

Diversity and spatial distribution of molluscs along the salinity gradient in Ashtamudi Lake Ramsar site, Kerala, India

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Abstract

Study of the diversity and spatial distribution of molluscs along salinity gradient in Ashtamudi Lake recorded the presence of 83 species with one polyplacophoran, 41 gastropods, 37 bivalves and four cephalopods. The species diversity in various salinity zones was in the order: saline zone- 80 species > estuarine zone- 28 species > freshwater zone- 14 species. The report includes three species new to the west coast of India: *Assimineia woodmasoniana* G. Nevill, 1880, *Rugalucina vietnamica* (Zorina, 1978) and *Platevindex martensi* (Plate, 1893). Species: such as *Chiton granoradiatus* Leloup, 1937; *Clithon sowerbianum* (Récluz, 1843); *Littoraria palleescens* (Philippi, 1846); *Acteocina decorata* (Pilsbry, 1904); *Alaona ala* (Hanley, 1845) and *Serratina siamensis* (E. von Martens, 1860) are new to Kerala. The paper analyses the alpha and beta diversity of molluscs in the Ashtamudi Lake, Kerala.

Keywords: Ashtamudi, Salinity, Estuary, Gastropods, Bivalves, Diversity index

Introduction

Estuaries are a unique class of transient, highly dynamic, productive aquatic habitats that act as the ecotone between terrestrial, fresh water and marine ecosystems (Shetye, 2011). Being semi-enclosed water bodies, the sea water entering the estuaries from one side is diluted by the fresh water from the other side, making these estuaries sites of spatial and temporal fluctuations in variables like salinity and community structure (Elliott and McLusky, 2002). The major environmental parameter determining the diversity and abundance of different organisms in the estuaries is water salinity, which varies along the longitudinal profile, transverse profile, depth, tides, and seasonally (Chertoprud *et al.*, 2013).

Macrobenthic fauna comprises a substantial portion of the estuarine biomass (Bailey-Brock *et al.*, 2002) and molluscs constitute the major component of the estuarine macrobenthic communities. Estuarine molluscs inhabit different feeding niches and are excellent ecological indicators (Asuquo and Anyanwu, 2018). Since they are highly sensitive

to the changes in their natural environment, they are ideal organisms for studying the relationship between species distribution and variables like salinity (Montagna and Kalke, 1995). Studies on estuarine molluscs of India began with the works of Stoliczka (1869), followed by contributions from Preston (1916), Desai and Krishnankutty (1967), Rao *et al.* (1983), Bhat and Neelakantan (1984), Nair *et al.* (1984), Mandal and Nandi (1989), Mohapatra (2001, 2008), Laxmilatha *et al.* (2006), Dey (2008), Dev Roy *et al.* (2009), Venkatesan *et al.* (2010), Behera and Nayak (2013), Vanmali and Jadhav (2015) and Tudu *et al.* (2018). Distribution of molluscs along the salinity gradient in Indian estuaries was studied by Gopal and Chauhan (2006), Roy and Nandi (2012), Roy *et al.* (2013), Jayachandran *et al.* (2019) and Rehitha *et al.* (2022).

The present study analyses the diversity and spatial distribution of molluscs in Ashtamudi Lake, Kerala along its salinity gradient. Studies on molluscs of the Ashtamudi estuary have been initiated by Divakaran *et al.* (1981), Nair *et al.* (1984), Velayudhan *et al.* (1998) Kripa and Mohammed Salih (1999), Raghunathan (2007), Vimalraj *et al.* (2014),

Venkatesan *et al.* (2015), Arathi *et al.* (2018), and Ravinesh *et al.* (2021), however none of these works have considered the effect of salinity gradient on the distribution of molluscan species in Ashtamudi Lake.

Materials and Methods

Ashtamudi Lake in Kollam district of Kerala, India (8°59' N 76°36' E) is the deepest and the second largest backwater system in Kerala, having an area of 61.4 km² and a maximum depth of 6.4 meters at the conflux where the lake merges with the Arabian Sea (Anoop *et al.*, 2008; Chinnadurai *et al.*, 2016). Ashtamudi Lake was designated as a Ramsar site in November 2002. The Kallada River, a mountainous river from the Western Ghats discharges into the Ashtamudi Lake (Jennerjahn *et al.*, 2008). The study was conducted in the Ashtamudi estuary from January 2022 to January 2023. Six sampling sites were selected randomly based on increasing salinity from Koivila where the Kallada River joins the lake, to Neendakara Barmouth, where the estuary discharges into the Arabian Sea (Figure 1). The sampling sites were divided into three distinct salinity zones based on the salinity gradient, namely the freshwater zone (salinity of 5 ppt - 14 ppt), estuarine zone (salinity, 15 ppt - 24 ppt) and saline zone (salinity of 25 ppt - 34 ppt). Koivila and Peringalam were taken as the freshwater zone, Ashtamudi and Tholukadavu as the estuarine zone and Dalavapuram and Neendakara Barmouth as the saline zone (Figure 1). The salinity of the water at each site was estimated using hand-held Refractometer and standard methods of APHA (2017). The specimens were collected by direct search in low tide, hand picking, hand lift netting and grab sampling. A Van veen grab sampler collected sediment up to 20 cm depth of roughly 0.1m² area. The quadrat method was also employed with 10 m × 10 m grid using 1 × 1 m² quadrats. The sediment collected during grab sampling was washed with lake water on the field, and the molluscan species were separated using sieves of varying mesh sizes. The fresh specimens of polyplacophorans, gastropods, bivalves and cephalopods were cleaned, washed, photographed and preserved in 70% ethanol. The empty shells of gastropods and bivalves were preserved dry (Geiger *et al.*, 2007; Edward *et al.*, 2022; Ravinesh and Biju Kumar, 2022). The collected specimens were identified with the help of taxonomic publications (Oliver, 1992; Bosch *et al.*, 1995; Subba Rao, 2003, 2017; Robin, 2008; Huber, 2010, 2015; Eichhorst, 2016; Goulding *et al.*, 2021; Edward *et al.*, 2022). All scientific names were finalized following the website World Register of Marine

Species (<http://www.marinespecies.org>). Statistical analyses were done using PAST 4.3 and SPSS Statistics 24.

Results and Discussion

The present study recorded 83 molluscan species classified under four classes (Polyplacophora, Gastropoda, Bivalvia and Cephalopoda), seven subclasses, 20 orders, 44 families and 72 genera. Class Gastropoda has the highest diversity with 41 species, followed by Bivalvia (37 species), Cephalopoda (four species) and Polyplacophora (one species) (Table 1). Earlier, 119 molluscan species classified under three classes have been reported from the Ashtamudi estuary (Ravinesh *et al.* 2021).

Species like *Assimineia woodmasoniana* G. Nevill, 1880, *Rugalucina vietnamica* (Zorina, 1978) and *Platevindex martensi* (Plate, 1893) are recorded from the lake and are first observation records to the West Coast of India also (Table 1, Figure 2). Species like *Chiton granoradiatus* Leloup, 1937, *Clithon sowerbianum* (Récluz, 1843), *Littoraria pallescens* (Philippi, 1846), *Acteocina decorata* (Pilsbry, 1904), *Alaona ala* (Hanley, 1845) and *Serratina siamensis* (E. von Martens, 1860) are also recorded from the lake and happens to be first time from Kerala (Table 1, Figure 2).

Based on the salinity gradient in Ashtamudi Lake, the molluscan species diversity was highest in the saline zone, with 80 species comprising of one polyplacophoran, 39 gastropods, 36 bivalves and four cephalopods. The estuarine zone reported 28 species (16 gastropods and 12 bivalves), and the freshwater zone with 14 species (nine gastropods and five bivalves), respectively. Roy and Nandi (2012) documented 48 molluscan species along the salinity gradient of Hugli- Matla Estuary with 39 gastropods and nine bivalves. The alien mussel, *Mytella strigata* (Hanley, 1843) has been established successfully in all the three salinity zones in Ashtamudi Lake. Studies by Yuan *et al.* (2010) shows wide range salinity tolerance exhibited by *Mytella strigata* (salinity ranging from 2 ppt - 40 ppt). A total of 11 species, represented by seven gastropods and four bivalves were recorded commonly from all three zones indicating that these species show a wider range of tolerance to salinity. Species like *Telescopium telescopium* (Linnaeus, 1758), *Melampus lividus* (Deshayes, 1830), *Cassidula nucleus* (Gmelin, 1791), *Pythia plicata* (Férussac, 1821) were recorded from the saline zone. These species are exclusively mangrove-associated species and they were collected live from mangrove patches adjoining the Neendakara Barmouth region.

For analysing the alpha diversity of the three zones, diversity indices like Shannon-Weiner diversity index, Margalef-richness index, Simpson- dominance index and Pielou's evenness index were calculated (Table 2). Shannon- Weiner index showed the highest value of 3.221 in the saline zone, followed by the estuarine zone (2.58) and the freshwater zone (2.083). According to Bath *et al.* (1999), the high diversity of molluscs is correlated with an increase in salinity. The Margalef species richness values were 5.732 for the saline zone, 3.095 for the estuarine zone and 1.705 for the freshwater zone. The Simpson-dominance index recorded a high value of 0.945 in the saline zone, accompanied by 0.895 in the estuarine zone and 0.86 at the freshwater zone. Pielou's evenness index showed a high value of 0.729 in the freshwater zone, indicating more even distribution of species and comparatively less values of 0.628 in the estuarine zone and 0.596 in the saline zone, indicating less even distribution of species as the saline zone is dominated only by the euryhaline species.

For beta diversity, the Whittaker diversity index was computed (Table 3), and it documented the lowest value of 0.365 between the saline and estuarine zone, indicating

a high level of similarity between these two zones. Among freshwater and estuarine zones, the beta diversity value was 0.375 and the highest beta diversity value of 0.660 was reported between freshwater and saline zones, indicating the least level of similarity shared by the freshwater zone and saline zone. The dendrogram (hierarchical clustering- group average linkage) of the molluscan families assemblages is shown in Figure 3. The results shows that families like Chitonidae, Trochidae, Chilodontidae, Planaxidae, Rostellariidae, Turritellidae, Pisaniidae, Conidae, Turridae, Haminoeidae, Pinnidae, Anomiidae, Ungulinidae, Cardiidae, Sepiolidae, Sepiidae and Loliginidae are clustered separately. This may be because species in these families are reported only from the saline zone.

The present survey was carried out for a short period covering only six random sites. Extensive studies covering more sites for a longer period are necessary to understand better the spatial distribution of molluscs along the salinity gradient and the β diversity index of Ashtamudi Lake. Considering the lake as an Ramsar site, its protection and conservation is imperative especially on the alien species of molluscs as well as pollution point of view.

Table 1: List of molluscs recorded from the three salinity zones in the Ashtamudi estuary

| Sl.No | Classification/Name of species | Salinity Zones | | |
|-------|---|-----------------|----------------|-------------|
| | | Freshwater Zone | Estuarine Zone | Saline Zone |
| 1 | CLASS: POLYPLACOPHORA FAMILY: CHITONIDAE <i>Chiton granoradiatus</i> Leloup, 1937 | - | - | + |
| 2 | CLASS: GASTROPODA FAMILY: TROCHIDAE <i>Umbonium vestiarius</i> (Linnaeus, 1758) | - | - | + |
| 3 | FAMILY: CHILODONTAIDAE <i>Euchelus asper</i> (Gmelin, 1791) | - | - | + |
| 4 | FAMILY: NERITIDAE <i>Clithon oualaniense</i> (Lesson, 1831) | + | + | + |
| 5 | <i>Clithon sowerbianum</i> (Récluz, 1843) | + | + | + |
| 6 | <i>Neripteron violaceum</i> (Gmelin, 1791) | + | + | + |
| 7 | <i>Nerita albicilla</i> Linnaeus, 1758 | - | - | + |

| Sl.No | Classification/Name of species | Salinity Zones | | |
|-------|--|-----------------|----------------|-------------|
| | | Freshwater Zone | Estuarine Zone | Saline Zone |
| 8 | FAMILY: PHENACOLEPADIDAE <i>Plesiothyreus cinnamomeus</i> (A. Gould, 1846) | + | + | + |
| 9 | FAMILY: PACHYCHILIDAE <i>Faunus ater</i> (Linnaeus, 1758) | + | - | - |
| 10 | FAMILY: PLANAXIDAE <i>Planaxis sulcatus</i> (Born, 1778) | - | - | + |
| 11 | FAMILY: POTAMIDIDAE <i>Pirenella cingulata</i> (Gmelin, 1791) | + | + | + |
| 12 | <i>Telescopium telescopium</i> (Linnaeus, 1758) | - | - | + |
| 13 | FAMILY: CALYPTRAEIDAE <i>Desmaulus extintorium</i> (Lamarck, 1822) | - | - | + |
| 14 | <i>Ergaea walshi</i> (Reeve, 1859) | - | + | + |
| 15 | FAMILY: LITTORINIDAE <i>Littoraria pallescens</i> (Philippi, 1846) | + | + | + |
| 16 | <i>Littoraria undulata</i> (Gray, 1839) | - | - | + |
| 17 | FAMILY: ROSTELLARIIDAE <i>Tibia curta</i> (G. B. Sowerby II, 1842) | - | - | + |
| 18 | FAMILY: TURRITELLIDAE <i>Turritella acutangula</i> (Linnaeus, 1758) | - | - | + |
| 19 | FAMILY: NATICIDAE <i>Eunaticina papilla</i> (Gmelin, 1791) | - | - | + |
| 20 | <i>Notocochlis gualteriana</i> (Récluz, 1844) | - | - | + |
| 21 | <i>Paratectonatica tigrina</i> (Röding, 1798) | - | - | + |
| 22 | FAMILY: ASSIMINEIDAE <i>Assiminea woodmasoniana</i> G. Nevill, 1880 | + | + | + |
| 23 | FAMILY: BURSIDAE <i>Bufonaria crumena</i> (Lamarck, 1816) | - | + | + |
| 24 | <i>Bufonaria echinata</i> (Link, 1807) | - | + | + |
| 25 | FAMILY: BABYLONIIDAE <i>Babylonia spirata</i> (Linnaeus, 1758) | - | - | + |
| 26 | <i>Babylonia zeylanica</i> (Bruguère, 1789) | - | - | + |

| Sl.No | Classification/Name of species | Salinity Zones | | |
|-------|---|-----------------|----------------|-------------|
| | | Freshwater Zone | Estuarine Zone | Saline Zone |
| 27 | FAMILY: NASSARIIDAE <i>Nassodonta insignis</i> H. Adams, 1867 | + | - | - |
| 28 | <i>Nassarius jacksonianus</i> (Quoy & Gaimard, 1833) | - | + | + |
| 29 | FAMILY: PISANIIDAE <i>Cantharus tranquebaricus</i> (Gmelin, 1791) | - | - | + |
| 30 | FAMILY: MURICIDAE <i>Indothais blanfordi</i> (Melvill, 1893) | - | + | + |
| 31 | <i>Indothais lacera</i> (Born, 1778) | - | - | + |
| 32 | <i>Murex pecten</i> Lightfoot, 1786 | - | - | + |
| 33 | FAMILY: CONIDAE <i>Conus inscriptus</i> Reeve, 1843 | - | - | + |
| 34 | FAMILY: CLAVATULIDAE <i>Turricula javana</i> (Linnaeus, 1767) | - | + | + |
| 35 | <i>Turricula tornata</i> (Dillwyn, 1817) | - | + | + |
| 36 | FAMILY: TURRIDAE <i>Unedogemmula indica</i> (Röding, 1798) | - | - | + |
| 37 | FAMILY: TORNATINIDAE <i>Acteocina decorata</i> (Pilsbry, 1904) | - | + | + |
| 38 | FAMILY: HAMINOEIDAE <i>Haminoea pemphis</i> (Philippi, 1847) | - | - | + |
| 39 | FAMILY: ELLOBIIDAE <i>Melampus lividus</i> (Deshayes, 1830) | - | - | + |
| 40 | <i>Cassidula nucleus</i> (Gmelin, 1791) | - | - | + |
| 41 | <i>Pythia plicata</i> (Férussac, 1821) | - | - | + |
| 42 | FAMILY: ONCHIDIIDAE <i>Platevindex martensi</i> (Plate, 1893) | - | + | + |
| 43 | CLASS: BIVALVIA FAMILY: MYTILIDAE <i>Arcuatula senhousia</i> (Benson, 1842) | - | - | + |
| 44 | <i>Brachidontes pharaonis</i> (P. Fischer, 1870) | - | - | + |
| 45 | <i>Byssogerdus striatulus</i> (Hanley, 1843) | - | - | + |
| 46 | <i>Modiolus moduloides</i> (Röding, 1798) | - | - | + |

| Sl.No | Classification/Name of species | Salinity Zones | | |
|-------|---|-----------------|----------------|-------------|
| | | Freshwater Zone | Estuarine Zone | Saline Zone |
| 47 | <i>Mytella strigata</i> (Hanley, 1843) | + | + | + |
| 48 | <i>Perna perna</i> (Linnaeus, 1758) | - | - | + |
| 49 | <i>Perna viridis</i> (Linnaeus, 1758) | - | - | + |
| 50 | FAMILY: ARCIDAE <i>Anadara inaequivalvis</i> (Bruguie`re, 1789) | - | - | + |
| 51 | <i>Anadara indica</i> (Gmelin, 1791) | - | + | + |
| 52 | <i>Didimacar tenebrica</i> (Reeve, 1844) | - | - | + |
| 53 | <i>Tegillarca aequilatera</i> (Dunker, 1868) | - | - | + |
| 54 | FAMILY: PINNIDAE <i>Pinna bicolor</i> Gmelin, 1791 | - | - | + |
| 55 | FAMILY: ISOGNOMONIDAE <i>Isognomon isognomum</i> (Linnaeus, 1758) | - | + | + |
| 56 | FAMILY: OSTREIDAE <i>Magallana bilineata</i> (Röding, 1798) | + | + | + |
| 57 | <i>Saccostrea cucullata</i> (Born, 1778) | + | + | + |
| 58 | FAMILY: ANOMIIDAE <i>Anomia</i> sp. | - | - | + |
| 59 | FAMILY: LUCINIDAE <i>Euanodontia ovum</i> (Reeve, 1850) | - | - | + |
| 60 | <i>Rugalucina vietnamica</i> (Zorina, 1978) | - | - | + |
| 61 | FAMILY: UNGULINIDAE <i>Felaniella cuneata</i> (Spengler, 1798) | - | - | + |
| 62 | <i>Diplodonta</i> sp. | - | - | + |
| 63 | FAMILY: CARDIIDAE <i>Vepricardium coronatum</i> (Schröter, 1786) | - | - | + |
| 64 | FAMILY: CYRENIDAE <i>Villorita cyprinoides</i> (Gray, 1825) | + | + | - |
| 65 | FAMILY: PSAMMOBIIDAE <i>Hiatula diphos</i> (Linnaeus, 1771) | - | - | + |
| 66 | <i>Gari elongata</i> (Lamarck, 1818) | - | - | + |
| 67 | FAMILY: TELLINIDAE <i>Alaona ala</i> (Hanley, 1845) | - | + | + |

| Sl.No | Classification/Name of species | Salinity Zones | | |
|-------|---|-----------------|----------------|-------------|
| | | Freshwater Zone | Estuarine Zone | Saline Zone |
| 68 | <i>Jitlada philippinarum</i> (Hanley, 1844) | - | - | + |
| 69 | <i>Nitidotellina unifasciata</i> (G. B. Sowerby II, 1867) | - | - | + |
| 70 | <i>Serratina siamensis</i> (E. von Martens, 1860) | - | + | + |
| 71 | FAMILY: MACTRIDAE <i>Standella pellucida</i> (Gmelin, 1791) | - | + | + |
| 72 | FAMILY: VENERIDAE <i>Anomalodiscus squamosus</i> (Linnaeus, 1758) | - | + | + |
| 73 | <i>Dosinia labiosa</i> Römer, 1862 | - | - | + |
| 74 | <i>Marcia opima</i> (Gmelin, 1791) | - | - | + |
| 75 | <i>Marcia recens</i> (Holten, 1802) | - | + | + |
| 76 | <i>Meretrix aurora</i> (Hornell, 1917) | - | - | + |
| 77 | <i>Meretrix casta</i> (Gmelin, 1791) | - | - | + |
| 78 | <i>Timoclea cochinchinensis</i> (G. B. Sowerby II, 1853) | - | - | + |
| 79 | FAMILY: PHOLADIDAE <i>Martesia nairi</i> (Turner & Santhakumaran, 1989) | + | + | + |
| 80 | CLASS: CEPHALOPODA FAMILY: SEPIOLIDAE <i>Euprymna berryi</i> Sasaki, 1929 | - | - | + |
| 81 | FAMILY: SEPIIDAE <i>Sepiella inermis</i> (Van Hasselt, 1835) | - | - | + |
| 82 | FAMILY: LOLIGINIDAE <i>Uroteuthis (Photololigo) duvaucelii</i> (d'Orbigny, 1835) | - | - | + |
| 83 | <i>Uroteuthis (Photololigo) singhalensis</i> (Ortmann, 1891) | - | - | + |

Table 2: α diversity indices of the three salinity zones.

| Biodiversity Indices | Freshwater zone | Estuarine zone | Saline zone |
|-------------------------|-----------------|----------------|-------------|
| Shannon- Weiner Index | 2.083 | 2.58 | 3.221 |
| Margalef Richness Index | 1.705 | 3.095 | 5.732 |
| Simpson Dominance Index | 0.86 | 0.895 | 0.945 |
| Pielou's Evenness Index | 0.729 | 0.628 | 0.596 |

Table 3: β diversity of the molluscan species between the three salinity zones.

| Whittaker beta diversity index | | | |
|--------------------------------|-----------------|----------------|-------------|
| | Freshwater zone | Estuarine zone | Saline zone |
| Freshwater zone | 0 | | |
| Estuarine zone | 0.375 | 0 | |
| Saline zone | 0.660 | 0.365 | 0 |

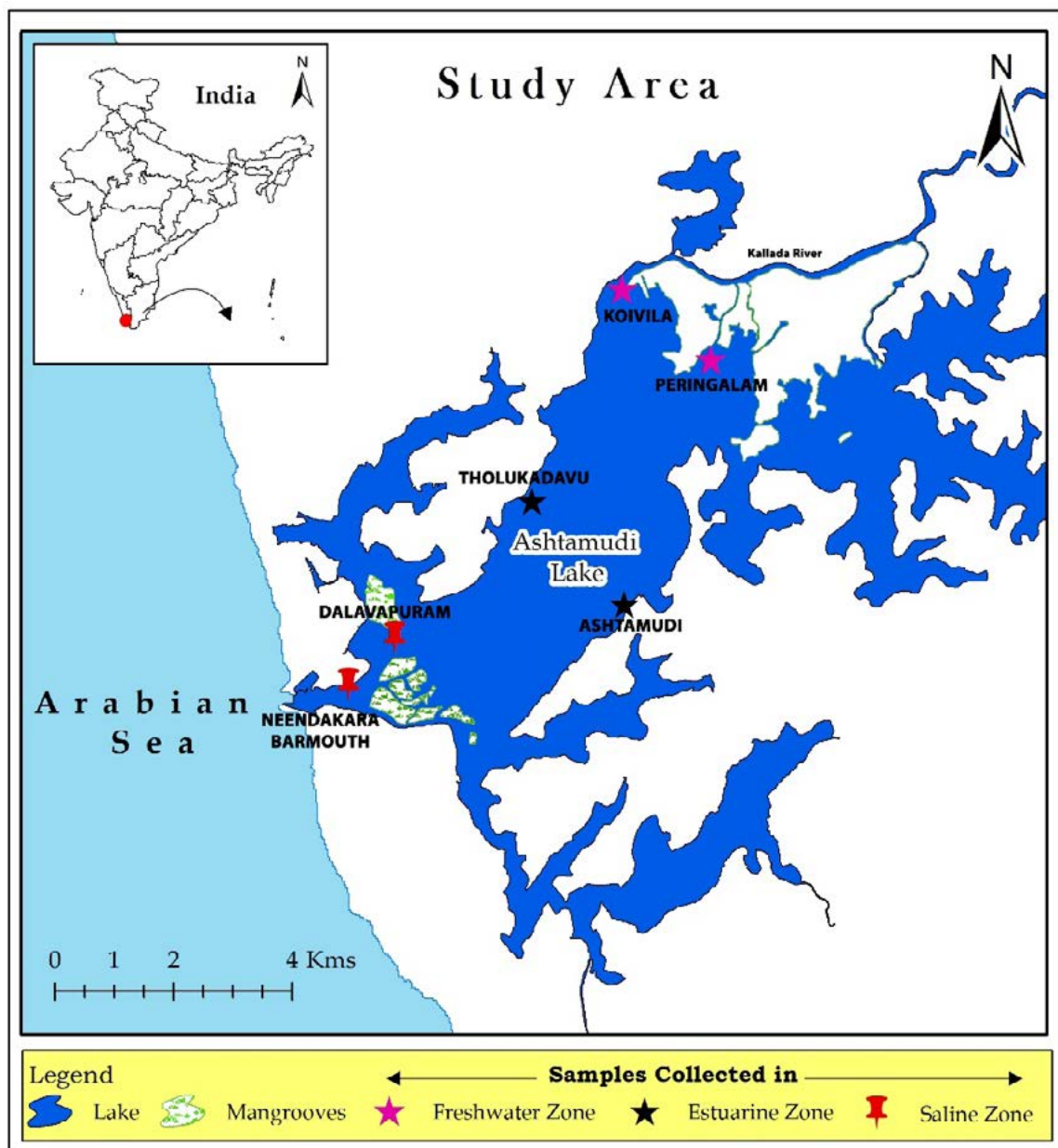


Figure 1: Map of Ashtamudi Lake showing the study sites.

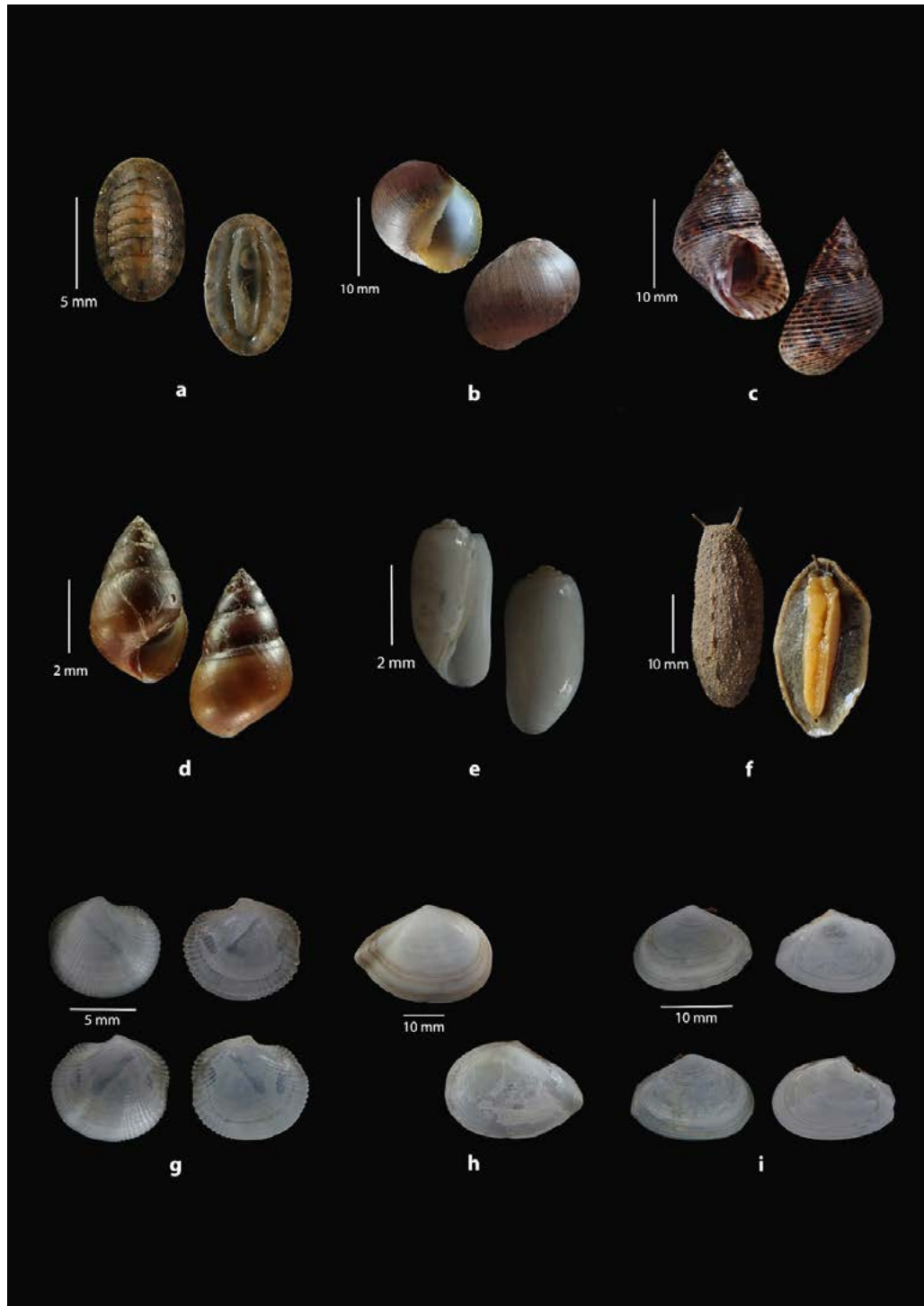


Figure 2: **a** *Chiton granoradiatus* Leloup, 1937; **b** *Clithon sowerbianum* (Récluz, 1843); **c** *Littoraria pallescens* (Philippi, 1846); **d** *Assiminea woodmasoniana* G. Nevill, 1880; **e** *Acteocina decorata* (Pilsbry, 1904); **f** *Platevindex martensi* (Plate, 1893); **g** *Rugalucina vietnamica* (Zorina, 1978); **h** *Alaona ala* (Hanley, 1845); **i** *Serratina siamensis* (Martens, 1860) (Photographs by: Chinnu Vishwanathan).

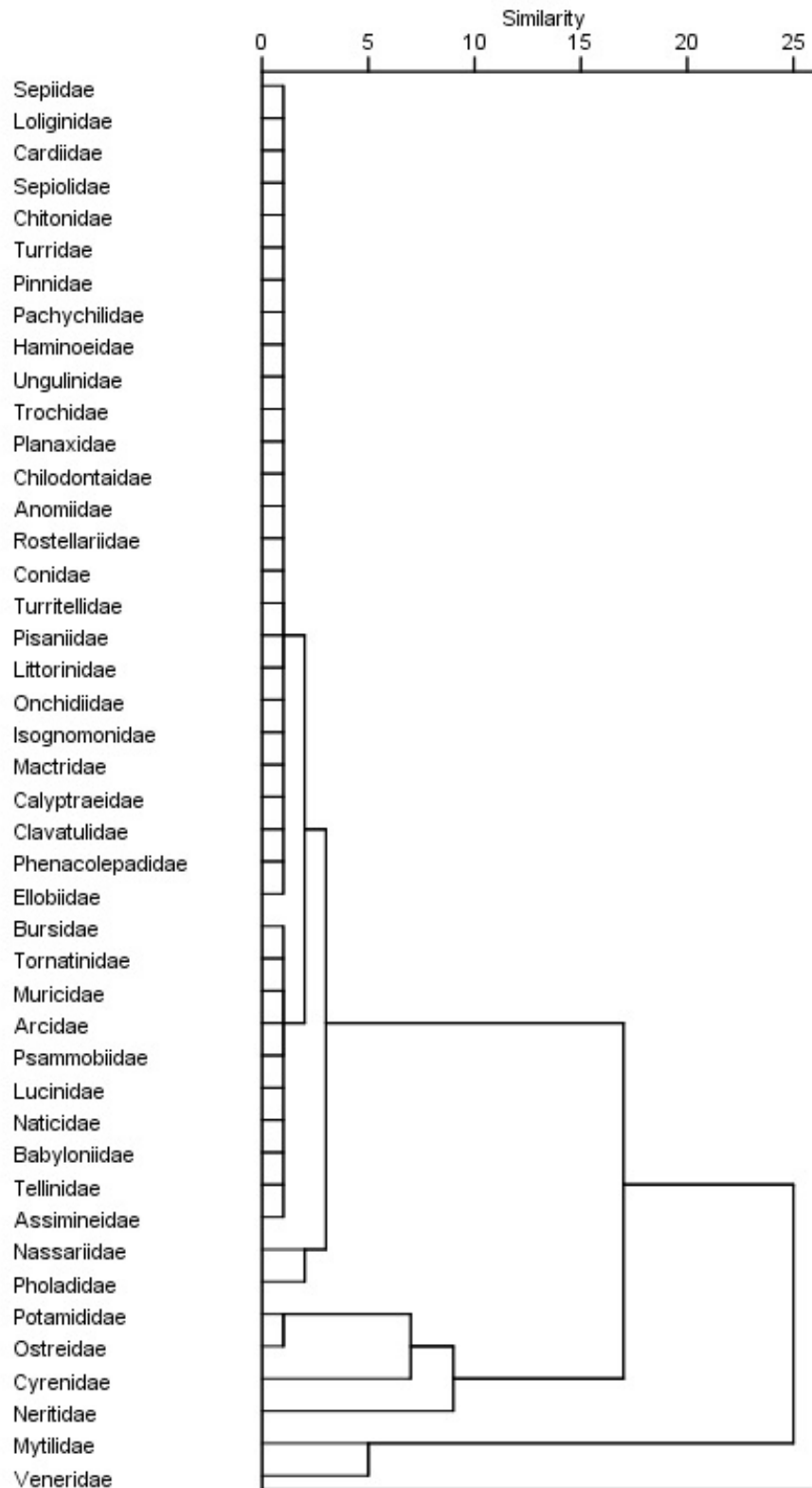


Figure 3: Dendrogram of hierarchical clustering (group average linkage) of the molluscan families in Ashtamudi Lake.

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