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Molluscan Shell Dissolution from the Poovar Region, Arabian Sea Coast, India: Implications on Environmental Health

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ABSTRACT

Dissolution of the molluscan shells from Poovar estuary, implying the environmental health is the foci of the present study. Twelve samples were collected from the study area, eleven were grab samples and the core sample was retrieved from the sporadic mangrove area. The predominant mangrove species in the Poovar region is *Avicennia marina.* The primary objective of the study was to ascertain the behavioural changes of molluscan shell with respect to the shifts in the sediment texture and nature. The examination of the grab sample focuses on the energy conditions that existed in the during the time of deposition. The sediments from the Poovar mangrove, Poovar lake, Poovar estuary, and Neyyar river display both individual and collective environmental characteristics. Within the phylum Mollusca, four major genera were examined: *Villorita, Crassostrea, Ostrea* and *Tibia.* The distribution of microfossils is limited, except for a single broken specimens of *Ammonia dentata,* which is of ex-situ origin and transported to the mangrove environment from marine waters. In Poovar region the mangroves mainly disappearing due to human activity, which is aided by fluctuations in energy condition of deposition and sea level variations. The minimal microfossil numbers are associated with the high dynamicity of the area and the molluscan shell dissolution was related to anthropogenic impact of tourism, fuel discharge urbanization in upper stream banks and with the coastal changes. Along with anthropogenic distubances, the dissolution in molluscan shells is accelerated due to the excessive organic matter accumulation in the stream bed from the land vegetation. The excessive inputs of floral debris of terrestrial origin is having an impact on the shift in the environmental parameters (pH, salinity, temperature, oxygen availabilty and $CaCO_3$ concentration) in the region.

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1. INTRODUCTION

Mollusca especially bivalves are the most important group of aquatic life, offer incredible ecological services, stabilizing the shoreline, providing habitat, aiding in the nitrogen and carbon cycles, and filter-feeding to purify the water (Catherine et al., 2024). Having a long life and benthic nature, molluscans are highly useful in integrating pollution impact at specific locations over extended time periods (Gregory et al., 1999). Dissolution in molluscan shell is of prime importance as the intensity is maximum on the outer shell surface and inherently different in their time course of shell deterioration (Eric et al., 2008). Numerous factors influence the dissolution of molluscan shells, the most important of them are the physico-chemical parameters of water and the energy condition of sediment deposition. Organisms exhibit morphological and anatomic fluctuations to granulometric changes, attributed to the energy condition of deposition. The morphology and behavioural traits of microfossils are controlled by temperature, pH, CO_2 and calcium carbonate saturation (Portner, 2008). The changes in the depositional pattern eventually act on the faunal forms thriving in the area.

Estuarine system is dynamic and possess environmental complexity. Mixing of fluvial and marine waters under the influence of wave, tide and river energy is a distinguished characteristic of an estuary (Murray et al., 2012). Poovar estuary maintains this dynamicity and an important tourist location in Thiruvananthapuram district and characterized by numerous floral forms. The uptake and translocation of the elements are observed in flora with respect to elemental concentration in the surrounding (Prasannakumari et al., 2014). As like flora, the faunal shells also imbibe the elements during their growth stages. A comparison and understanding of the elemental composition of both flora and fauna will give a much-clarified environmental analysis of the region. *Avicennia marina* is the dominant mangrove specimen in Poovar region. However, distribution pattern of fossil and microfossil assemblages in mangrove environment vary concerning to the regional factors and not dependent on the mangrove species (Hussain et al., 2022). The region between Karamana and Poovar river is characterized by poor surface water quality which is due to considerable influence of urbanization, when compared to the non-urbanized upstream locations (Krishnakumar et al., 2017).

From the Indian subcontinent, research on molluscan diversity and the relationship between changing environmental circumstances and climate change is still in its infancy (Catherine et al., 2024). The present work is intended to bring the changes happening in a molluscan shell and the microfaunal distribution from Poovar and nearby coastal zone. Surprisingly, not many studies have been done on the shell dissolution of mollusca from the region. The work report the rapid dissolution of molluscan shell and provide a database and to nullify the research gap identified. Already different studies highlighting the impacts of urbanisation and anthropogenic activities in Poovar is studied by different authors. However, the characteristics and record of molluscan shells are least reported.

1.1. Poovar (Area of Study)

Poovar estuary is located at the southern tip of Thiruvananthapuram and marks the confluence of Arabian sea, Poovar lake and Neyyar river. The basin area of Neyyar is attributed to a number of dynamic, interrelated physical, social and economic factors (Suresh Babu and Thrivikramaji, 1993). The river sheds are having steep slope along with less vegetation cover contributes to high erosion and surface runoff (Dinagara et al., 2017). The region is highly turbid (18 NTU) and being located close to sea, the region has a higher concentration of TDS (445 mg/l) and sodium (68 mg/l) during post monsoon period (Sheeja et al., 2020). The coastal zones of Poovar region are severely affected by seawater intrusion. Being a tourist destination and a major fishing spot in Kerala, the area also is impacted by anthropogenic activities. Contradicting the patchy distribution of mangroves, the molluscan distribution and productivity is high in the environment. The map of the study area is shown in Fig. 1.

2. MATERIALS AND METHODS

2.1. Field work

Sample sediments were retrieved through a field work conducted in the Poovar estuary, Karamana river and the adjacent coast. A core sample of length 78 cm and 11 grab samples were taken up for the study. Grabs samples were collected using Van veen grab from different depth zones (0.5 to 15 meters) of the water column. The grab was freely dropped

Fig. 1. Sampling locations from the study area.

into the water with the lock open, when it touches the bottom bed, the grab traps the sediments inside. Sample retrieved were dehydrated and transferred to tray and then to zip lock covers using spatula. Each time after the sample collection the grab sampler and the tray were cleaned. The core sample was manually collected using PVC pipes pressurised by hammering. The core was collected near to the mangrove vegetation at an approximate depth of 1.5 meters in the water column.

2.2. Lab protocols followed

Samples taken from the study area location were subsampled, analyzed and scientifically studied in the lab. The core sample collected were kept in a deep freezer at a temperature of -10^0C. Using electrical core cutter, the core sample is recovered and 16 subsampling was made at a core interval of 5 cm. The sub-samples were wet sieved using ASTM 230 mesh transferred to china dish and allowed to dry in hot oven at a temperature of 500°C. The dried samples were checked for microfossils (both foraminifera and ostracoda).

Sand mud ratio has been plotted using the conventional methodology followed by Krumbein and Pettijohn (1938). The conventional method allows to reuse the sediment samples even after carrying out the textural analysis. Sieve analysis retains the particle larger than 230ASTM and mud particles are washed away through the mesh. The sediments left in the mesh were collected in the beaker and dried to weight the sand percentage. Sediment characteristics are plotted to bring out the relationship of the biota and the sediment deposited within the environment. Variation in the grain size pattern to downcore are evident from the visual observation itself. Deeper understanding of the sediments apprises on the energy condition during the sediment deposition, palaeoclimate and palaeoenvironmental behaviours, sedimentation pattern, granulometric changes etc. Paleontological statistics (PAST) version 4.03 is the software used to prepare the matrix plot and cluster dendrogram.

2.3. Modern methodologies for molluscan studies

Molluscan shell studies are one of the highly researched topics across the globe in connection with animal studies. Literature survey highlights the pollution impacts, eutrophication status, sewage discharge, over productivity, water quality changes etc. (Anzamol and Sabu, 2022; Krishnakumar et al., 2017; Divya and Mary, 2016; Helen et al., 2008). Being abundant and the proper register of the environmental changes in the molluscan shell marks them as a highly useful proxy for vivid geological studies. Some of the recent studies pertaining to molluscan shell studies are listed in Table 1.

3. RESULTS AND DISCUSSIONS

3.1. Core analysis

Physical properties of sediments (colour, size and properties of grains, sand and mud percentage), to

Table 1. Recent studies on mollusca pertaining to the shell studies and pollution aspects.

Molluscan species	Location	Important Findings	Reference
Multiple species	Review	Mollusca can avail time-constrained, multi-proxy records of climate change in any aquatic environment with extraordinary temporal resolution, ranging from individual days to years.	Catherine et al. (2024)
Uinio tigridis Corbicula fluminea	Euphrates river, South of Iraq	Seasons and temperature shift has a great importance in pollution studies using molluscan shells	Qasim et al. (2022)
Terrestrial Gastropoda	Review	Pollutants can disturb physiological and behaviour of mollusca	El-Gendy et al. (2021)
Limnoperna fortunei *Corbicula fluminea* *Melanoides tuberculata* *Aylacostoma tenuilabris* *Pomacea* aff. *canaliculata*	Volta Grande Reservoir, Brazil	Concentration of banned pesticides are found in molluscan shells and traced the ecological risk in the Volta Grande Reservoir region.	Andressa et al. (2021)
Multiple species	Review	Evolvability of the mantle secretome provides a molecular explanation for the evolution and diversity of molluscan shells	Carmel and Bernard (2018)
Planorbella pilsbryi	Fresh water habitats of North America	Reconstructed a phylogeny using gene sequencing. Evolutionary and ecological analysis of the species	Emma et al. (2021)
Tellinides timorensis and *Vepricardium coronatum*	Sonadia Island, Bangladesh	Bivalves and gastropods are being enormously collected and shells used for different purposes causing negative impact on the population	Parsha et al. (2021)
Meiofauna mollusca	Caspian Sea	Density of mollusca varying significantly with depth and season	Zarghami (2021)
Macrobenthic mollusca	Eastern Antarctic peninsula	Region undergoing colonisation following the recent ice shelf collapse	Madeline et al. (2021)
Multiple species	Review	Quality of the surrounding environment can be determined by the metal concentrations in molluscan shells.	Gupta and Singh (2011)
Multiple species	Gulf of Mexico and Bahamas	The subset of conclusions that may be reliably drawn from brief deployment periods is limited by the slow taphonomic process and nonlinearity in rates with time.	Eric et al. (2008)
Buccinum undatum	Breidafjordur, Iceland	Imposex in the species is biological indicator of (Tributyltin) TBT pollution in marine environment	Svarsson et al. (2001)
Perna perna	Lab analysis	*P. perna* is similar to other bivalves in that it accumulates mercury in its soft tissues	Gregory et al. (1999)

TOP CORE

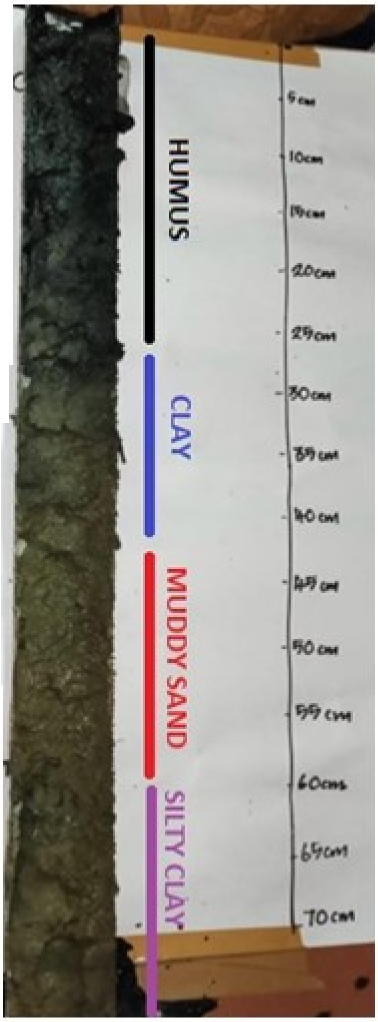

Fig.2a

BOTTOM CORE

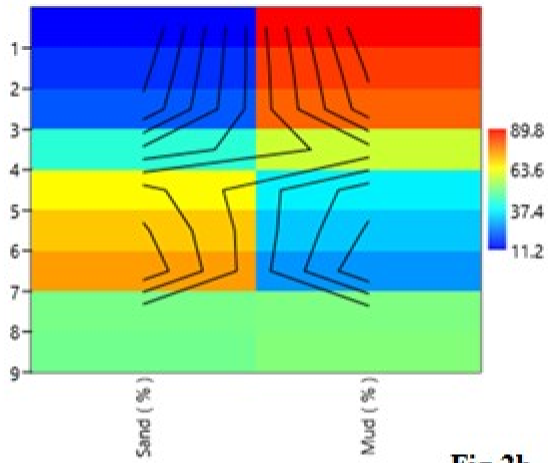

Fig.2b

Fig. 2. **a** - Cross section of the core sample exhibiting the downcore textural variation and **b** - Matrix plot prepared by PAST software exhibiting the downcore variation of sand and mud.

downcore are analyzed. Colour is mainly identified from visual observation of the molluscan shell, size is marked through scaling, grain size characteristics are studied under stereozoom microscope. Sand and mud percentage was estimated using settling tube method proposed by Krumbein and Pettijohn (1938). Core sample from Poovar have a length of 78 cm, which can be differentiated to horizons of humus, clay, muddy sand, silt clay. Variation in grain texture downcore, explain the shifts in the energy condition of deposition. Top portion (up to 27cm) of core sample contain dark coloured humus (Fig. 2**a**). Humus formation is attributed to the terrestrial and aquatic organic matter derived from plant materials. Channelising the sewage and resort wastes to the water body are also a reason for the very thick humus layer. Granulometric study indicates that fine clay is dominant texture below humus to the downcore. Grey colored mud with a significant sand amount (muddy sand) is observed after fine clay to downcore. At the core to a depth of 60 cm texture changes to brownish grey colored silty clay which implies on the low energy condition of deposition of the region.

The sand percentage in the all the subsamples of core ranges from 11.21 to 73.62. The lowest values for sand are located in the core subsample 1 and highest values in subsample 7. Mud value is maximum in core subsample 1 and least in 7. The sample values observed indicates a change in the energy condition of the area. Matrix plot (Fig. 2**b**) elucidates the variation occurring in the sediment texture to the downcore. Table 2 displays the exact values for sand and mud percentage from the Poovar region.

To the downcore initially the sand percentage increases steadily up to subsample 7 (60 cm) and sand percentage decreases thereafter (Fig. 3**a**). This is an

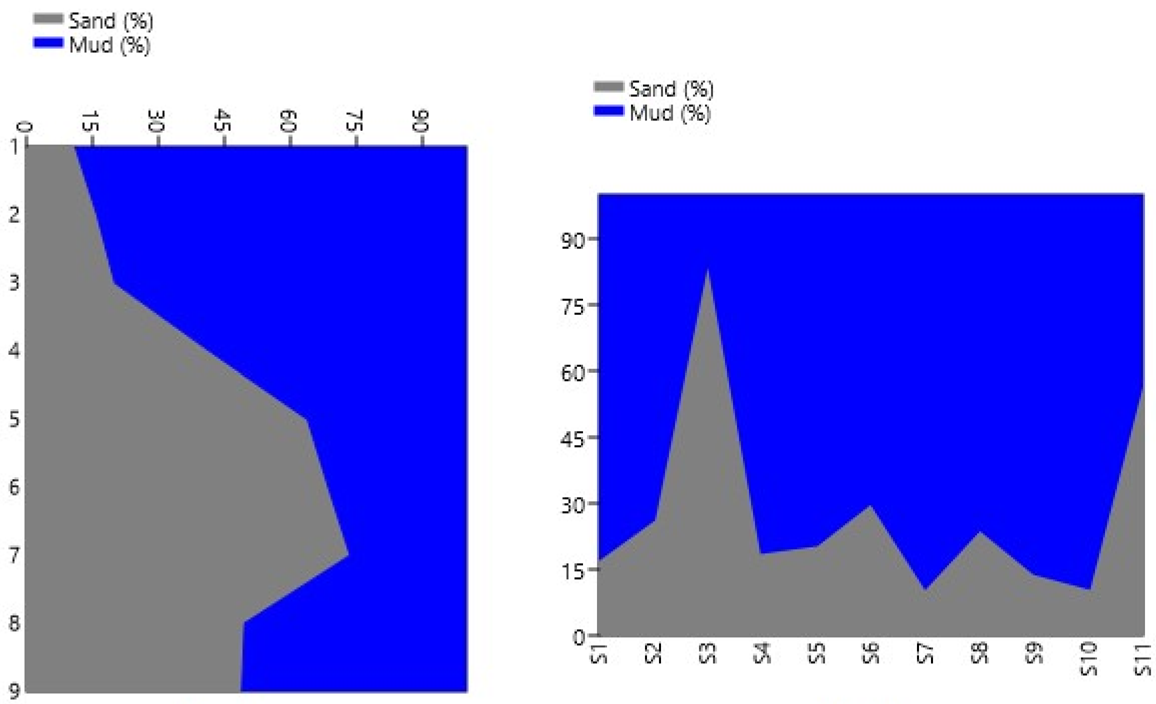

Fig. 3a **Fig.3b**

Fig. 3. **a** - Downcore area graph of mud with respect to sand percentage. **b** - Vertical distribution of mud and sand from the area of study.

Table 2. Downcore values of sand and mud percentage from core samples collected near mangroves with respect to the subsamples.

Core subsample	Depth in cm	Sand (%)	Mud (%)
1	1–8	11.21	89.79
2	9–17	16.07	83.93
3	18–26	20.12	79.88
4	27–35	41.62	58.38
5	36–44	63.94	36.06
6	45–53	69.35	31.65
7	54–62	73.62	26.38
8	63–71	49.61	50.38
9	71–78	48.98	51.01

indicative of shifting energy condition of deposition. Downcore have a comparatively low energy condition with respect to the top core sediments. Tidal influence on the mangrove area is high as the location is near to estuarine proximity. The core sample was taken near the mangrove vegetation and does not yield any Foraminifera and Ostracoda. High turbulence and bioturbation in a region normally restricts the growth of the calcareous microfossils. The mangrove distribution in Poovar is patchy and its environmental set up is disturbed by tourism activities and boat services. However, one broken form of foraminifera (*Ammonia dentata*) species is identified from the sediments adjacent to sea shore. No molluscan shells are recovered from the core collected from the mangrove environment. The thick muddy substrate with over enriched elements and pollutants influences on the normal population growth and ecological balance of the region.

3.2. Grab Analysis

Eleven grab samples were collected, studied and analysed (Table 3). Heavy dark deposit of clay and humus were observed in the Poovar lake region. The samples from Neyyar lake have sand as the dominant sediment texture (Fig. 3**b**). The sediment deposition adjacent to the beach and coast of the Poovar lake exhibit fine grained sand. The maximum values of sand are observed in S3 (14.2%), which was taken near the coast and minimum value is observed for S10 (85.8%). The mud value is fluctuating between 14.2% (S3) and 89.1% (S10) in the region. Higher sand grains in an area indicates higher energy condition. Higher mud percentage indicates medium to lower energy condition. The region is dynamic as the environment is influenced by multiple factors like sea level fluctuation, seasonal climate changes, tidal action and high organic productivity.

Table 3. Vertical distribution of sand and mud in percentage from the sampling locations.

Grab sample	Sand (%)	Mud (%)
S1	17.5	82.5
S2	26.4	73.6
S3	85.8	14.2
S4	19	81
S5	20.7	79.3
S6	30.3	69.7
S7	11	89
S8	24.3	75.7
S9	14.2	85.8
S10	10.9	89.1
S11	58. 3	41.7

3.3. Cluster Analysis

Classical clustering has been done for the grab samples from Poovar environment. The environment is significantly influenced by Neyyar river and Poovar lake, along with the shore line changes and tidal activities in adjacent Arabian sea. Dendrogram has been plotted using the software PAST (Paleontological Statistics) to classify the sediments based on depositional characteristics. Two biotypes are identified from the dendrogram (Fig. 4) for the location, based on granulometric studies; Biotype 1 and Biotype 2. Biotope 1 include samples S1, S2, S4, S5, S6, S7, S8, S9 and S10. Biotope 2 includes samples S3 and S11. Biotype 1 are subdivided into to three sub biotopes to understand the molluscan variation with respect to the sedimentation. Molluscan forms recovered from S3 and S11 are not showing much shell dissolution. The biotope 2 is having a direct influence of river Neyyar and in higher energy condition. Only variation in the sediment texture was observed from the environment (where sample was collected) except for sample S3 (near to sea) and S11 (exactly in Neyyar river near to sea).

3.4. Taxonomy of Dominant Molluscan Forms

Van veen grab was used to collect samples from different depths ranging from 0.5 metres to 15 metres. All shells recovered from the area were taxonomically grouped under phylum Mollusca. The grab samples were studied and randomly checked for molluscan shells, but thoroughly observed for microfaunal forms. Taxonomic chart of the dominant forms of molluscan species from the area is prepared (Table 4).

The shells which are found in the shallow environments (less than 5 cm water depth) show less dissolution, however the deeper counter parts show higher rate of dissolution. Predominantly the crumbled shells are present in black humus and carbonaceous clay. The important group of marine life found in the lake bottom are Black clam, *Ostrea, Tibia,* Pacific oyster etc. Four genera are dominant in the confluence *Villorita cyprinoides*, *Crassostrea* sp., *Ostrea* sp., *Tibia* sp. The shell dissolution in the molluscan shells made them unable to identify to the specific level.

3.5. Environmental Health of the Region

Benthic ecosystems from the coastal region fluctuates with the alterations in physico-chemical factors of the water column (Lathika et al., 2020). The water quality parameters (pH), electrical conductivity, Total Dissolved Solids, sulphate and Biological Oxygen Demand are fluctuating in Poovar due to high anthropogenic disturbances, which is due to the effect of upstream pollution and sea water influence (Badusha and Santhosh, 2018). Booming urbanization near Neyyar affects its physical process and further changes the natural vegetation into various land use patterns (Dinagara et al., 2017). Many studies suggested that in whole Neyyar river system, Poovar is the most polluted region. Shell dissolution is linked with anthropogenic and natural activities. The shell dissolution also is an indicative of over production and excess decalcification. Except for the black clam (*Villorita cyprinoides*) (Fig. 5**j**) from Neyyar river and *Tibia* (Fig. 5**i**) all other dominant molluscan shells identified from the mouth of Poovar region are exhibiting intense shell dissolution (Fig. 5**a**–**h**).

A high percentage of organic matter accumulation was observed from Poovar region. This can be attribute to the velocity changes of Neyyar river along with the plant and animal material decay. River Neyyar flow with a comparatively higher velocity and when it reaches Poovar it gets divided into two: first zone with higher velocity and another lower velocity zone. Some locations which are falling in the lower velocity zone are deeply disturbed by excavation and sand mining activities before a decade and was filled with thick humus in the upper layer of the stream bed. The lower velocity region is exhibiting maximum molluscan shell dissolution. An enhanced sodium concentration in downstream portion of the Neyyar river attributed to anthropogenic activities (Sheeja et al., 2011). Close proximity of the location to the sea is also a factor which controls the distribution of sodium in the estuary. The urbanized region,

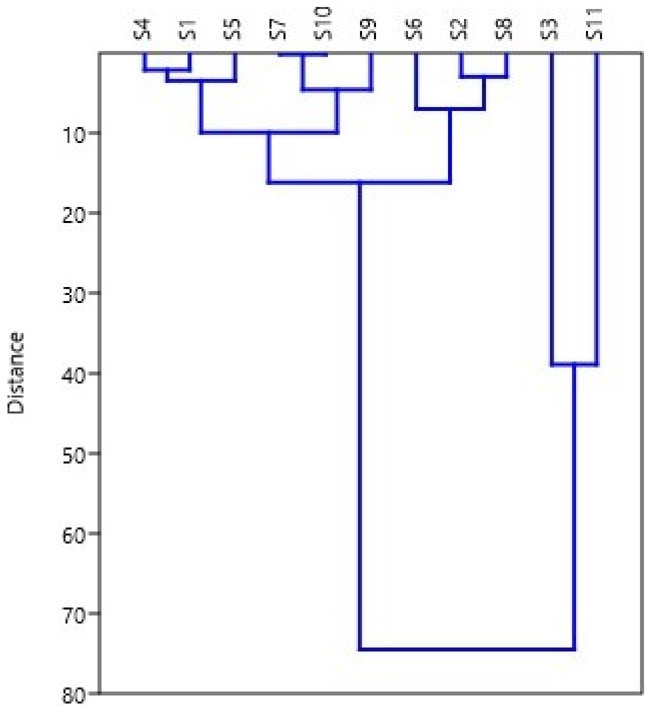

Fig. 4. Dendrogram exhibiting different biotopes and environmental regimes.

Table 4. Taxonomic chart of the abundant Molluscan from the study area.

Kingdom	Phylum	Class	Family	Genus	species
ANIMALIA	**MOLLUSCA**	**Bivalavia**	**Cyrenidae**	***Villorita***	***cyprinoides***
			Ostreidae	***Crassostrea***	**sp.**
				Ostrea	**sp.**
		Gastropoda	**Rostellariidae**	***Tibia***	**sp.**

in the upstream, use the drainage to pour the sewage and industrial wastes. The ecosystem in Neyyar is influenced by indiscriminate mining and quarrying activity (Shobha and Krishnakumar, 2003). Around 25 clay mines are present in the vicinity of Neyyar river. This is quite a huge number and the wastes from this mines eventually reaches Poovar region. The shift in the water parameters (Na-Cl-HCO_3 to Na-Ca-Cl-HCO_3) can be attributed to anthropogenic pollution (Sheeja et al., 2020). This shift eventually reaches the Poovar region. The water environment near Poovar region is unhealthy, so as the ecosystem. The molluscan shells are impacted and getting deteriorated because of the combined impact of all these factors. Hence attention is to be paid to take the control measures to prevent the pollution in this stretch of the river.

4. CONCLUSION

Four genara (*Villorita, Crassostrea, Ostrea* and *Tibia*) of mollusca are dominantly observed in the Poovar river and its mouth. The shells of molluscan genera *Crassostrea* and *Ostrea* are subjected to maximum dissolution and *Tibia* and *Villorita cyprinoides* is having minimum shell dissolution. Shell deterioration and the entire absence of insitu microfauna (Foraminifera and Ostracoda) is not only attributed to the higher anthropogenic activity, but also due to the fluctuations in physicochemical variations (pH, TDS, Salinity, Elemental Concentration etc.) and marine influence. An absence of insitu microfossils are observed, except for a single specimen of broken *Ammonia dentata*, which is a strong marker of environmental health of the region.

The molluscan population in the region is badly hit by the human activities. Pollution from local tourist homes, boat fuel waste discharge, effluents from upstream, high humus deposits (attributed to terrestrial vegitation mostly), landfilling, clay mining near upstream areas, household sewage of waste water, seawater inundation, husk retting and decaying are the multiple reasons in the environmental fluctuations in the Poovar region. Along with the mangroves, the species thriving on mangrove environment is getting endangered in the region. What we are

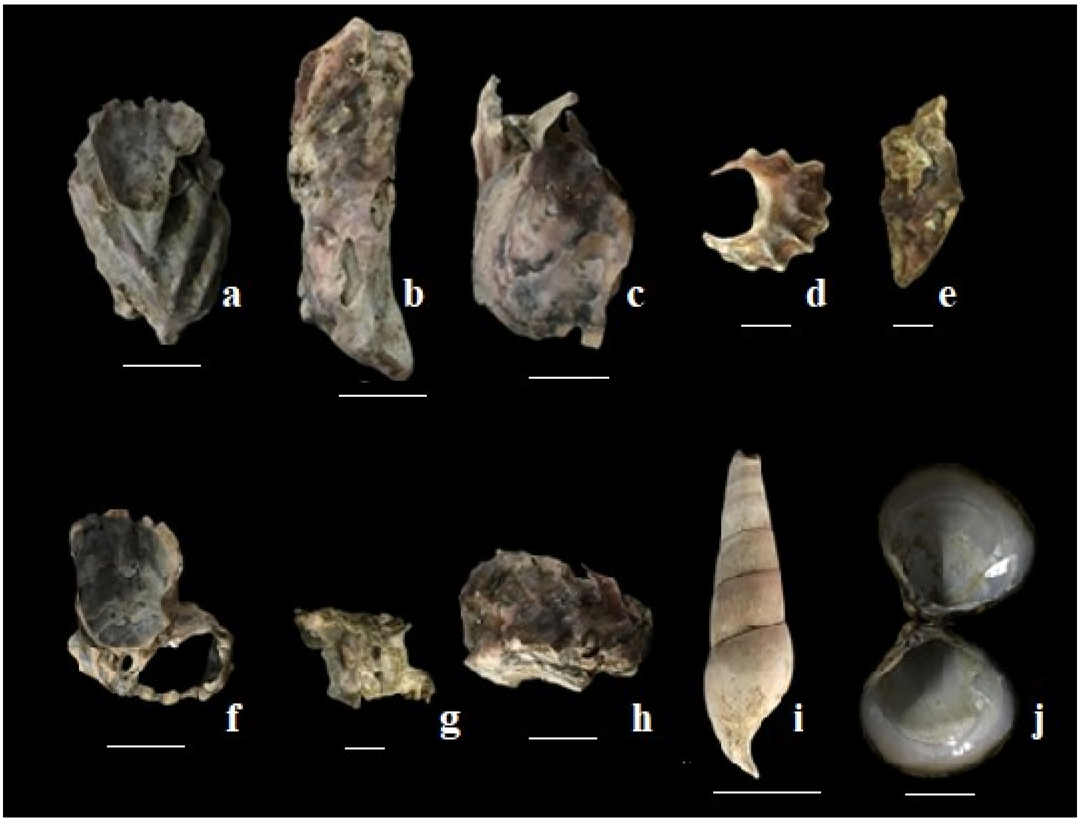

Fig. 5. **a**–**h** - Shell dissolution in *Ostrea sp.*, **i** - *Tibia* sp. resistant to dissolution, **j** - *Villorita cyprinoides.*

trying to explain is the silent destruction of natural habitat of molluscan forms and the report of absence of microfauna in the region. The study calls for the need of the implementation of much-needed sustainable development model as the anthropogenic activities are catastrophically hitting the environmental health of the region. Sustainable development model is to be implemented and the environmental health should be frequently monitored to restore the environmental fertility of the region.

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