

Molecular insights into *Uca* crab diversity in the Nizampatnam mangroves: COI gene-based evidence and ecological zonation

Vaishnavi K, Neelima M, Bhanu Prakash K, Prathap S, Srinivas K

Department of Zoology, Government College for Women (Autonomous), Guntur, Andhra Pradesh, India

DOI: <https://doi.org/10.66856/ijer.2026.11.2.11183>

Abstract

This study investigated the diversity and spatial arrangement of fiddler crabs in the Nizampatnam mangroves of Andhra Pradesh by integrating field-based ecological observations with cytochrome oxidase I (COI) gene evidence. Four distinct species were recorded: *Austruca annulipes*, *Austruca variegata*, *Gelasimus hesperiae*, and *Tubuca alcocki*. A total of 245 specimens were documented, with the highest concentration in the lower intertidal zone (123 individuals), followed by the middle (71) and upper zones (51). Diversity analysis yielded a Shannon–Wiener index of approximately 1.36 and an evenness of 0.98, indicating a moderately diverse and highly balanced community. COI-based phylogenetic interpretation supported species-level differentiation and ecological partitioning, with broad-front and narrow-front lineages reflecting distinct evolutionary histories. The findings classify the Nizampatnam mangrove ecosystem as moderately disturbed but resilient, with fiddler crabs serving as effective bioindicators of habitat health.

Keywords: Fiddler crabs, CO I gene, CLUSTAL W algorithm

Introduction

Mangrove forests are globally significant coastal ecosystems that provide critical services, including nutrient cycling, carbon sequestration, and shoreline protection. Within these environments, crabs—particularly fiddler crabs—are dominant macroinvertebrates. They are widely recognized as ecosystem engineers because their burrowing and feeding activities rework sediment, modulate microbial processes, and enhance soil aeration. Fiddler crab bioturbation can alter between 35% and 80% of mangrove sediment, significantly impacting organic matter turnover. Fiddler crab diversity is tightly linked to vegetation zonation, substrate type, and salinity gradients. Recent taxonomic revisions, informed by molecular data, have elevated several subgenera to distinct genera, such as *Austruca*, *Gelasimus*, and *Tubuca*. Despite their ecological importance, many regions lack standardized surveys integrating taxonomic and genetic diversity. The COI gene has emerged as a reliable mitochondrial marker for identifying these species and studying their population structure and connectivity.

The objectives of this study were to

- Assess the species diversity and zonation of the *Uca* genus in Nizampatnam.
- Quantify richness and evenness using multiple diversity indices.
- Analyze genetic diversity and phylogenetic relationships using COI gene sequences.
- Relate these findings to hydrological parameters and evaluate the crabs as bioindicators of mangrove health.

Materials and Methods

Study Area The study was conducted in the Nizampatnam Reserve Forest mangroves (15°54' N; 80°43' E) in Andhra Pradesh. This area features a network of tidal creeks, including the Palrevu, Rellakalva, and Gudderu, which feed into the Krishna estuary. The site is characterized as a

mosaic of swamps and mangrove patches under moderate anthropogenic pressure.

Field Sampling and Morphological Identification Sampling was organized across three tidal zones: lower, middle, and upper intertidal. Three quadratic plots were drawn at each zone for specimen capture and burrow counts. Species were identified using standard taxonomic keys, including *Crabs: A Global Natural History* (Davie, 2021) and the *Atlas of Crabs of the Persian Gulf* (Naderloo, 2017).

Bioinformatics Pipeline COI gene sequences for the identified species were retrieved from the NCBI/GenBank database. Sequence alignment was performed using the CLUSTAL W algorithm to determine genetic similarity. Phylogenetic trees (phylograms) were constructed to visualize evolutionary relationships and validate the broad-front versus narrow-front morphological split.

Data Analysis Relative abundance (R) was calculated for each species. Diversity was measured using the Shannon–Wiener Index (H') and Evenness Index (E). Community composition differences were assessed in relation to hydrological factors such as salinity, temperature, and pH.

Results

Species Composition and Abundance: Four species were identified at the study site:

1. *Austruca annulipes* (Ring-legged Fiddler Crab)
2. *Austruca variegata* (Motley Fiddler Crab)
3. *Gelasimus hesperiae* (Western Calling Fiddler Crab)
4. *Tubuca alcocki* (Alcock's Fiddler Crab)

Specimen counts across the zones showed that *A. annulipes* was the most abundant (84 individuals), particularly in the lower zone, while *T. alcocki* was primarily found in the upper zone.

Hydrological Parameters and Zonation Hydrological conditions significantly influenced species distribution (Table 1):

- *A. annulipes* and *G. hesperiae* predominated in the lower zone, characterized by sandier sediments and salinity ranges of 10–35 ppt.
- *T. alcocki* and *A. variegata* were mostly distributed in the middle to upper regions, which feature muddier microhabitats and salinity between 10–35 ppt.

Table 1: The Species-specific hydrology and zonation

Species	Pore -water salinity(ppt)	Pore-water temperature	Pore-water PH	Zonation	Relative abundance
<i>Austruca annulipes</i>	~10-35	25-32°C	~6.5-8.0	Lower inter -tidal zone	34.3%
<i>Austruca varieagata</i>	~15-35	26-32°C	~6.5-7.8	Middle to Upper inter- tidal zone	21.6%
<i>Gelasimus hesperiae</i>	~12-34	28-31°C	~6.5-7.8	Lower	25.3%
<i>Tubuca alcocki</i>	~10-30 ppt	25-31°C	~6.5-7.9	Middle	18.8%

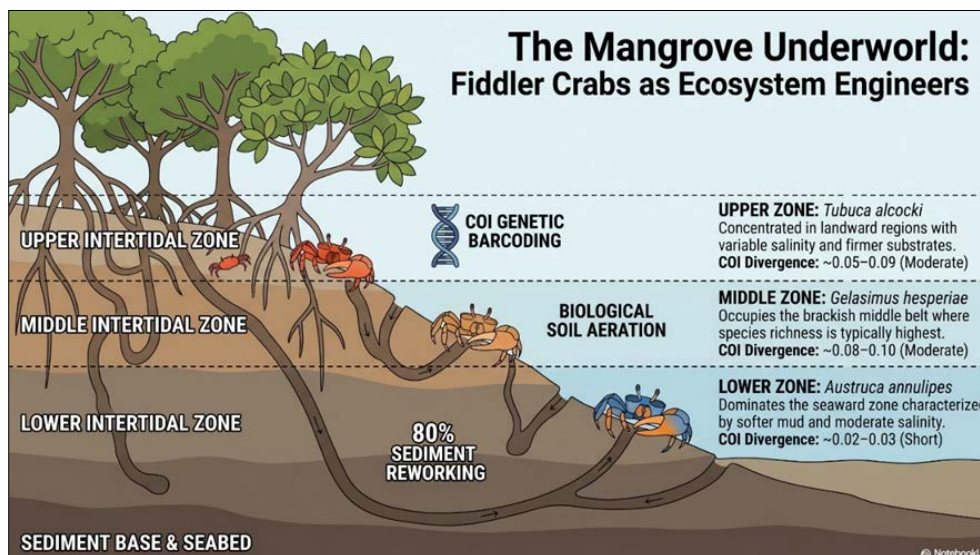


Fig 1: Zonation of the Fiddler Crab Species

Diversity Indices the diversity metrics calculated from the 245 specimens are as follows:

- Shannon–Wiener Index (H') \approx 1.356 (indicating moderate diversity).
- Maximum Diversity ($\ln S$) = 1.386.
- Evenness Index (E) \approx 0.978 (indicating near-uniform distribution across species).

Molecular Phylogeny (COI Gene) The CLUSTAL W alignment and phylogram construction revealed clear genetic partitioning:

- **Broad-front Group:** *A. annulipes* and *A. variegata* clustered together with high bootstrap support (96-97%) and short branch lengths, reflecting close genetic similarity.
- **Narrow-front Group:** *G. hesperiae* and *T. alcocki* formed distinct separate clades with moderate branch lengths, confirming their status as separate genera according to the 2016 molecular revision.

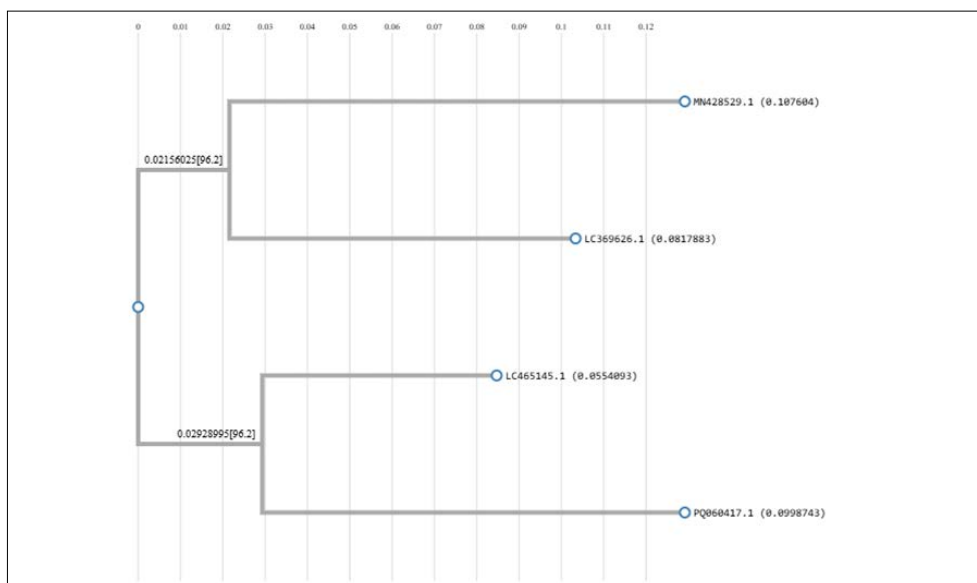


Fig 2: Phylogram showing the evolutionary relationship among the 4 fiddler crab species

Discussion

The fiddler crab assemblage in the Nizampatnam mangroves was structured by clear intertidal zonation, with species segregated according to sediment type, salinity, and tidal exposure. This pattern is consistent with earlier work showing that fiddler crab distribution is strongly shaped by sediment grain size and habitat heterogeneity, especially in tropical mangrove systems (Nobbs, 2003; Cannicci *et al.*, 2008) [4, 13]. In the present study, *Austruca annulipes* and *Gelasimus hesperiae* were concentrated in the lower intertidal zone, while *Tubeuca albocki* was more common in middle to upper zones, suggesting niche partitioning that reduces overlap in resource use (Kristensen, 2008) [8]. It is a kind of adaptive strategy. The presence of *A. variegata* across all zones at lower densities indicates a wider ecological tolerance (Mokhtari *et al.*, 2015) [12].

The observed community structure also reflects the role of fiddler crabs as ecosystem engineers. Their burrowing activity alters sediment aeration, organic matter turnover, and microbial conditions, thereby influencing mangrove soil processes at landscape scales (Kristensen *et al.*, 2012; Botto & Iribarne, 2000) [3, 9]. The high evenness recorded here indicates that the assemblage remained relatively balanced rather than dominated by one taxon, which may support stable bioturbation and sediment mixing across the study area (Penha-Lopes *et al.*, 2009) [14]. Such resilience is important in mangroves under moderate anthropogenic pressure, where crab activity helps sustain ecosystem functioning (Alongi, 2008) [1].

The COI-based molecular results supported the ecological and morphological observations. The clustering of *Austruca* species and the separation of *Gelasimus* and *Tubeuca* into distinct clades align with prior taxonomic revisions that used molecular evidence to refine fiddler crab classification (Shih *et al.*, 2016; Rosenberg, 2019) [15, 16]. COI is widely used as a species-level marker in crustaceans because it detects divergence that may not be obvious from morphology alone, making it especially useful in closely related intertidal taxa (Hebert *et al.*, 2003; Costa *et al.*, 2007) [5, 6]. The agreement between genetic grouping and habitat use in this study strengthens the interpretation that ecological divergence in these crabs is tied to evolutionary separation (Knowlton, 1993) [7]. The species exhibit molecular-ecological coupling where the genetic divergence captured by the COI gene maps directly onto morphological and ecological traits (Avisé, 2000) [2]. The split between broad-front and narrow-front species in the phylogram reinforces the idea that evolutionary divergence has been shaped by ecological gradients such as substrate texture and tidal exposure (Shih *et al.*, 2016) [16].

The diversity indices further suggest a moderately diverse but highly even community. The Shannon–Wiener value of approximately 1.36 and evenness of 0.98 indicate that the assemblage was not highly species-rich, but the species present were distributed very uniformly (Magurran, 2004) [11]. In disturbed mangrove habitats, such a pattern can indicate persistence of tolerant taxa and retention of core ecological functions rather than complete community collapse (Twilley & Rivera-Monroy, 2009) [17]. This makes fiddler crabs useful bioindicators for tracking environmental change in the Nizampatnam mangroves (Zeil & Hemmi, 2006) [18]. The fiddler crabs serve as indicators of ecosystem health. Despite the moderate level of human disturbance (wood harvesting, pollution), the high evenness (0.98)

suggests the crab community remains resilient and continues to sustain vital processes like sediment mixing (Penha-Lopes *et al.*, 2009) [14]. Because they are sensitive to environmental shifts, these crabs act as sentinel species for mangrove restoration success (Cannicci *et al.*, 2008; Lee, 2008) [4, 10].

Overall, the study demonstrates that fiddler crab distribution in Nizampatnam is controlled by fine-scale environmental gradients and that COI-based phylogenetic evidence complements field ecology in resolving species boundaries. Conserving tidal connectivity, sediment heterogeneity, and mangrove cover will be essential for maintaining both crab diversity and the ecosystem processes they support (Alongi, 2008; Twilley & Rivera-Monroy, 2009) [1, 17]. These findings support the use of integrated ecological and molecular approaches for mangrove biodiversity assessment and management (Hebert *et al.*, 2003; Shih *et al.*, 2016) [6, 16].

Conclusion

The Nizampatnam mangroves host a balanced population of four fiddler crab species whose spatial distribution is structured by salinity and intertidal gradients. Molecular evidence from the COI gene confirms species-level differentiation and supports the taxonomic elevation of *Austruca*, *Tubeuca*, and *Gelasimus*. This study demonstrates that the integration of ecological surveys with bioinformatics tools provides a robust framework for assessing biodiversity and informing conservation strategies in India's coastal wetlands.

References

1. Alongi DM. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*, 2008;76(1):1–13.
2. Avisé JC. *Phylogeography: The history and formation of species*. Harvard University Press, 2000.
3. Botto F, Iribarne O. Contrasting effects of two burrowing crabs on sediment composition and transport in estuarine environments. *Estuarine, Coastal and Shelf Science*, 2000;51(2):141–151.
4. Cannicci S, Burrows D, Fratini S, Smith TJ, Offenber J, Dahdouh-Guebas F. Faunal impact on vegetation structure and ecosystem function in mangrove forests. *Estuarine, Coastal and Shelf Science*, 2008;78(3):501–509.
5. Costa FO, deWaard JR, Boutillier J, Ratnasingham S, Dooh RT, Hajibabaei M, et al. Biological identifications through DNA barcodes. *Molecular Ecology Notes*, 2007;7(2):214–218.
6. Hebert PDN, Cywinska A, Ball SL, deWaard JR. Biological identifications through DNA barcodes. *Proceedings of the Royal Society B*, 2003;270(1512):313–321.
7. Knowlton N. Sibling species in the sea. *Annual Review of Ecology and Systematics*, 1993;24:189–216.
8. Kristensen E. Mangrove crabs as ecosystem engineers; with emphasis on sediment processes. *Journal of Sea Research*, 2008;59(1–2):30–43.
9. Kristensen E, Mangion P, Tang M, Flindt MR, Holmer M, Ulomi S. Microbial carbon oxidation rates and pathways in sediments of two Tanzanian mangrove forests. *Biogeochemistry*, 2012;103:143–158.

10. Lee SY. Mangrove macrobenthos: Assemblages, services, and linkages. *Journal of Sea Research*,2008;59(1–2):16–29.
11. Magurran AE. *Measuring biological diversity*. Blackwell Publishing, 2004.
12. Mokhtari M, Ghaffar MA, Usup G, Cob ZC. Determination of key environmental factors responsible for distribution patterns of fiddler crabs in a tropical mangrove ecosystem. *PLOS ONE*,2015;10(1):e0117467.
13. Nobbs M. Effects of vegetation on the distribution of the fiddler crabs in a tropical mangrove forest. *Journal of Experimental Marine Biology and Ecology*,2003;284(1–2):1–19.
14. Penha-Lopes G, Bartolini F, Limbu S, Cannicci S, Kristensen E, Paula J. Are fiddler crabs potentially useful ecosystem engineers in mangrove wastewater wetlands? *Marine Pollution Bulletin*,2009;58(11):1694–1703.
15. Rosenberg MS. A fresh look at the phylogeny and evolution of fiddler crabs. *Journal of Crustacean Biology*,2019;39(3):352–362.
16. Shih HT, Naruse T, Ng PKL. *Austruca* and allied genera: Molecular phylogeny and taxonomic revision of the fiddler crabs. *Zoological Journal of the Linnean Society*,2016;178(4):781–802.
17. Twilley RR, Rivera-Monroy VH. Sediment and nutrient trade-offs in restoring mangrove ecosystems. *Estuarine, Coastal and Shelf Science*,2009;82(4):653–660.
18. Zeil J, Hemmi JM. The visual ecology of fiddler crabs. *Journal of Comparative Physiology A*,2006;192(1):1–25.