism Management. Individual crabs were identified and measured on site.

C. Size Distribution

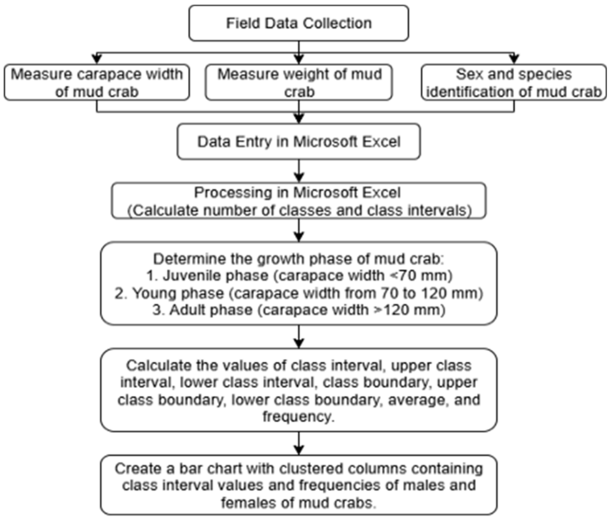

Fig. 3. Workflow of mud crab size distribution.

We summarised size structure by species and sex using CW (mm) and body weight (g), and constructed frequency distributions of CW (Figure 3). The number of histogram classes (K) and class width (i) followed Sturges' rule, as applied in [8]:

$$K = 1 + 3.322\,\mathrm{Log}_{10}\,N \quad (1)$$

$$i = \frac{CW_{max} - CW_{min}}{K} \quad (2)$$

where N is the sample size, and CW_{max} and CW_{min} are the maximum and minimum observed carapace widths. We rounded K to the nearest integer and set i to the nearest practical resolution of the measuring device (0.05 mm; reported bins rounded sensibly for readability). Class boundaries were defined using $[CWmin\ , CWmin\ +i), [CWmin\ +i, CWmin\ +2i), \ldots$ and histograms were produced for pooled samples and by sex. These distributions provide the basis for descriptive statistics (mean ± SD, range) and for subsequent length–weight relationship analyses.

D. Relationship of Carapace Width and Weight

Statistical analyses were conducted using Microsoft Excel. We modelled LWR as $W = \alpha L^b$ where W is the body weight (g), L is the carapace width (mm), α is the intercept, and b is the allometric exponent following common *Scylla* spp. applications [8] (see Figure 4). The model was fitted in log10-transformed space using ordinary least square regression. All hypothesis tests used α = 0.05. Regression assumptions were verified using the Shapiro–Wilk test for residual normality.

$$\log_{10}W = \log_{10}\alpha + b\log_{10}L \quad (3)$$

Closed-form estimators for the simple linear fit in log space were:

$$b = \frac{N\sum(\log_{10}W\log_{10}L) - (\sum\log_{10}W)(\sum\log_{10}L)}{N\sum(\log_{10}L)^2 - (\sum\log_{10}L)^2} \quad (4)$$

$$\log_{10}\alpha = \frac{\sum\log_{10}W}{N} - b\frac{\sum\log_{10}L}{N} \quad (5)$$

We report the allometric exponent b, its standard error SE(b), a two-tailed t-test of isometry $H_0{:}\, b = 3$ ($t = \frac{b-3}{SE(b)}$, $df = N - 2$) , 95% confidence intervals, and the coefficient of determination R^2 for the log-transformed regression. For interpretability, we also provide Pearson's r in log space. For simple linear models, $R^2 = r^2$ [9]. Final equations are back-transformed as $W = \alpha L^b$ for presentation [4].

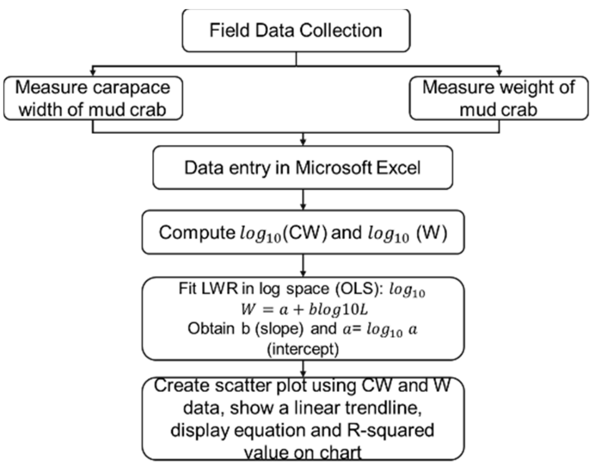

Fig. 4. Workflow of acquiring the relationship of CW and W.

E. Growth Pattern of Mud Crab

Growth pattern was assessed from the allometric exponent *b* in the LWR model following the common *Scylla* spp. applications. By definition, b = 3 indicates isometric growth (width and mass increase proportionally), b > 3 positive allometry (mass increases faster than width), and b < 3 negative allometry (width increases faster than mass). The analytical workflow is shown in Figure 5.

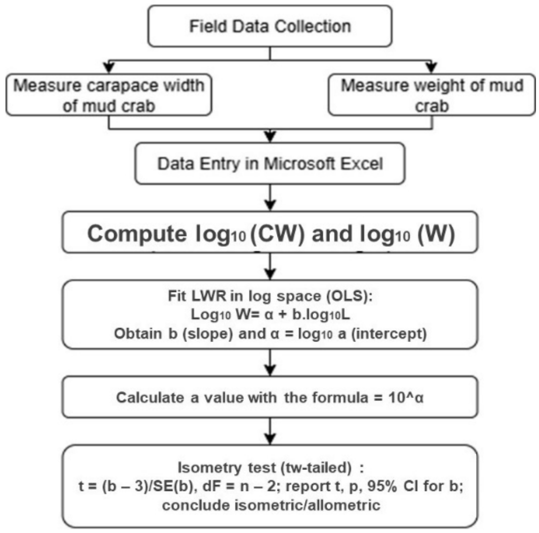

Fig. 5. Workflow of the growth pattern acquisition.

Isometry was tested with a two-tailed t-test on b: $H_0{:}\, b = 3$ vs. $H_1{:}\, b \neq 3$. The test statistic was $t = (b - 3)/SE(b)$ with $df = N - 2$ at $\alpha = 0.05$. We reported b, SE(b), two-tailed p − values, and 95% confidence intervals. Conclusions are based on $p < 0.05$ (equivalently, whether the 95% CI excludes 3).

III. RESULTS AND DISCUSSION

A. Identification

A total of 15 mud crabs were captured and assigned to two species—*Scylla serrata* and *Scylla olivacea*. Station-wise catches are summarised in Table I. Species-level identification followed the WWF Indonesia BMP key and handling guidance [9], using diagnostic external characters on the frontal margin and chelipeds.

Key traits are illustrated in Figures 6 and 7: (i) frontal margin spine shape and spacing (thin, slightly blunt, concave–rounded, elevated in S. *serrata* vs. blunt spines separated by narrow spaces in S. *olivacea*), and (ii) outer cheliped armature (sharp carpal spines and two sharp spines on the propodus in S. *serrata* vs. reduced propodus spines and a smooth carpal outer side in S. *olivacea*). A concise comparison of diagnostic features (including carapace colour range and polygonal patterns) is provided in Table II. .

TABLE I. MANGROVE CRAB CATCHES BY STATION IN WONOREJO MANGROVE ECOTOURISM, SURABAYA

Station	**First Catch**		**Second Catch**		**Third Catch**		**Total**
	Scylla serrata	***Scylla olivacea***	***Scylla serrata***	***Scylla olivacea***	***Scylla serrata***	***Scylla olivacea***	
1	0	1	0	2	1	1	5
2	0	0	2	1	0	2	5
3	0	0	2	1	1	1	5
Total	0	1	4	4	2	4	15

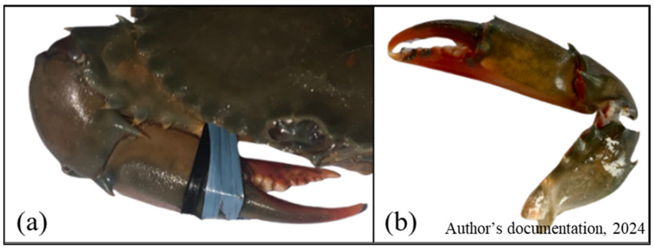

Fig. 6. Differences in cheliped spines: (a) *Scylla serrata* and (b) *Scylla olivacea.*

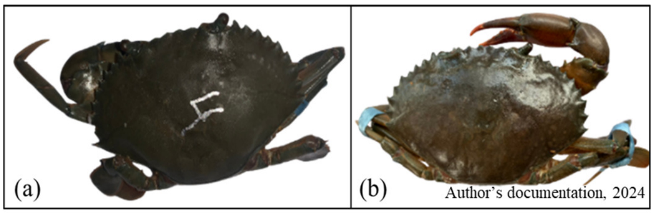

Fig. 7. Spine differences on the frontal margin: *Scylla serrata* and (b) *Scylla olivacea*

TABLE II. MORPHOLOGY OF MANGROVE CRABS CAUGHT IN WONOREJO MANGROVE ECOTOURISM, SURABAYA [6]

Morphology	*Scylla serrata*	*Scylla olivacea*
Carapace color	Colors range from purple to brownish green	Color from orange to blackish-brown
Polygon pattern	Has a perfect polygon pattern on the claws and feet	Has a clear polygon pattern on the claws and legs
Spine shape on frontal margin	Thin slightly blunt with concave, rounded, and high edges	Blunt spines surrounded by narrow spaces
Spine shape on outer cheliped	A pair of sharp spines on the carpus and two sharp spines on the propodus	The spines on the propodus are shrunken, and the outer side of the carpus is free of spines.

B. Size Distribution of Mud Crab

We captured 15 individuals (*Scylla serrata* and S. *olivacea*): 5 females and 10 males. CW ranged from 49.00 to 85.00 mm and W from 15.81 to 102.47 g. Summary statistics by sex are provided in Table III. On average, females had a larger CW (71.54 ± 7.30 mm) than males (66.38 ± 12.13 mm), whereas males spanned a wider mass range and showed a slightly higher mean mass (60.00 ± 30.73 g vs. 56.37 ± 23.96 g). These differences should be interpreted cautiously given the small female sample size (n = 5). In contrast, research in Malaysia, for S. *olivacea* and S. *serrata*, CW ranges in males was greater than in females [10].

The CW frequency distributions (female vs. male) are shown in Figure 8. Most individuals clustered in the mid-size classes (approximately 65–73 mm CW), with fewer crabs in the smallest and largest bins, indicating a unimodal, mid-peaked structure.

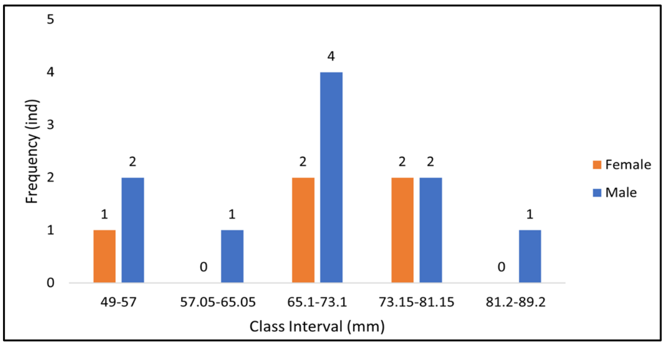

Fig. 8. Frequency distribution of mangrove crab CW (mm measures: females and males).

For context, sizes recorded at Wonorejo were generally smaller than those reported for S. *serrata* from the Sanrangang River, South Sulawesi (June–August 2020; folding traps: 34.07–99.02 mm CW; 21.62–389.57 g) [8] and the Marudu mangrove (May-June; female and male CW; 146.70 and 87.69 mm, BW; 683.8 and 121.7 g) [10], likely reflecting differences in sampling period, gear, bait, and local population structure [8]. Additional factors that may be considered are: (i) harvesting pressure can depress population density and truncate size structure [11]; (ii) seasonal reproduction may shift female availability (females migrating offshore; reproductive activity around the rainy season with spawning peaks in February–March) [12]; and (iii) habitat quality strongly modulates condition and growth in *Scylla* spp. [13]. Finally, estuarine hydrodynamics (tides, river discharge, wave regime) influence salinity, sediment, and nutrient fields that underpin mangrove and crab population dynamics [14].

TABLE III. SIZE DISTRIBUTION OF CW AND W OF MANGROVE CRABS IN WONOREJO MANGROVE SITE

Sex	**N**	**CW (mm)**			**Weight/W (g)**		
		Min	**Max**	**Average**	**Min**	**Max**	**Average**
Female	5	59.3	77.05	71.54 ± 7.30	16.36	80.7	56.37 ± 23.96
Male	10	49.00	85.00	66.38 ± 12.13	15.81	102.47	60.00 ± 30.73

C. Relationship of Carapace Width and Weight

Length–weight relationships were separately evaluated by sex. The diagnostic log–log scatterplots are shown in Figure 9. Coefficient of determination (R^2) and Pearson's correlation (r) indicated a strong, positive association between CW and W in all cases:

- Females: $R^2 = 0.9806$ ($r = 0.9902$) with an allometric exponent of b = 3.47 ± 0.05 (95% CI = 3.31–3.64).
- Males: $R^2 = 0.8704$ ($r = 0.9329$) with $b = 3.20 \pm 0.04$ ($95\%\ CI = 3.11 - 3.29$).
- Total: $R^2 = 0.9806$ ($r = 0.9902$) with $b = 3.24 \pm 0.03$ (95% CI = 3.17–3.32).

These values imply that CW explains ~87–98% of the variance in mass. We note that the female subset has a small sample size ($n = 5$), so its fit should be interpreted with caution.

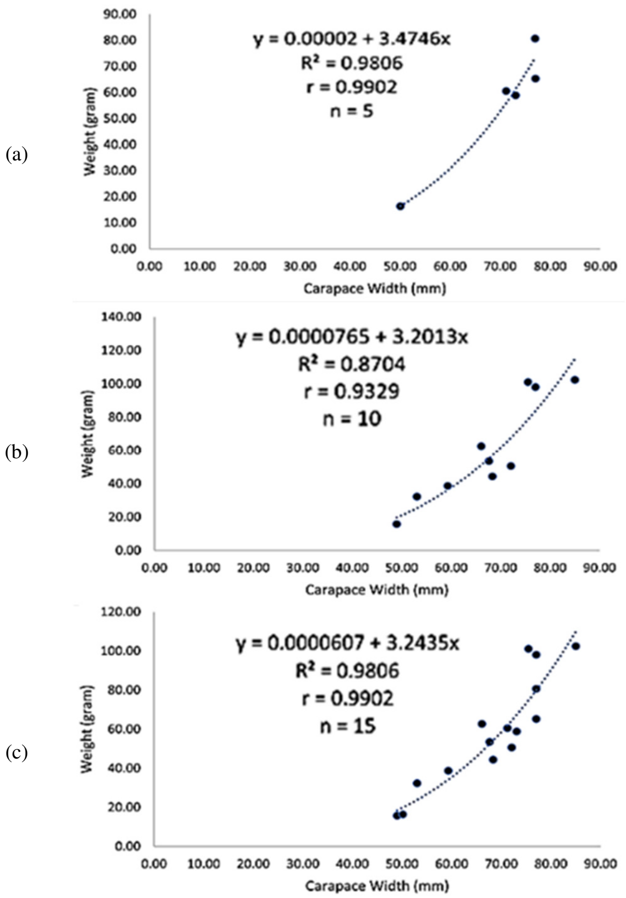

Fig. 9. Relationship between CW (mm) and W (g). (a) Female, (b) male, and (c) total mud crabs.

Our results are consistent with prior Indonesian studies. In Pemalang Regency, a total of 1,317 mud crabs were analyzed, and the reported ranges were $r = 0.886 - 0.995$ and $R^2 = 0.780 - 0.990$, also showing strong positive CW–W relationship [10], while in the Brantas Estuary, 318 individuals (160 males and 158 females) were examined ($r = 0.9188; 0.9544; 0.9127$), confirming the strong monotonic association between width and mass in *Scylla* spp. [15]. The results of this study also align with those of a study on the *Scylla olivacea* species in Sundarbans mangrove forest, Bangladesh, which found a strong correlation between carapace length and body weight in both males and females ($r^2 > 93\%$) [16].

D. Growth Pattern

The length–weight parameters and isometry tests are summarized in Table IV. The allometric exponent exceeded 3 in females ($b = 3.4746 \pm 0.0390, 95\%\ CI = 3.307 - 3.642, t = 9.034, p = 0.0029$), males ($b = 3.2013 \pm 0.0390, 95\%\ CI = 3.111 - 3.291, t = 5.168, p = 0.00086$), and total pooled samples ($b = 3.2435\pm, 95\%\ CI = 3.171 - 3.316, t = 7.220, p = 6.7e-06$). The two-tailed tests against isometry rejected H_0: b = 3 in all cases with $p < 0.01$, and the 95% CIs for b excluded 3. These results indicate positive allometry (mass increases faster than carapace width), with the female estimate interpreted cautiously given the small sample size ($n = 5$). By contrast, S. *olivacea* in Bangladesh [16] reported positive allometry in males (b = 3.336) but negative allometry in females (b = 2.618), while in Malaysia [10] both males and females exhibited negative allometry, emphasizing the location-specific variability in female growth and the unusual negative growth pattern in Malaysian male mud crabs. To position the present findings within a broader regional context, we compared the Wonorejo baseline with selected Indonesian and Southeast Asian studies (Table V). The results confirm that the Wonorejo population shows a narrower CW range but consistent positive allometry, aligning with patterns reported regionally. Interpretively, sex-specific differences can reflect biological allocation and environmental context. Prior work in Indonesian estuaries showed phase-dependent patterns (e.g., males shifting between negative and positive allometry across lunar phases; females often showing negative allometry), highlighting the role of reproductive timing and behavior [17]. Broader physiological and habitat-quality drivers (food availability, salinity, temperature) are also known to modulate growth and condition in *Scylla* spp. [13]. Sex differences in energy allocation (e.g., chelae development) have likewise been reported in regional biomorphometric studies [12].

E. Limitations

These patterns should be read in the light of our micro-site scope, i.e. two sampling dates, and a small sample, especially regarding females. Accordingly, inferences are preliminary and site-specific. Building on the reported CWR and catch-size profile, managers can set a site-specific minimum size and a simple trap-selectivity workflow: measure CW at landings, communicate a local size rule (retain mid-size, release small), tune entrances/mesh so small crabs can escape, and audit monthly using existing indicators (median CW, proportion-above-minimum-size rule, CPUE). This low-cost, site-based approach fits East Java co-management practices [18] and aligns with fisheries' use of size structure and LWR/maturity for operational rules and sustainability tracking [19], and, within feasibility/zoning-style ecotourism planning, helps balance visitor use with conservation while keeping enforcement practical [20].

TABLE IV. LENGTH–WEIGHT PARAMETERS AND ISOMETRY TESTS FOR MUD CRABS (*SCYLLA* SPP.)

Sex	n	b	SE(b)	df	t (calc.)	p (2-tailed)	95% CI for b	Equation $W = aL^b$	R^2	r	Pattern
Female	5	3.4746	0.0525	3	9.034	0.0029	3.307–3.642	$W = 2.0e\text{-}5 \times L^{3.4746}$	0.9806	0.9902	Allometric (+)
Male	10	3.2013	0.0390	8	5.168	0.00086	3.111–3.291	$W = 7.65e\text{-}5 \times L^{3.2013}$	0.8704	0.9329	Allometric (+)
Pooled	15	3.2435	0.0337	13	7.220	6.7e-06	3.171–3.316	$W = 6.07e\text{-}5 \times L^{3.2435}$	0.9806	0.9902	Allometric (+)

TABLE V. COMPARISON TABLE BETWEEN WONOREJO MANGROVES AND SELECTED AREAS

Location / Study	Species	N	CW Range (mm)	Growth Pattern (b)	Notes
Wonorejo, Surabaya (this study)	*S. serrata*, *S. olivacea*	15	49.00–85.00	3.20–3.47 (positive allometry)	First micro-site baseline; management implications
Brantas Estuary, East Java [15]	*S. paramamosain*	318	53.60–132.00	3.08–3.21	Strong positive CW–W relationship
Malaysia [10]	*S. olivacea*, *S. serrata. S. tranquebarica, S. paramosain, SH (Hybrid)*	383	59.53–146.70	Positive and negative allometry	Sympatric species, hybrid cases
Bangladesh [16]	*S. olivacea*	250	45.00–122.0	Positive allometry	Habitat-specific differences

IV. CONCLUSION

This work provides a micro-site, data-limited baseline for mud crabs (*Scylla olivacea, S. serrata*), documenting carapace width and body weight ranges and showing strong CW–W scaling with positive allometry for females, males, and total pooled samples. A total of 15 individuals were measured, showing carapace widths of 49–85 mm and body weights of 15.81–102.47 g. The length–weight relationships indicated strong positive associations, and growth was positively allometric for males, females, and pooled samples. These findings, although limited by the sample size and temporal scope, demonstrate that even small datasets can yield useful biometric parameters for local monitoring and comparison with other estuaries. Future research should expand sample numbers, seasonal coverage, and environmental covariates to strengthen inference and support management applications. A key limitation of this study is the small female sample size (n = 5), which restricts sex-specific inference. Future studies should increase female sample coverage to strengthen the results.

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