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Original Article

Biodiversity assessment and spatio-temporal dynamics of gastropods with 66 new records to Sri Lanka

Uventhikka Sivanantham • Sutharshiny Sathyaruban • Kuddythamby Gunaalan • Sivashanthini Kuganathan

Department of Fisheries, Faculty of Science, University of Jaffna, Jaffna, Sri Lanka

Joint correspondence
Sivashanthini Kuganathan; Department of Fisheries, Faculty of Science, University of Jaffna, Jaffna, Sri Lanka
sivashanthini@univ.jfn.ac.lk

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Abstract
The present study aims to investigate the gastropod diversity in Mathagal (MAL), Kankesanthurai (KKS), Akkarai (AKI), and Mandaithivu (MAU), along the Northern coast of Sri Lanka. A systematic monthly survey was conducted from December 2022 to November 2023 using fifteen 0.5 m² quadrats per location. Gastropod shells were quantitatively sampled and taxonomically identified. Additionally, key water quality parameters were measured to determine their influence on the abundance of gastropods. A total of 92 gastropod species from 43 families comprising 1962 individuals were identified. The present study authenticated 66 new species to Sri Lanka's gastropod database and 12 new locality records to Jaffna. Significant spatial variation in gastropod abundance was observed among sites. MAU exhibited the highest dominance (0.202), indicating potential environmental stress or habitat homogeneity favouring particular species. KKS showed the highest evenness (0.841), suggesting a well-balanced community structure, while MAL demonstrated the highest species richness despite moderate evenness (0.688). The Shannon index ranged from 2.52 (KKS) to 2.09 (MAU), reflecting moderate to high biodiversity across all sites. These diversity patterns suggest heterogeneous habitat conditions, with some locations supporting more equitable species distributions while others are dominated by few taxa. No significant differences among the sites for water quality, suggesting these parameters are not influencing gastropods' abundance. This research provides an essential baseline for implementing targeted conservation strategies to protect these organisms from growing anthropogenic pressures, while the substantial number of new records highlights previously underestimated malacological richness of Sri Lanka's northern coastal waters.

Keywords: Cerithiidae; diversity indices; gastropods; tidal zone; water quality

1 | INTRODUCTION

Shelled molluscs, primarily comprising the class Gastropoda (e.g. snails and conches), represent a fundamental component of marine biodiversity (Oehlmann and Schulte-Oehlmann 2003). Their significance extends far beyond their aesthetic appeal, as they perform critical ecological functions that underpin coastal ecosystem health (Pawar and Al-Tawaha 2017). Gastropods contribute substantially to nutrient cycling through their feeding and excretion processes, facilitating the breakdown and redistribution of organic matter (Gutiérrez *et al*. 2003). As grazers, predators, and detritivores, they occupy multiple trophic levels and form vital links in benthic food webs, serving as both consumers of algae and detritus and as prey for fishes, birds, and crustaceans (Pawar and Al-Tawaha 2017). Many gastropod species also function as ecosystem engineers; their shells provide hard substrata for epibiont attachment, their burrowing activities enhance sediment aeration and stability, and empty shells create microhabitats for other organisms (Gutiérrez *et al*. 2003; Chapman 2012). The study of their diversity offers a valuable window into evolutionary biology and adaptation, revealing how species respond to environmental pressures over time (Catherine *et al*. 2024). Furthermore, their importance is profoundly socio-economic; they are a crucial source of protein for coastal communities and the basis for lucrative industries, including the pearl and ornamental shell trade (Haszprunar and Wanninger 2012). Therefore, comprehensive knowledge of molluscan diversity is not merely an academic pursuit but a prerequisite for effective ecosystem-based management, conservation planning, and the sustainable use of marine resources.

Globally, the intertidal and shallow subtidal zones of tropical and subtropical regions are recognized as hotspots for molluscan species richness (Heng *et al*. 2025; Majumder 2025; Mohamed *et al*. 2025). The warm, stable waters and high productivity of these areas foster exceptional levels of biodiversity. Sri Lanka, an island nation in the Indian Ocean, falls squarely within this biodiverse realm and is expected to host a significant yet incompletely documented molluscan fauna. However, despite this global pattern, significant geographical biases in research effort persist. In the Sri Lankan context, molluscan studies have been largely concentrated on the more accessible and developed coastal regions. Systematic surveys and biodiversity inventories have predominantly focused on the northwestern (Kithsiri *et al*. 2004; Weerakoon *et al*. 2021), southwestern (Rubesinghe and Krishnarajah 2014), southern (Corea and Madagedara 2019), and western coasts (Jayawickrema and Wijeyaratne 2009). In contrast, the northern coast of Sri Lanka remains one of the most critically understudied regions, due to historical factors, including three decades of civil conflict (1983–2009) that limited scientific access and research activity. This prolonged period of isolation from systematic biodiversity assessment has resulted in a pronounced knowledge gap regarding the composition, abundance, and distribution of shelled molluscs in the North, with research limited to very localized studies, such as the one conducted in Thondaimanaru (Amarasinghe *et al*. 2021).

The lack of baseline data is especially challenging for the northern coast, a region characterized by a unique and impactful environmental history. The region has endured significant anthropogenic and natural pressures, including the long-term effects of a civil conflict, ongoing post-conflict recovery and development, pollution, and the escalating impacts of climate variations. These cumulative stressors have likely induced substantial changes in coastal habitats, making the study of resident biota, such as molluscan communities, particularly urgent. Molluscs, with their sedentary nature and specific environmental tolerances, are excellent bioindicators; studying their population dynamics in this stressed region can yield invaluable insights into ecological resilience, adaptation mechanisms, and the overall health of the coastal ecosystem.

Therefore, to address this critical data deficiency and provide a scientific basis for understanding the region's malacological diversity, the present study was initiated with the following objectives: (1) to systematically investigate the diversity, abundance, and distribution of shelled gastropod molluscs along the Northern coast of Sri Lanka; (2) to assess spatial and seasonal variations in gastropod community structure; (3) to evaluate the influence of environmental parameters on gastropod abundance; and (4) to establish a comprehensive baseline dataset that contributes to updating national and global taxonomic databases.

2 | METHODOLOGY

2.1 Study area

Four coastal areas, Mathagal (MAL) (9°47′59″N 79°57′33″E), Kankesanthurai (KKS) (9°48′57″N 80°02′50″E), Akkarai (AKI) (9°49′12″N 80°07′55″E), and Mandaithivu (MAU) (9°36′13″N 80°00′00″E), were selected in the northern coastal region for the present study based on the availability of mollusc shells (Figure 1).

The four study sites, located at varying distances from Jaffna, encompass diverse coastal habitats. Mathagal and KKS, both approximately 20 km from Jaffna, which is home to various habitats, feature sandy beaches and rocky shores, with bordering the open Indian Ocean and its harbours. The AKI coastal ecosystem away within the Thondaimanaru Lagoon, located far from Jaffna (24.7 km), is a diverse and unique environment. It features a mix of habitats, including sandy and rocky shores, interspersed with features like river and lagoon estuaries, and sandstone beach reefs. MAU is an island located off the coast of the Jaffna Peninsula in northern Sri Lanka, approximately 3 km south of Jaffna. It covers an area of 7.56 km^2 and is known for its unique features, including mangroves and muddy shores, which provide a habitat for diverse marine organisms.

2.2 Sampling

A systematic survey was conducted across the four selected locations over a complete annual cycle, encompassing the four principal monsoon seasons of Sri Lanka: The North-East Monsoon (NEM), the First Inter-Monsoon (FIM), the South-West Monsoon (SWM), and the Second Inter-Monsoon (SIM). Sampling was carried out on a monthly basis from December 2022 to November 2023 to capture seasonal variations. At each location, a standardised sampling protocol was employed. Three replicate positions, spaced 5 m apart, were established. At each position, a 30 m transect line was laid perpendicular to the shoreline to ensure coverage across the intertidal gradient, from the high to the low tide zones. During low tide periods (tidal range: approximately 0.3–0.8 m), when the intertidal zone was maximally exposed, mollusc shells were quantitatively sampled from within a total of fifteen 0.5 m^2 quadrats per location. These quadrats were systematically arranged in a zigzag pattern along each transect line to maximise habitat coverage and ensure a representative sample while avoiding bias toward shell accumulations. Sampling was conducted across the full intertidal gradient, encompassing depths from approximately 0 m (high tide mark) to 1.5 m below mean low water level, depending on tidal conditions and site-specific bathymetry. Specimens were collected from the seafloor to a sediment depth of 5 cm via manual hand-picking.

All collected samples were immediately placed in pre-labelled plastic sample bags and transported to the laboratory for further processing. There, the shells were thoroughly cleaned using tap water to remove sediment and debris, drained in a sieve, and subsequently air-dried at ambient temperature for 24 hours. The processed samples were then stored in labelled containers for subsequent taxonomic identification and analysis.

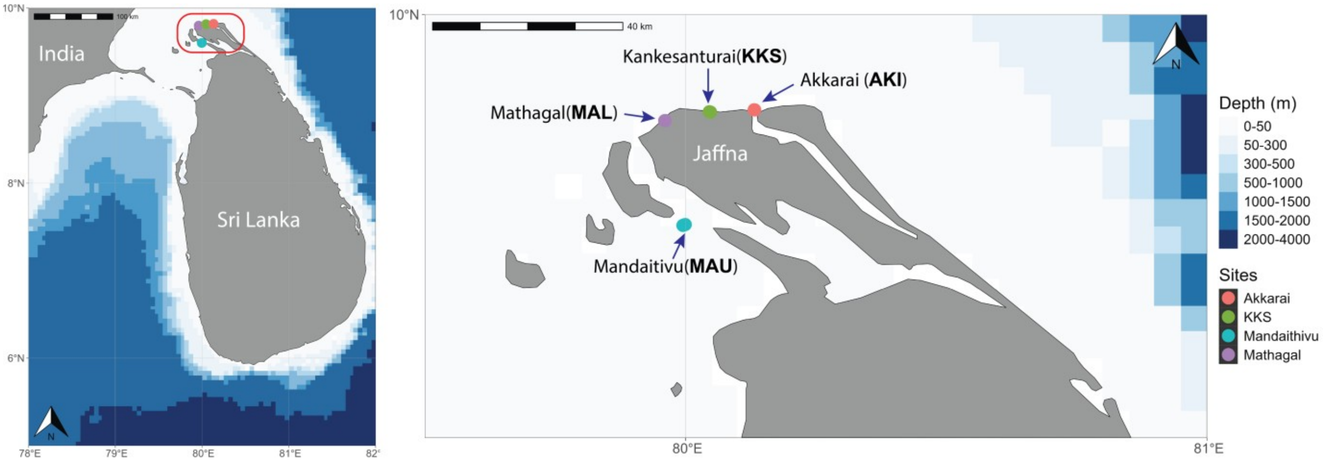

FIGURE 1 Sampling sites in the Northern province of Sri Lanka.

2.3 Identification

The specimens were photographed to aid identification. Species were classified morphologically based on shell characteristic, including colour, pattern, and distinctive features, following standard taxonomic literature (Abbott and Dance 1990; Carpenter and Niem 1998; Rao and Dey 2000; Anbalagan and Samuel 2012). Scientific names were verified against the World Register of Marine Species (WoRMS 2025) database, and the resulting checklist reflects currently accepted nomenclature.

2.4 Water quality variables

Key water quality parameters, including water temperature, salinity, pH, conductivity, and total dissolved solids, were measured in situ at each sampling point using a SMARTROLL^{TM} multiparameter instrument (Insitu 458389, USA). Supplementary environmental data, namely air temperature, wind speed, and soil pH were also collected and these parameters were measured by SMARTROLL^{TM} multiparameter instrument (Gobiraj *et al*. 2022), TFA digital anemometer and EctechTM pHSpear pH meter, respectively. Dissolved oxygen concentrations were subsequently analysed in the laboratory by following the Winkler's method.

2.5 Data analysis

The abundance of the shelled molluscs was quantified for each species across the four monsoon seasons. Community structure was assessed using standard ecological indices calculated in R software (version 4.2.1; R Core Team 2022) using the 'vegan' package (Oksanen *et al*. 2022):

Shannon-Wiener diversity index (H'): H' = –Σ p_i ln(p_i), where p_i is the proportion of individuals belonging to species i

Pielou's evenness (J'): J' = H'/ln(S), where S is the number of species

Simpson's dominance index (D): D = Σ (n_i/N)², where n_i is the number of individuals of species i and N is the total number of individuals

Species richness (S): total number of species observed

To evaluate significant differences in community composition across sites and seasons, a permutational analysis of variance (PERMANOVA) was applied using the 'adonis2' function in the 'vegan' package with 999 permutations. This non-parametric multivariate test was selected as it does not require assumptions of normality and is appropriate for community composition data. When significant overall differences were detected, pairwise PERMANOVA comparisons were conducted to identify which site pairs differed significantly.

The relationship between gastropod species abundance and environmental parameters was examined using Spearman's rank correlation analysis. Statistical significance for differences in water quality variables among sites was assessed using one-way ANOVA (for normally distributed data) or Kruskal-Wallis tests (for non-normal data), with a significance threshold of $p < 0.05$.

3 | RESULTS

3.1 Species identification and categorization

The survey of gastropod conducted across four research sites in Northern Sri Lanka revealed a diverse assemblage of 92 species from 43 families (Table 1). Among the 43 families identified, six families, namely Muricidae, Cerithiidae, Cypraeidae, Littorinidae, Neritidae and Strombidae, each contain more than five species. In contrast, the remaining families are represented by relatively rare species across all four research sites. The Muricidae family is notably well-represented, with 12 species including *Drupella margariticola*, *Chicoreus virgineus*, *Muricopsis rosea* and *Murex aduncospinosus*. This abundance suggests a prevalence of rocky substrates and sandy habitats, which are suitable for these predatory snails. The family Cerithiidae shows the highest species richness, with notable representation of gastropods such as *Clypeomorus batillariaeformis* and *Cerithium* sp. This family is consistently present across all sites, indicating its adaptability to various habitats.

A significant number of species from 33 families were classified as rare, each found in low numbers at just a single site. This underscores the need for continued monitoring, as these infrequent occurrences could indicate true rarity or represent specimens washed in from elsewhere. In contrast, species such as *Clypeomorus batillariaeformis* (Family: Cerithiidae), *Cerithium* sp. (Family: Cerithiidae), *Nerita polita* (Family: Neritidae), *Trochus radiatus* (Family: Trochidae), *Oliva* sp. (Family: Olividae), *Littoraria cingulifera* (Family: Littorinidae), *Turbo intercostalis* (Family: Turbinidae) and *Leucozonia* sp. (Family: Fasciolariidae) were deemed very common (Table 1). Their presence at all four sites in high abundance suggests stable populations and potentially healthy ecological conditions in their habitats.

Based on the number of individuals collected from all sampling sites, the most dominant species were *Clypeomorus batillariaeformis* (184 individuals), *Cerithium* sp. (165 individuals), *Nerita polita* (155 individuals), *Trochus radiatus* (152 individuals), *Pirenella cingulata* (148 individuals), *Anachis* sp. (94 individuals), *Chauvetia* sp. (70 individuals), *Clypeomorus bifasciata* (69 individuals), *Marginella* sp. (62 individuals) and *Drupella margariticola* (61 individuals). Dorsal view of these species is illustrated in Figure 2.

In the present study, a total of 66 new records has been documented in Sri Lanka and additionally 12 new locality records for Northern Sri Lanka were discovered. Interestingly, it could be delivered as a novel finding which have never been scientifically documented or reported in Sri Lanka before. These findings significantly expanding the country's documented biodiversity. The study yields an increase of approximately 72% of gastropods to the known gastropod fauna of the country.

TABLE 1 Taxonomic list of mollusc species with their abundance at each site (MAL - Mathagal, KKS - Kankesanthurai, AKI - Akkarai and MAU - Mandaithivu) of Sri Lanka.

Family	Species	Sites			
		MAL	KKS	AKI	MAU
Muricidae	*Drupella margariticola* (Broderip, 1833)[*]	+	+	+	-
	Chicoreus virgineus (Röding, 1798)	+	-	-	+
	Muricopsis rosea (Reeve, 1846)[*]	+	+	+	-
	Murex aduncospinosus G. B. Sowerby II, 1841	-	-	-	+
	Murex indicus Houart, 2011	+	+	-	-
	Haustrum scobina (Quoy & Gaimard, 1833)[*]	+	-	-	-
	Urosalpinx cinerea (Say, 1822)[*]	-	-	-	+
	Rapana venosa (Valenciennes, 1846)[*]	-	-	-	+
	Haustellum haustellum (Linnaeus,1758)	+	-	-	+
	Bolinus brandaris (Linnaeus, 1758)[*]	-	-	+	-
	Homalocantha anatomica (G. Perry, 1811)[*]	-	-	-	+
	Favartia Jousseaume, 1880[*]	+	-	-	-
Cerithiidae	*Bittium reticulatum* (da Costa, 1778)[*]	+	+	-	-
	Rhinoclavis sinensis (Gmelin, 1791)[#]	-	-	+	-
	Cerithium zonatum (W. Wood, 1828)[*]	-	-	-	+

TABLE 1 Continued.

Family	Species	Sites			
		MAL	KKS	AKI	MAU
	Clypeomorus batillariaeformis T. Habe & Kosuge, 1966[#]	+	+	+	+
	Cerithium Bruguière, 1789[#]	+	+	+	+
	Clypeomorus bifasciata (G. B. Sowerby II, 1855)[#]	+	-	-	-
	Cerithium atratum (Born, 1778)[*]	+	-	-	-
Cypraeidae	*Erronea onyx* (Linnaeus,1758)[*]	-	-	-	+
	Monetaria moneta (Linnaeus, 1758)[*]	-	+	+	-
	Ovatipsa chinensis (Gmelin, 1791)[*]	-	+	-	-
	Naria spurca (Linnaeus, 1758)[*]	-	-	+	-
	Erronea caurica elongata (Perry, 1811)[*]	-	-	-	+
Littorinidae	*Littoraria luteola* (Quoy & Gaimard, 1833*)*[*]	-	-	-	+
	Echinolittorina T. Habe, 1956	+	-	-	-
	Littoraria cingulifera (Dunker, 1845)[*]	+	+	+	+
	Littoraria scabra (Linnaeus,1758)[#]	-	-	-	+
	Echinolittorina placida D. Reid, 2009[*]	-	-	-	+
Neritidae	*Nerita albicilla* Linnaeus, 1758[#]	-	-	+	-
	Nerita polita Linnaeus, 1758[#]	+	+	+	+
	Nerita Linnaeus, 1758[#]	-	+	-	+
	Nerita plicata Linnaeus, 1758[#]	-	-	+	-
Strombidae	*Lambis* Röding, 1798[*]	+	-	-	+
	Margistrombus robustus (G. B. Sowerby III, 1875)[*]	-	+	-	+
	Maculastrombus microurceus (Kira, 1959)[*]	+	-	-	-
	Laevistrombus canarium (Linnaeus,1758)	-	-	-	+
	Lambis lambis (Linnaeus, 1758)	+	-	-	+
Marginellidae	*Volvarina* Hinds, 1844[*]	+	-	-	-
	Marginella Lamarck, 1799[*]	-	+	+	-
	Volvarina angustata (G. B. Sowerby II, 1846)[*]	+	-	-	-
	Melongena bispinosa (R.A.Philippi, 1844)[*]	-	-	-	+
Angariidae	*Angaria rugosa* (Kiener, 1838)[*]	+	-	-	-
	Angaria nodosa (Reeve, 1842)[*]	-	-	-	+
	Angaria delphinus (Linnaeus, 1758)[*]	-	-	-	+
Columbellidae	*Sulcomitrella monodonta* (T.Habe, 1958)[*]	-	-	-	+
	Anachis H. Adams & A. Adams, 1853[*]	+	-	+	+
	Euplica scripta (Lamarck, 1822)[*]	+	+	-	-
Trochidae	*Clanculus puniceus* (R. A. Philippi, 1846)[*]	+	+	-	-
	Umbonium vestiarium (Linnaeus, 1758)	-	-	+	+
	Trochus radiatus Gmelin, 1791[#]	+	+	+	+
Conidae	*Conus pascuensis* Rehder, 1980[*]	+	+	+	-
	Conus asiaticus da Motta, 1985[*]	+	-	+	-
Fasciolariidae	*Leucozonia* J. E. Gray, 1847[*]	+	+	+	+
	Fusinus colus (Linnaeus, 1758)[*]	-	-	-	+
Turbinidae	*Turbo intercostalis* Menke, 1846[*]	+	+	+	+
	Turbo gruneri R. A. Philippi, 1846[*]	+	-	-	-
Nassariidae	*Nassarius arcus* Cernohorsky, 1991[*]	+	-	+	-
	Nassarius Duméril, 1805[#]	-	+	+	-
Olividae	*Oliva* Bruguière, 1789	+	+	+	+
	Agaronia acuminata (Lamarck, 1811)[*]	-	+	+	-
Costellariidae	*Vexillum* Röding, 1798[*]	+	-	-	-
	Vexillum leucozonias (Deshayes, 1833)[*]	-	-	+	-
Potamididae	*Pirenella cingulata* (Gmelin, 1791)	-	+	+	+
	Terebralia palustris (Linnaeus, 1767)	-	-	-	+

TABLE 1 Continued.

Family	Species	Sites			
		MAL	KKS	AKI	MAU
Chauvetiidae	*Chauvetia* Monterosato, 1884*	-	+	+	+
Cerithiopsidae	*Cerithiopsis* Forbes & Hanley, 1850*	+	-	-	-
Mitridae	*Quasimitra solida* (Reeve, 1844)*	+	-	-	-
Buccinidae	*Buccinum* Linnaeus, 1758*	+	+	-	-
Planaxidae	*Supplanaxis nucleus* (Bruguière, 1789)*	+	+	-	-
Neritidae	*Nerita undata* Linnaeus, 1758*	+	-	-	-
Terebridae	*Terebra* Bruguière, 1789*	+	-	+	-
Turritellidae	*Helminthia vermicularis* (Brocchi, 1814)*	-	-	-	+
Turbinellidae	*Turbinella pyrum* (Linnaeus, 1767)	-	-	-	+
Bursidae	*Dulcerana granularis* (Röding, 1798)*	+	+	-	-
Pyramidellidae	*Turbonilla lactea* (Linnaeus, 1758)*	+	-	-	-
Volutomitridae	*Volutomitra groenlandica* (Møller, 1842)*	-	-	+	-
Bullidae	*Bulla ampulla* Linnaeus, 1758*	+	-	+	-
Eulimidae	*Niso* Risso, 1826*	-	+	-	-
Naticidae	*Neverita duplicata* (Say,1822)*	+	-	-	-
Volutidae	*Melo melo* ([Lightfoot], 1786)	-	-	-	+
Ampullarioidae	*Pomacea paludosa* (Say, 1829)*	+	-	-	-
Ancillariidae	*Ancilla marmorata* (Reeve, 1864)*	+	-	-	-
Architectonicidae	*Heliacus implexus* (Mighels, 1845)*	+	-	-	-
Cancellariidae	*Bivetiella cancellata* (Linnaeus, 1767)*	-	-	+	-
Cassidae	*Semicassis labiata* (G. Perry, 1811)*	+	-	-	-
Cymatiidae	*Gyrineum natator* (Röding, 1798)*	-	-	+	-
Ellobiidae	*Melampus* Montfort, 1810#	-	-	+	-
Epitoniidae	*Gyroscala commutata* (Monterosato, 1877)*	+	-	-	-
Naticidae	*Natica* Scopoli, 1777*	-	-	-	+
Tonnidae	*Tonna dolium* (Linnaeus, 1758)	+	-	-	-
Turridae	*Polystira* Woodring, 1928*	-	-	-	+

*Indicates new species records for Sri Lanka whereas, # indicates new locality records for Northern Sri Lanka.

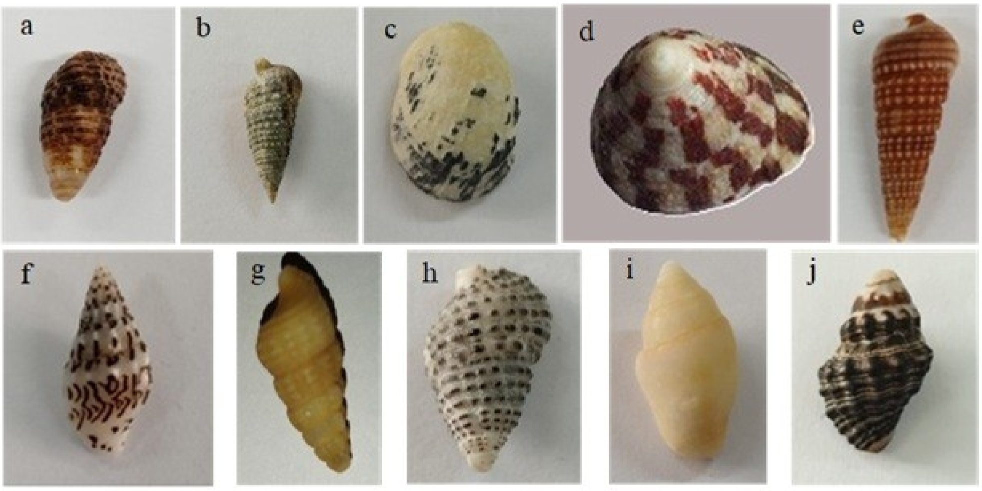

FIGURE 2 Dorsal view of most dominant gastropod species recorded along the Northern coast of Sri Lanka; a) *Clypeomorus batillariaeformis*; b) *Cerithium* sp.; c) *Nerita polita*; d) *Trochus radiatus*; e) *Pirenella cingulata*; f) *Anachis* sp.; g) *Chauvetia* sp.; h) *Clypeomorus bifasciata*; i) *Marginella* sp.; j) *Drupella margariticola*.

3.2 Variability of shelled gastropods across sites and seasons

Figure 3 illustrates the relationship between the study sites and the abundance of gastropod families observed in all four seasons. The majority of families (27 in total) were relatively scarce, each constituting less than 10% of the total abundance across all sites.

Muricidae family demonstrates a robust population in MAL and MAU, indicating ecological stability in rocky and sandy environments. Conversely, at KKS and AKI it is minimally present. The Cerithiidae family shows a strong presence at KKS and a moderate presence at AKI The variation in Cerithiidae species numbers between sites suggests that while sandy habitats can support this family, they are less favourable than muddy environments, highlighting the family's adaptability to different substrates. The Neritidae family displays remarkable resilience across all sites, with *Nerita polita* consistently being the most abundant species. Its prevalence indicates a broad ecological tolerance for both rocky and sandy habitats, which enhances population stability. In contrast, the Cypraeidae family is poorly represented across all sites. Overall, rocky and muddy environments support a richer gastropod diversity, particularly for families like Muricidae and Cerithiidae, while sandy substrates appear more challenging, leading to reduced abundance for families like Muricidae and Strombidae.

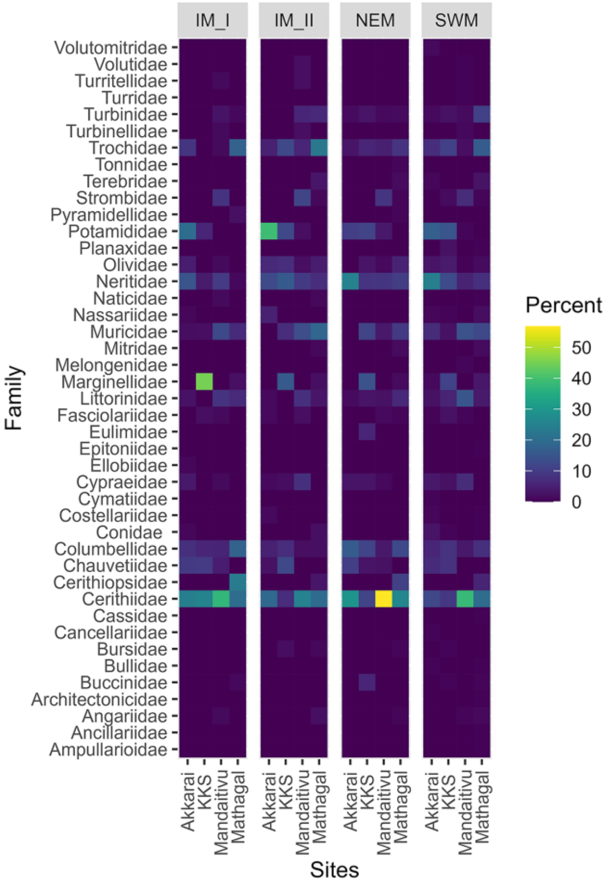

FIGURE 3 Family compositions of the gastropod shells (%) at the four sites and four seasons.

3.3 Diversity indices of the shelled molluscan across the sites and seasons

Figure 4 illustrates the diversity indices of gastropod species observed across all sampling sites throughout the four seasons. The MAL site consistently recorded the highest total number of individuals, whereas KKS showed markedly lower counts across all seasons suggesting a potential decline in mollusc abundance or activity. At MAL, the dominance indices (0.109 to 0.159) indicate a relatively balanced biodiversity with significant species richness. In contrast, KKS exhibited a wider range of dominance, peaking at 0.273 during the IMI season, indicating higher dominance and potentially lower biodiversity. Akkarai and Mandaithivu exhibited even greater variation, with Mandaithivu recording a high dominance index of 0.338 during the NEM, suggesting low evenness and a high degree of species monopoly.

Species richness fluctuated significantly across the sites, peaking uniformly during the SWM season MAU exhibited variable richness, reflecting ecosystem instability, with its highest value also occurring in the SWM. Similarly, MAL's, species richness was greatest in the SWM and the lowest in the IMI. The community demonstrates high evenness and low dominance during the SWM, indicating a balanced ecosystem. In contrast, KKS showed a concerning trend with a significant drop in richness in the NEM and dropped to just a few species in the IMI, which coincided with a peak dominance index that suggests a declining diversity during this period. AKI maintained relatively stable species richness, which peaked in the SWM while consistently sustaining low dominance across all seasons.

The findings of the present study underscore the complexities of biodiversity assessment using both the Shannon-Wiener and Simpson's diversity indices, which provide distinct insights into species composition at the studied sites. At MAL, a Shannon-Wiener diversity index of 1.651 during the First Inter-Monsoon (FIM) indicates a lower level of biodiversity and uneven species distribution. This low value is primarily due to the influence of a few dominant species, resulting in a relatively imbalanced representation of different species. In contrast, the Simpson's Index at MAL during the Southwest Monsoon (SWM) was lower (0.72), restating that, although there may be numerous species, their representation is uneven, highlighting the dominance of certain species over others. Conversely, MAU demonstrates a higher Shannon Index value of 2.265 in the SWM, reflecting a richer diversity and a more equitable distribution of individuals among species. This higher sensitivity of the Shannon index to rare species contributes to the indication of significant biodiversity at this site. The Simpson's Index confirmed this finding by reaching the highest value of 0.851 in MAU during the SWM, emphasizing that while there is high species richness, the presence of abundant individuals from a few species does not overshadow the overall diversity, as it is less sensitive to the rarer ones. AKI exhibited a similar pattern, with an impressive Shannon Index that highlights decent species evenness and richness, particularly in the SWM due to its higher score of 0.85 for evenness. The dominance index in this area (0.214) suggested a strong presence of particular bivalve species in the Second Inter-Monsoon (SIM), affecting the perception of biodiversity based on the Simpson's Index, which is influenced more by these dominant species.

3.4 Univariate analysis to evaluate significant differences in each species across sites and seasons

The results of the PERMANOVA revealed significant variability in gastropod community composition among the sites, as evidenced by an F-value of 3.4748 with a corresponding p(perm) value of 0.001 indicates that at least one site is distinctly different from others.

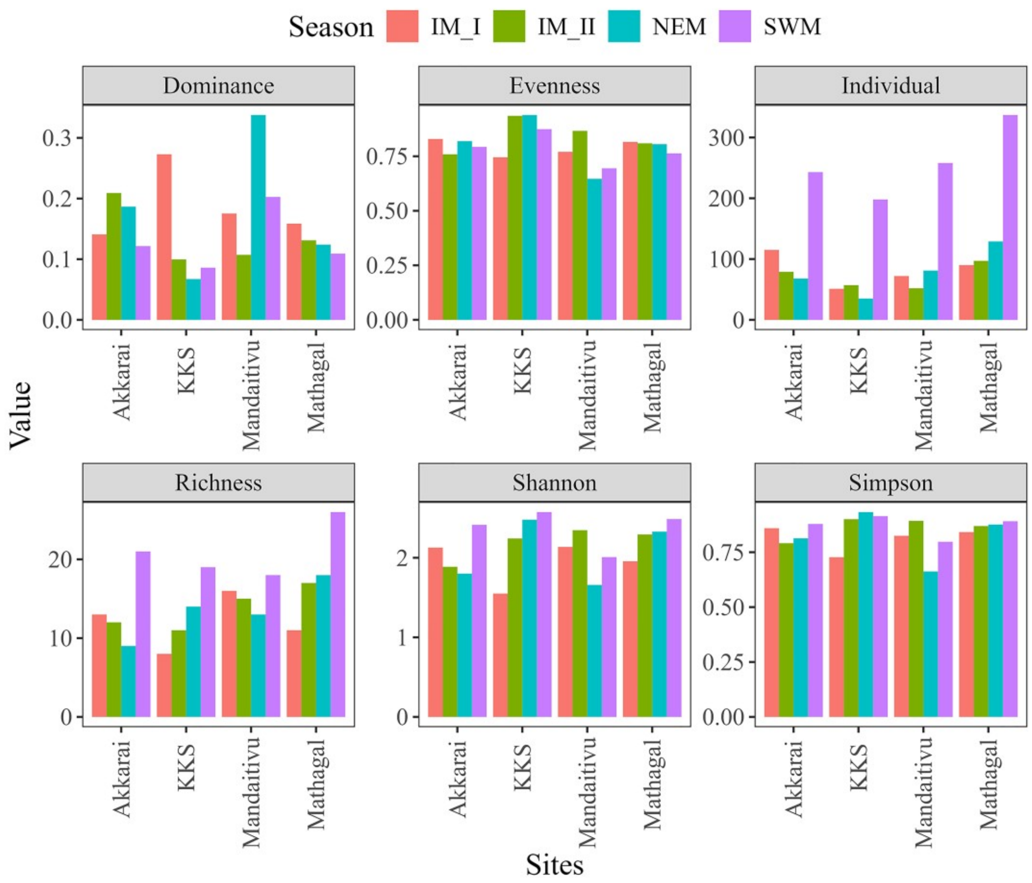

FIGURE 4 Gastropod species diversity indices among sites and seasons.

Table 2 shows significant differences ($p < 0.05$) in gastropod communities between several site pairs, specifically Akkarai-Mandaithivu, Akkarai-Mathagal, KKS-Mandaithivu, and KKS-Mathagal. In contrast, the comparison between Akkarai and KKS was not significant ($p = 0.088$). The PERMANOVA found no significant seasonal effect on gastropod community composition ($F = 1.4409$, $p = 0.111$). This suggests that seasonality does not play a critical role in shaping gastropod species assemblages within the study area.

TABLE 2 Results from pair-wise comparisons of gastropod among four study sites.

Pair-wise test	*t*	*p*
Akkarai, KKS	2.4906	0.088
Akkarai, Mandaithivu	3.6886	0.032
Akkarai, Mathagal	4.2645	0.032
KKS, Mandaithivu	3.4305	0.023
KKS, Mathagal	4.0052	0.026
Mandaithivu, Mathagal	3.0857	0.025

3.5 Relationship between the water quality parameters and shelled mollusc abundance

No significant differences ($p > 0.05$) in water quality parameters were detected among the sites, suggesting they are not a primary factor influencing gastropod abundance.

4 | DISCUSSION

4.1 Spatial distribution of shelled species

It could be pointed out that from the present study a wide range of gastropod species were collected along the northern coast, identified and recorded. A significant range of abundance, diversity, and richness was reported for the first time in Sri Lanka. Several previous studies were conducted on mollusc diversity in Sri Lanka, however, the species count was not attained the level reported in the present study. It is the major deviation of earlier studies from that of the present study. In a study, Rubesinghe and Krishnarajah (2014) documented the presence of 53 species of gastropods across 29 families, comparatively low number of species along the coasts of

Tangalle, Panadura, Chilaw, and Negombo. Interestingly, it is obvious that the sites chosen for the present research allowed room to collect numerous populations of shelled molluscs including 'new records' for Sri Lanka. It could be attested that the high occurrence is due to the most favourable environmental conditions preferred by the individual molluscs, prevailed in the chosen study area. The notably high abundance of species such as *Drupella margariticola*, *Chicoreus virgineus*, *Muricopsis rosea* and *Murex aduncospinosus* could be due to the presence of unique and favorable ecological conditions, such as rocky or coralline substrate providing surface for attachment and grazing, diverse prey assemblages, suitable hydrological conditions and optimum salinity and temperature ranges.

The highest number of species of gastropods was obtained from the MAL site whereas lowest count was obtained from KKS site. This elevated density of gastropods at MAU and MAL indicates a strong preference for these ecosystems. Conversely, previous research by Hendawitharana and Ranatunga (2020), documented a limited diversity comprising only 12 gastropod species from eight families across various key harbors in Colombo Port, including Dikkowita Fisheries Harbor, the Kirulapone Canal opening, and Panadura Fisheries Harbor reveals a pronounced contrast between the study sites.

The present study examined the mangrove ecosystem at the MAU site, identified 92 gastropod species. However, a previous study by Fernando (2018) reported the lowest number of gastropods among the mangroves of Sri Lanka, identifying only 14 species. In the present study, intertidal zones at the two sites, MAL and AKI, facilitate the diversity of gastropod shelled species (92) recorded, revealing the significance of habitat heterogeneity in promoting biodiversity. In a similar study at the intertidal zone in the Matara district, specifically in Wellamadama and Kamburugamuwa, conducted by Wickramasinghe *et al*. (2021), a few numbers of gastropod shells (34 species) were identified across different tidal zones.

The marked variation in gastropod diversity and abundance among the four study sites can be attributed to several key ecological factors. Substrate type emerges as a primary determinant: MAL and MAU, characterized by heterogeneous substrates including rocky shores, muddy flats, and mangroves, supported the highest species richness (49 and 45 species, respectively). Rocky substrates provide stable surfaces for attachment, refuge from predators, and favourable conditions for grazing gastropods such as *Nerita* and *Trochus* species. In contrast, KKS, dominated by sandy substrates with limited structural complexity, exhibited the lowest species richness (28 species), consistent with observations that sandy habitats generally support lower gastropod diversity due to substrate instability and limited refuge availability (Gray and Elliott 2009).

Habitat heterogeneity significantly influenced community structure. MAL and AKI, featuring mosaic habitats including rocky intertidal zones, sandy patches, and lagoon influences, supported distinct gastropod assemblages. This pattern aligns with the habitat heterogeneity-diversity relationship, where structurally complex environments provide more niches and diverse resource opportunities (Tews *et al*. 2004). The presence of mangroves at MAU contributed to its unique assemblage, including potamidid gastropods (*Pirenella cingulata*, *Terebralia palustris*) that are typically associated with organic-rich muddy sediments in mangrove ecosystems.

Coastal productivity likely contributed to observed patterns. MAU's location near productive lagoon and mangrove systems may explain the high abundance of deposit-feeding cerithiids and potamidids, which benefit from elevated organic matter inputs. Similarly, MAL's proximity to open ocean influences may enhance larval supply and nutrient availability, supporting its high species richness.

Human disturbance gradients may also explain inter-site differences. KKS, located near a historically active harbour area with ongoing development activities, showed reduced diversity and abundance, potentially reflecting cumulative impacts from anthropogenic disturbance. This finding is consistent with studies documenting reduced molluscan diversity in areas subject to coastal development, pollution, and human trampling (Ysebaert *et al*. 2002). In contrast, MAU's relative isolation as an island with limited development may contribute to its diverse gastropod assemblage, although its higher dominance indices suggest some environmental stress or natural monopolization by adapted species.

These factors likely interact in complex ways; for instance, substrate type influences how gastropod communities respond to productivity gradients and disturbance regimes. Future studies incorporating quantitative measurements of sediment characteristics, organic matter content, and anthropogenic pressure indicators would help disentangle these interacting factors.

4.2 Variability in shelled molluscs across sites

A key finding of the present study highlights that *Cerithium* sp (Family Cerithiidae: Gastropod) is a significant species at the MAU site. This area, characterised by muddy substrate and rocky shores, supports suitable habitat for these molluscs. Some species which were identified in the present study have already been recorded in other parts of Sri Lanka. For example, *Cellana* sp. collected at the MAL site in the present study was identified in Tangalle (Rubesinghe and Krishnarajah 2014), in the low tide zone of the Wellamadama and Kamburugamuwa in the Matara district (Wickramasinghe *et al*. 2021). In 2018, Malik Fernando recorded four gastropod families such as, Ellobiidae, Littorinidae, Neritidae, and Potamididae in the mangrove ecosystems of Sri Lanka (Fernando 2018), which are referenced in the present study.

4.3 Monsoon seasonal variation of shelled species

Examining diversity indices across various studies provides valuable insights into the ecological patterns of gastropods in different coastal environments. When comparing the present study's findings with those of previous research, an apparent variance in diversity indices across different locations became evident. The current research focuses on MAU, MAL, AKI, and KKS, highlighting notable indices for gastropods.

The dominance of gastropods (0.454) is particularly noteworthy, indicating a more significant presence of these organisms. Regarding species diversity, the Simpson index values of 0.546 for gastropods suggests a greater diversity within gastropod species. Furthermore, the Shannon index scores (9.392 for gastropods) reflect a rich community composition, with the evenness values (2.497 for gastropods) providing insight into how species are distributed within these communities. Contrasting these figures with those reported by Rubesinghe and Krishnarajah (2014), which focused on the shores of Chilaw, Negambo, Panadura, and Tangalle, reveals significant differences in species richness and evenness. Their findings indicated the lowest Shannon-Weiner diversity values at Tangalle (3.37), Negombo (3.36), and Panadura (2.68).

Also, the evenness in Negombo was notably higher than the values reported in the present study, emphasizing a more balanced distribution of organisms. Such differences could stem from environmental factors, specific habitat characteristics, or variations in sampling methods. Additionally, Wickramasinghe *et al*. (2021) offer insights from Wellamadama and Kamburugamuwa, with Shannon-Weiner indices of 1.8271 and 1.9281, respectively. Their findings show lower diversity indices compared to the present research. The present findings demonstrate higher diversity and dominance of specific taxa in the studied locations compared to the previous references. This discrepancy may reflect unique ecological conditions, such as habitat quality, resource availability, and anthropogenic impacts, which warrant further investigation into the factors driving these variations in biodiversity across different coastal environments.

In this study, no significant differences were observed in the abundance of mollusc-shelled species across the different seasons. Currently, there is no available data on the diversity of shelled molluscs associated with the monsoon seasons in Sri Lanka. However, other countries worldwide have conducted assessments on the assemblage of mollusc diversity in relation to the monsoon seasons, such as the Goa coastline, India (David 2013), Southeast coast of India (Satheeshkumar and Khan 2012), and Uttara Kannada Coast, Southwest coast of India (D'Souza and Shenoy 2020). In addition, other seasonal factors, such as temperature fluctuations (Urra *et al*. 2013), habitat dynamics (Hamsiah *et al*. 2016), and ecological interactions (Barker and Mayhill 1999), can influence their diversity.

4.4 Relationship between the water quality parameters and shelled mollusc abundance

No significant differences were observed among the sites for any water quality parameters, indicating that water quality likely does not impact the abundance of gastropods. However, various studies have highlighted how temperature, pH, salinity, dissolved oxygen, vegetation, and nutrient concentrations can significantly influence mollusc populations (Horsák and Hájek 2003, Satheeshkumar and Khan 2012, Mansingh *et al*. 2021, Kelaher *et al*. 2022).

5 | CONCLUSIONS

The present study provides the first comprehensive assessment of gastropod diversity along Sri Lanka's northern coast, documenting 92 species from 43 families, including 66 new national records and 12 new locality records for the Jaffna region. This substantial expansion—representing approximately 72% increase to the known gastropod fauna of Sri Lanka—attests to the region's previously underestimated malacological diversity and underscores the critical importance of surveying understudied areas.

Implications for marine biodiversity conservation: The high number of new records and the presence of rare species at single sites highlight the urgent need for habitat protection in these locations. MAL and MAU, which supported the highest species richness and unique assemblages including mangrove-associated species, should be prioritized for conservation attention. The discovery that sandy substrates (KKS) support lower diversity suggests that habitat modification leading to substrate homogenization could negatively impact gastropod communities. Conservation strategies should therefore focus on maintaining habitat heterogeneity, particularly preserving rocky intertidal zones, mangrove forests, and muddy habitats that harbor specialized gastropod assemblages.

Implications for coastal ecosystem monitoring: The significant spatial variation in community structure, coupled with the lack of significant seasonal variation, suggests that gastropod assemblages in this region are primarily structured by habitat characteristics rather than monsoon-driven environmental fluctuations. This finding establishes gastropods as reliable bioindicators for long-term monitoring programs; changes in community composition over time would likely reflect alterations in habitat quality or anthropogenic impacts rather than natural seasonal variability. The baseline data established here enables future detection of ecological changes resulting from coastal development, pollution, climate change, or other stressors.

Furthermore, these findings contribute to global biodiversity knowledge by updating taxonomic databases and highlighting the biogeographical significance of Sri Lanka's northern coast within the Indian Ocean region. The substantial number of new records suggests that similar biodiversity surveys in other understudied Sri Lankan coastal areas may yield additional discoveries. We recommend establishing a long-term monitoring program incorporating quantitative sampling of gastropod communities alongside standardized environmental measurements to track ecosystem health and inform evidence-based management decisions. Such efforts will be essential for protecting these ecologically and socioeconomically valuable organisms from growing anthropogenic pressures in the post-conflict development context of northern Sri Lanka.

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ETHICAL APPROVAL

All applicable international, national and/or institutional guidelines for the care and use of animals were followed in this study.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

Uventhikka Sivanantham: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Investigation, Writing the original draft. Sutharshiny Sathyaruban: Conceptualization, Supervising, Validation, Writing – review and edit. Kuddythamby Gunaalan: Conceptualization, Data analysis. Sivashanthini Kuganathan: Conceptualization, Supervising, Validation, Funding acquisition, Writing – review and edit, Project administration.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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S Sathyaruban http://orcid.org/0000-0002-5540-8578
K Gunaalan http://orcid.org/0000-0001-7920-0176
S Kuganathan http://orcid.org/0000-0002-3005-2325