Diversity And Distribution Of Molluscan Fauna From The Coastal And Mangrove Ecosystems Of Kakinada, Andhra Pradesh

Gubbala Rama Devi[1], *Alavala Matta Reddy[2], P. Vijaya Nirmala[3]

[1]Research Scholar School of Life and Health Sciences, Adikavi Nannaya University, Rajamahendravaram
ramadevibio@gmail.com
[*2]Associate Professor School of Life and Health Sciences, Adikavi Nannaya University, Rajamahendravaram
alavalareddy@hotmail.com
[3]Associate Professor School of Life and Health Sciences, Adikavi Nannaya University Rajamahendravaram
vijayanirmala.p@aknu.edu.in

***Corresponding Author:** Dr . Alavala Matta Reddy
*alavalareddy@hotmail.com

ABSTRACT:
In the present study conducted along the Kakinada coast and its associated mangrove regions from 2013 to 2014, a total of 185 molluscan species were identified. These species were classified into three major classes: Gastropoda, Bivalvia, and Cephalopoda, which were further subdivided into 7 subclasses, 24 orders, and 69 families. Among these, the class Gastropoda exhibited the highest species richness, comprising 112 species distributed across 5 subclasses, 11 orders, and 46 families. The families Cerithidae, Nassaridae, Trochidae, Turitellidae, and Turridae were particularly dominant among the gastropods. Following closely, the class Bivalvia contained 66 species categorized into 1 subclass, 11 orders, and 21 families, with families such as Arcidae, Veneridae, Donacidae, and Pectinidae being especially prominent. The class Cephalopoda was represented by 7 species across 1 subclass, 2 orders, and 2 families in the study locations. Several bivalve and gastropod species, including *Tegillarca granosa, Placuna placenta, Meretrix meretrix, Magallana bilineata, Meretrix casta, Perna viridis, Pirenella cingulata, Telescopium telescopium, Umbonium vestiarium, Volegalea cochlidium, Turritella duplicata, Murex trapa,* and *Tonna dolium* form a dominant fishery and possess considerable commercial value. These species are crucial to local economies, supporting both the fishing industry and various related sectors. Their significance extends beyond mere economic value, as they also play vital roles in the marine ecosystem, contributing to biodiversity and ecological balance.

Keywords: Molluscan diversity, Mangroves, Kakinada Coast

Introduction:

Biodiversity is a fundamental component in the preservation of ecological equilibrium, significantly enhancing the adaptive capacity of ecosystems while providing a wide array of essential ecological services vital for human well-being. Coastal regions and mangroves, in particular, are recognized as biodiversity hotspots, harbouring a rich variety of flora and fauna that are crucial for maintaining ecological balance and sustaining the socio-economic livelihoods of local communities (Oguh et al., 2021; Wang & Gu, 2021). Mangroves hold significant environmental and economic value, contributing to a wealth of genetic diversity. Organisms in mangrove ecosystems have evolved unique adaptations that enable them to thrive in this specific environment. These ecosystems not only contribute to biodiversity but also offer essential resources and benefits, enhancing the livelihoods of those who depend on them. (Spalding et al., 1997; Odum and Heald, 1972).

In the intricate web of energy transfer within mangrove ecosystems, invertebrates serve as crucial mediators, connecting initial detritus at the base of food chains to apex predators. Among these, molluscs are the significant fauna, having enormous influence on the ecological dynamics and functioning of mangrove communities. Their dominance emphasizes the pivotal role in shaping the structure and operations of these crucial ecosystems (Printrakoon et al., 2008).

Molluscs, a diverse phylum within the animal kingdom, exhibit a remarkable variety of forms and adaptations, making them one of the most diverse groups of organisms on Earth. They comprise a total of seven classes, with the most prominent being Gastropoda (snails and slugs), Bivalvia (clams, mussels, and oysters), and Cephalopoda (squids and octopuses). These major classes are distinguished by unique characteristics and ecological roles. Gastropods are known for their spiraled shells and varied feeding behaviors, bivalves for their two-part shells and filter-feeding lifestyle, and cephalopods for their intelligence, mobility, and predatory nature. The estimated count of valid species stands at approximately 50,000 to 55,000 marine, 25,000 to 30,000 terrestrial, and 6,000 to 7,000 freshwater species (MolluscaBase, 2024). In India, a total of 5,070 molluscan species have been documented, of which 3,271 species are found in marine environments. The marine molluscs of India represent 220 families and 591 genera. Specifically, these include 1,900 gastropods, 1,100 bivalves, 210 cephalopods, 41 polyplacophores, and 20 scaphopods. (Venkatraman and Venkataraman, 2012). Molluscs found in a wide range of habitats, including oceans, freshwater bodies, and terrestrial environments and their distribution spans from Polar Regions to tropical ecosystems, showcasing their adaptability to diverse environmental conditions (Ruppert, et al., 2004). The taxonomy of molluscs includes a vast array of species, each with unique morphological and ecological characteristics (Bouchet & Rocroi, 2005). Understanding the taxonomic diversity of molluscs involves exploring into the intricate relationships among these diverse groups, focuses on their evolutionary histories and adaptive strategies.

Despite numerous studies on mollusc species (Narasimham, 1973; 1980; 1987; 2004; Murthy et al., 1979; Radhakrishna & Ganapati, 1967; Radhakrishna & Janakiram, 1975; Laxmilatha, 2015; Ramakrishna et al., 2007; Raut et al., 2005), there remains a significant gap in scientific research focusing on mollusc diversity within Kakinada Bay and its associated mangrove regions. To address this gap, the present study was initiated with the primary objective of providing baseline data on the distribution and abundance of mollusc fauna. This information will serve as a foundational resource for developing future conservation strategies.

MATERIALS AND METHODS:

Study Area:

The current study on the diversity and distribution of mollusc fauna in the Kakinada Bay and Godavari mangroves was conducted within the surrounding areas, covering both riverine and estuarine regions. The Godavari River, India's second-longest river spanning about 1,465 kilometers begins near Nasik in the Western Ghats of Maharashtra. With over 12 major tributaries, it travels about 770 kilometers through Andhra Pradesh before merging into the Bay of Bengal near Kakinada, located in the East Godavari district, currently Kakinada District. In its lower reaches the river bifurcates into two significant distributaries at Dawaleswaram (near Rajahmundry), Vasista-Godavari to the west and Gautami-Godavari to the east. These branches, after flowing through a broad delta, ultimately merge into the sea. The Vasistha Godavari further divides at Gannavaram into two branches: the Vasistha Godavari to the west and the Vaintheyam Godavari to the east, both independently opening into the Bay of Bengal. The Gautami Godavari flows southeast and meets the Bay of Bengal at two distinct locations, south of Yanam, specifically in the villages of Kottapalem and Bhairavapalem. Two main distributaries of Gautami-Godavari, namely the Coringa originating at Yanam and the Gaderu at Bhairavapalem, discharge freshwater into Kakinada Bay on its southern side during the southwest monsoon period.

Sampling stations:

1. **Kakinada Bay:** 17°1′7.66 North latitude and 82°17′24.11 East longitude.

This sampling station is situated at the northern point of Kakinada Bay, where the influence of high-salinity waters from the Bay of Bengal is prominent due to prevailing coastal currents.

2. **Coringa River:** $16^0$54.335 N latitude, $82^0$15.304 E longitude.

The river emerges through Yanam as an important distributary of the Gautami Godavari. Over its course of 26 kilometers, it flows across expansive agricultural fields before converging into the Kakinada Bay. Most of the mangrove molluscs were collected from this creek and associated mangroves.

3. **Gaderu River:** 16° 51′ 03.59″ N latitude 82° 18′ 56.91″ E longitude

The Gaderu River, the other distributary of Goutami Godavari is a unique water body that connects to the sea at both its northern end, joining Kakinada Bay, and its southern end, merging with the Bay of Bengal.

4. **Bhairavapalem**: 16°44'35"N and 82°18'59"E.

Godavari River flows into the sea through two mouths, one near Bhairavapalem and the other near Kottapalem.

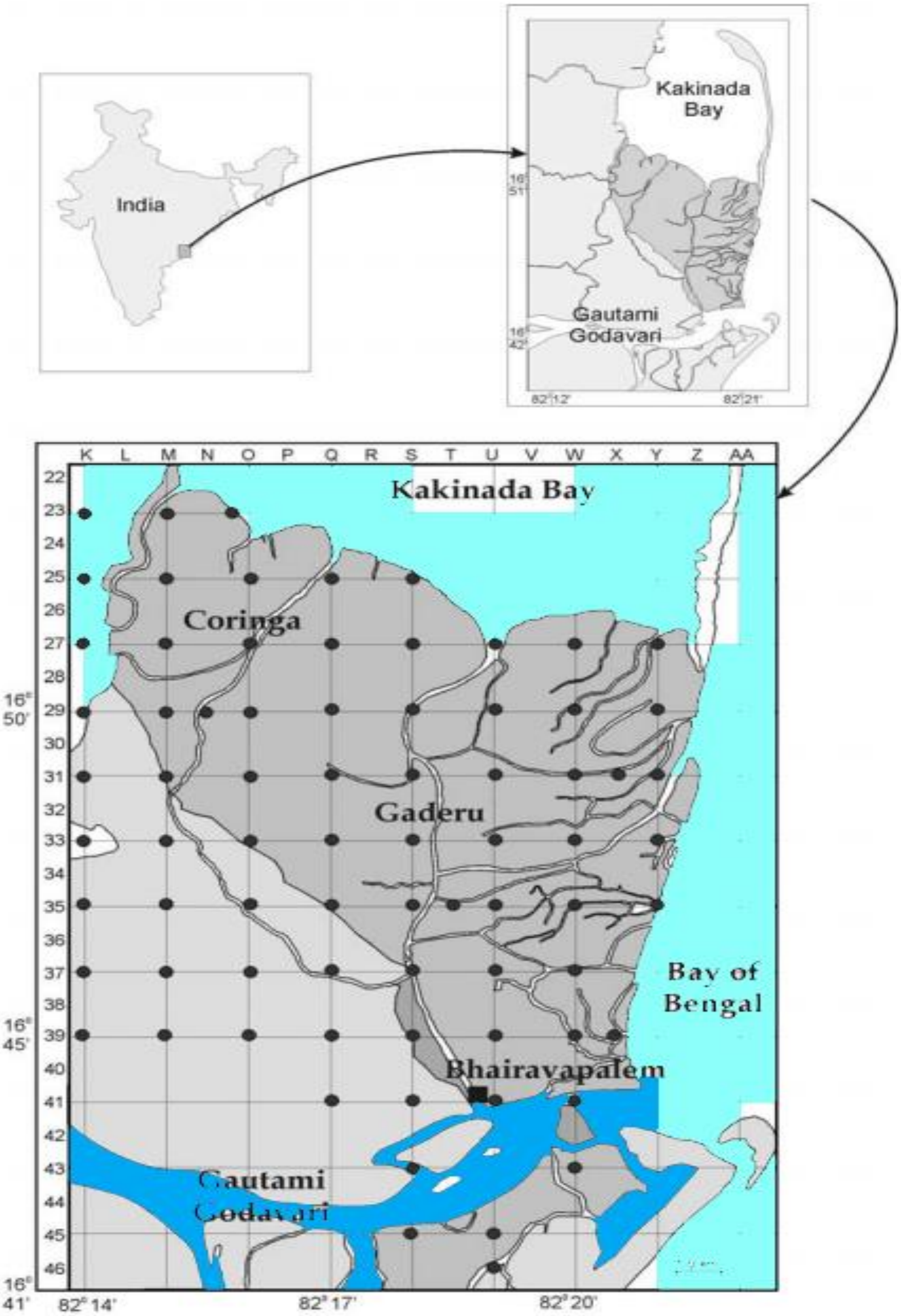


Figure: 1.Sampling stations of study area modified (Source: Satyanarayana et al., 2002)

The study sites were systematically surveyed on a monthly basis during low tides, employing various collection methods to ensure widespread sampling of mollusc fauna. Molluscs were primarily collected using the hand-picking method from intertidal zones and shallow coastal waters (Gosliner, 1996). Bivalves such as mussels and oysters were obtained by scraping with knives or spatulas. Infaunal bivalves were collected through hand-digging the substratum to access deeper layers of sediment. To diversify the sampling approach, some specimens were obtained as bycatch from local fishing boats operating in the vicinity of the study sites. Additionally, both bivalves and gastropods were collected from areas adjacent to shell collecting canals, utilizing scoop nets and dredges to capture specimens from the water column and sediment (Silva & Calheiros, 2004). Mollusc fauna specific to mangrove ecosystems were collected from mangrove trees and adjacent mudflat regions. Here, methods such as visual surveys and hand-netting were employed to capture both arboreal and ground-dwelling species. Following the collection of samples, all mollusc specimens were subjected to a thorough cleaning process to remove debris and external contaminants. They were then transferred to clean containers and stored in a temperature-controlled environment within the laboratory of the Coringa Wildlife Sanctuary. The identification process of molluscs involved meticulous examination of the specimens to identify the organisms up to species level. This was achieved by comparing them with reference specimens found in the mollusc identification guides of ZSI (Zoological Survey of India) (Subbarao, 2003) (Ramakrishna & Dey, 2010) and utilizing the digital identification resources available on the World Register of Marine Species (WoRMS). Species identification was conducted with reference to field guides, standard books, FAO (Food and Agriculture Organization) (FAO, 2002) identification keys, and various online databases such as 'Molluscabase'.

Results and Discussion:

In the present study conducted along the Kakinada coast and associated mangrove regions, a detailed survey identified a total of 185 molluscan species. These species represent 3 classes, encompassing 7 subclasses, 24 orders, and 69 families. The class Gastropoda demonstrated the highest species richness, comprising 112 species distributed across 5 subclasses, 11 orders and 46 families (Table: 1) in the study area. Dominant gastropod species were found within the families of Cerithidae, Nassaridae, Trochidae, Turitellidae, and Turridae. Bivalves were represented by 66 species, falling under 1 subclass, 11 orders, and 21 families in this region. Dominant bivalve species were from the families of Arcidae, Veneridae, Donacidae, and Pectinidae. Cephalopods were represented by 7 species, classified into 1 subclass, 2 orders, and 2 families in this study locations.

Table: 1. Total checklist of molluscan diversity in the study area

Class	Subclasses	Orders	Families	Species
Gastropoda	5	11	46	112
Bivalvia	1	11	21	66
Cephalopoda	1	2	2	7
Total	**7**	**24**	**69**	**185**

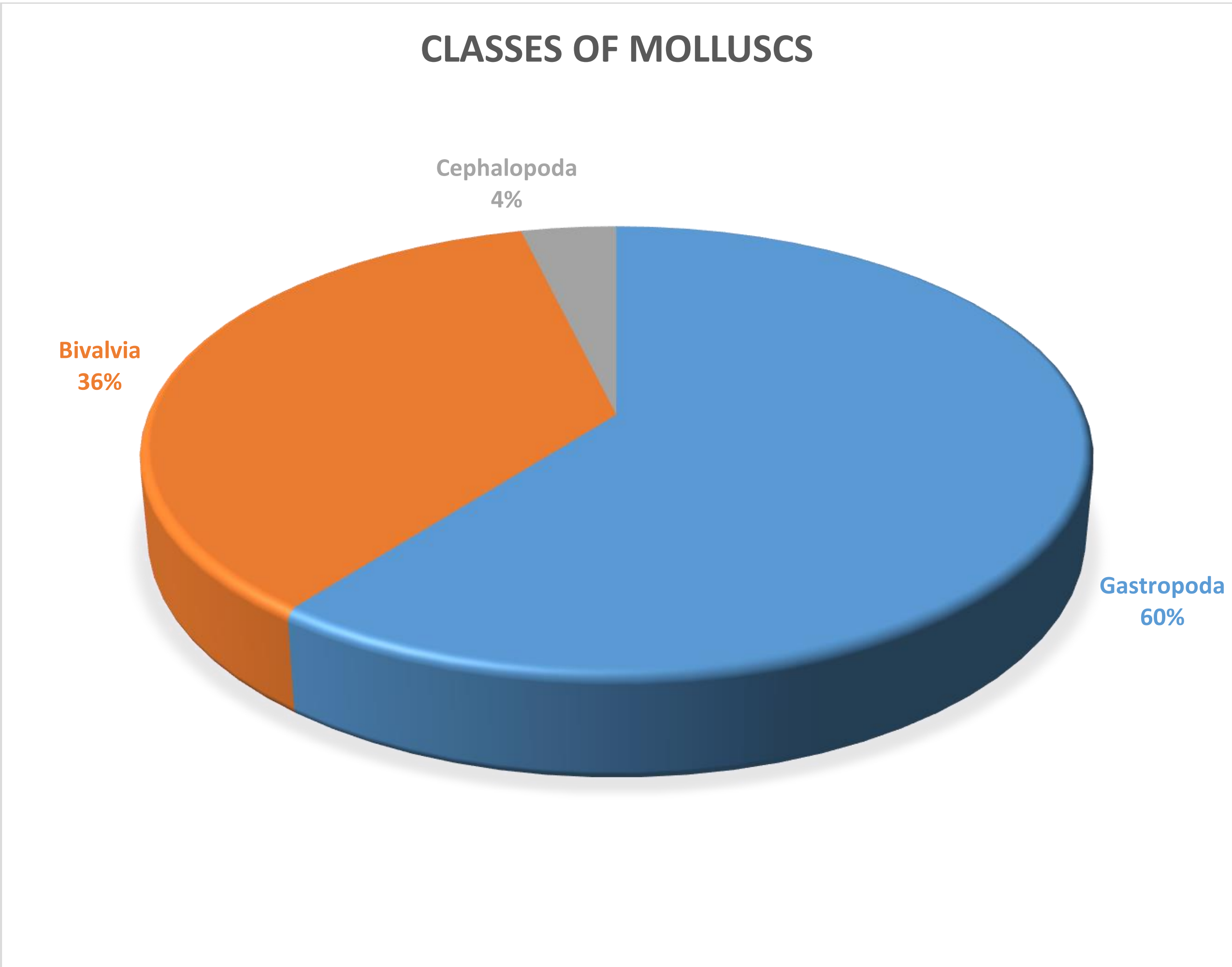


Fig:2. Percentages of Classes of Pylum Mollusca in the study area

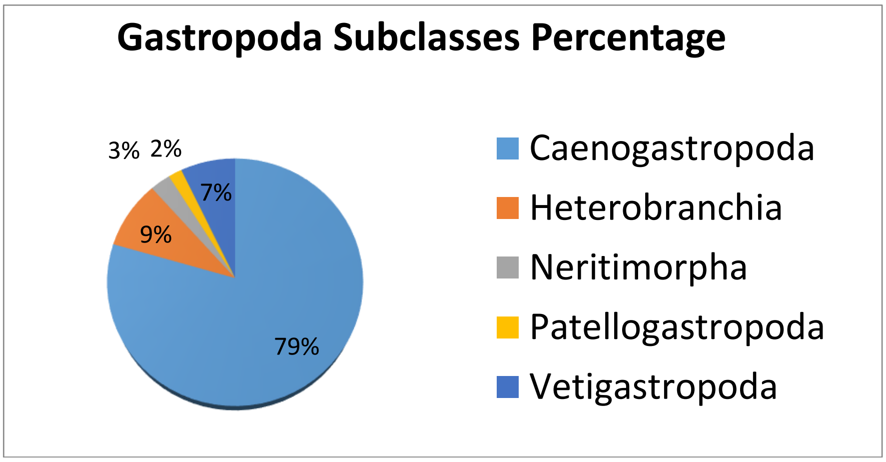
Commonly Available species of Kakinada Bay and Associated Mangrove Regions:

Fig: 3. Significant molluscan species (i- xxiv) of Kakinada Bay and associated mangrove regions.

Overview of Class Gastropoda in the study area:
The class Gastropoda was the most dominant in terms of species richness, with 112 species identified, representing approximately 60% of the total molluscan species recorded in the study area. (fig: 1). These gastropod species were distributed across 5 subclasses 11 orders and 46 families, indicating a wide range of ecological niches occupied by this class in the study area (Tab: 2). The dominance of gastropods in this coastal and mangrove ecosystem is consistent with their general adaptability and ecological roles in such environments. Several studies conducted by researchers also suggest the dominance of gastropod populations in the study area. These studies found that gastropods constitute 60% of the total molluscan population in these regions, aligning with the findings of our research (Monolisha & J.K. Patterson, 2015).

Table: 2. Total number of orders, families and species distributed among various subclasses of Class Gastropoda in the study area.

GASTROPODA				
Subclass	Total No. of Orders	Families	Species	Species Percentage
Caenogastropoda	4	33	89	79.5
Heterobranchia	4	7	10	8.9
Neritimorpha	1	1	3	2.7
Patellogastropoda	0	1	2	1.8
Vetigastropoda	2	4	8	7.1



Fig; 4. Percentages of species distributed among various subclasses of class Gastropoda in the study area

A substantial number of studies have been conducted on the molluscan fauna of Kakinada Bay and the adjacent Godavari mangrove areas. A report from the Zoological Survey of India (ZSI) identified approximately 357 molluscan species from these regions. Earlier, Ganapati and Rao (1959) investigated the molluscan species of the Godavari estuary, documenting 11 species. Additionally, Murthy and Balaparameswara (1977) recorded 10 species from the mangroves of Machilipatnam, while Radhakrishna and Janakiram (1975) reported nine species from the Krishna estuary. Further studies by Surya Rao and Subba Rao (1991) identified 13 species from Andhra Pradesh, and Subbarao et al. (1992) expanded this inventory by identifying 41 species of marine and estuarine molluscs in the same region.
The highest species diversity was recorded in the areas of Chollangi, Bhairavapalem, and Hope Island. This could be attributed to the nutrient-rich waters and favorable physicochemical conditions in these regions. Similar observations have been made by Raut et al. (2005), who reported that macrobenthic densities were highest near mangrove outlets. However, species such as *Turritella duplicata*, *Tonna dolium,* and *Placuna placenta* were noted to have declined in abundance, as of anthropogenic activities and human encroachment.
Numerous studies have been carried out by scientists to explore the biodiversity and distribution of molluscan fauna. Vian et al. (2022) investigated the diversity of molluscs in the seagrass beds of Pulau Gazumbo, Penang. Their research documented 28 species of gastropods from 16 families and 22 genera, as well as 13 species of bivalves. Among these, *Cerithium coralium* from the Cerithiidae family was found to be the most abundant species. The researchers suggested

that this abundance could be attributed to the species higher tolerance to environmental stresses such as desiccation and erosion, its relative resilience, and the ample availability of food within the seagrass ecosystem. Rahmawati et al. (2021) documented the diversity and distribution of molluscs in the intertidal zones of Nglambor Beach, reporting the presence of 19 species across 12 families. They highlighted that molluscs are predominantly detritus feeders, thriving in substrates rich in organic matter such as detritus and macroalgae. The study also found out that molluscs prefer habitats protected from strong currents, waves, and direct sunlight. Key environmental factors such as temperature, pH, and salinity were also identified as crucial determinants influencing the abundance of molluscs in these areas.

Keerthana et al. (2023) investigated the macrofaunal diversity within the mangrove forests of the Gulf of Mannar Marine Biosphere. Their study focused on assessing the spatial diversity of the molluscan community along the Thoothukudi coast, where they identified 84 species spanning 2 classes, 12 orders, 26 families, and 61 genera. The genus *Pirenella* exhibited the highest diversity, with 7 species, while the order Caenogastropoda accounted for the largest number of species, totaling 19, followed by the family Veneridae. The researchers proposed that environmental factors significantly influence molluscan population dynamics in these areas.

Species such as *Pyrinella cingulata*, *Telescopium telescopium*, *Crossostrea madrasensis*, *Umbonium vestiarium*, *Volegalea cochlidium*, *Turritella duplicata*, *Murex trapa*, and *Tonna dolium* hold significant commercial value. Marine mollusc shells serve both consumptive and productive purposes. They are utilized as food and in the production of commercially valuable products such as pearls, as well as raw materials for shell crafts, paper, buttons, ornaments, and in industries such as cement and lime manufacturing. Additionally, they provide a source of calcium for poultry feed. Handicrafts and ornaments made from molluscan shells have become highly valued in both Indian and international markets (Appukuttan, 1996).

Table: 3. Systematic List of Gastropods distributed in Kakinada Bay and associated mangroves:

Class : Gastropoda					
Sub Class	**Order**	**Family**	**Genera**	**Species Name**	**Occurance**
Caenogastropoda	Architaenioglossa	Ampullariidae	Pila	Pila ampullacea (Linnaeus, 1758)	Fresh Water
				Pila globosa (Swainson, 1822)	Fresh Water
		Viviparidae	Filopaludina	Filopaludina bengalensis (Lamarck, 1822)	Fresh Water
	Caenogastropoda	Cerithiidae	Clypeomorus	Clypeomorus batillariaeformis Habe & Kosuge, 196	marine
		Potamididae	Cerithidea	Cerithidea obtusa (Lamarck, 1822)	Brackish
			Pirenella	Pirenella cingulata (Gmelin, 1791)	marine, brackish
			Telescopium	Telescopium telescopium (Linnaeus, 1758)	marine, brackish
		Turritellidae	Turritella	Turritella duplicata (Linnaeus, 1758)	marine
				Turritella terebra (Linnaeus, 1758)	marine
	Littorinimorpha	Assimineidae	Optediceros	Optediceros breviculum (L. Pfeiffer, 1855)	brackish
		Bursidae	Bufonaria	Bufonaria echinata (Link, 1807)	marine
				Bufonaria rana (Linnaeus, 1758)	marine
				Bufonaria crumena (Lamarck, 1816)	marine
		Cassidae	Phalium	Phalium areola (Linnaeus, 1758)	marine
				Phalium glaucum (Linnaeus, 1758)	marine
		Calyptraeidae	Calyptraea	Calyptraea species	marine
				Calyptraea species	marine
				Calyptraea species	marine
		Cymatiidae	Gyrineum	Gyrineum natator (Röding, 1798)	marine
			Linatella	Linatella caudata (Gmelin, 1791)	marine
			Lotoria	Lotoria lotoria (Linnaeus, 1758)	marine
		Cypraeidae	cyprea	cyprea species	marine
			Mauritia	Mauritia arabica (Linnaeus, 1758)	marine
			Monetaria	Monetaria moneta (Linnaeus, 1758)	marine
				Monetaria annulus (Linnaeus, 1758)	marine
		Ficidae	Ficus	Ficus gracilis (G. B. Sowerby I, 1825)	marine
				Ficus variegata Röding, 1798	marine
		Naticidae	Natica	Natica vitellus (Linnaeus, 1758)	marine
			Neverita	Neverita didyma (Röding, 1798)	marine
			Paratectonatica	Paratectonatica tigrina (Röding, 1798)	marine

Class : Gastropoda

Sub Class	Order	Family	Genera	Species Name	Occurance
Caenogastropoda	Littorinimorpha	Naticidae	Polinices	Polinices mammilla (Linnaeus, 1758)	marine
				Polinices peselephanti (Link, 1807)	marine
			Tanea	Tanea lineata (Röding, 1798)	marine
		Ovulidae	Volva	Volva volva (Linnaeus, 1758)	marine
		Personidae	Distorsio	Distorsio reticularis (Linnaeus, 1758)	marine
		Rostellariidae	Rostellariella	Rostellariella delicatula (G. Nevill, 1881)	marine
			Tibia	Tibia curta (G. B. Sowerby II, 1842)	marine
		Strombidae	Conomurex	Conomurex luhuanus (Linnaeus, 1758)	marine
			Mirabilistrombus	Mirabilistrombus listeri (T. Gray, 1852)	marine
			Neodilatilabrum	Neodilatilabrum marginatum (Linnaeus, 1758)	marine
		Tonnidae	Tonna	Tonna dolium (Linnaeus, 1758)	marine
				Tonna sulcosa (Born, 1778)	marine
		Xenophoridae	Onustus	Onustus indicus (Gmelin, 1791)	marine
			Stellaria	Stellaria solaris (Linnaeus, 1764)	marine
	Neogastropoda	Babyloniidae	Babylonia	Babylonia spirata (Linnaeus, 1758)	marine
				Babylonia zeylanica (Bruguière, 1789)	marine
		Clavatulidae	Turricula	Turricula javana (Linnaeus, 1767)	uned
				Turricula tornata (Dillwyn, 1817)	marine
				Turricula species	marine
		Conidae	Conus	Conus textile Linnaeus, 1758	marine
				Conus figulinus Linnaeus, 1758	marine
				Conus striatus Linnaeus, 1758	marine
				Conus amadis Gmelin, 1791	marine
				Conus betulinus Linnaeus, 1758	marine
				Conus inscriptus Reeve, 1843	marine
				Conus species	marine
				Conus species	marine
				Conus species	marine
				Conus virgo Linnaeus, 1758	marine

Class : Gastropoda

Sub Class	Order	Family	Genera	Species Name	Occurance
Caenogastropoda	Neogastropoda	Fasciolariidae	Filifusus	Filifusus filamentosus (Röding, 1798)	marine
			Goniofusus	Goniofusus dupetitthouarsi (Kiener, 1840)	marine
		Harpidae	Harpa	Harpa davidis Röding, 1798	marine
				Harpa major Röding, 1798	marine
		Marginellidae	Cryptospira	Cryptospira species	marine
			Volvarina	Volvarina angustata (G. B. Sowerby II, 1846)	marine
		Melongenidae	Volegalea	Volegalea cochlidium (Linnaeus, 1758)	marine
		Muricidae	Haustellum	Haustellum haustellum (Linnaeus, 1758)	marine
			Indothais	Indothais lacera (Born, 1778)	marine
			Murex	Murex trapa Röding, 1798	marine
			Nassa	Nassa serta (Bruguière, 1789)	marine
			Rapana	Rapana rapiformis (Born, 1778)	marine
		Nassariidae	Bullia	Bullia vittata (Linnaeus, 1767)	marine
			Nassaria	Nassaria coromandelica E. A. Smith, 1894	marine
			Nassarius	Nassarius conoidalis (Deshayes, 1833)	marine
				Nassarius dorsatus (Röding, 1798)	marine
				Nassarius foveolatus (Dunker, 1847)	marine
				Nassarius pullus (Linnaeus, 1758)	marine
				Nassarius species	marine
				Nassarius stolatus (Gmelin, 1791)	marine
		Olividae	Agaronia	Agaronia gibbosa (Born, 1778)	marine
				Agaronia lutaria (Röding, 1798)	marine
			Oliva	Oliva oliva (Linnaeus, 1758)	marine
		Pisaniidae	Cantharus	Cantharus melanostoma (G. B. Sowerby I, 1825)	marine
		Terebridae	Hastula	Hastula trailli (Deshayes, 1859)	marine
		Turridae	Gemmula	Gemmula speciosa (Reeve, 1842)	marine
				Gemmula vagata (E. A. Smith, 1895)	marine
			Turris	Turris crispa (Lamarck, 1816)	marine
			Unedogemmula	Unedogemmula indica (Röding, 1798)	marine
		Volutidae	Melo	Melo melo ([Lightfoot], 1786)	marine

Class : Gastropoda					
Sub Class	**Order**	**Family**	**Genera**	**Species Name**	**Occurance**
Heterobranchia	Cephalaspidea	Bullidae	Bulla	Bulla ampulla Linnaeus, 1758	marine
		Haminoeidae	Atys	Atys naucum (Linnaeus, 1758)	marine
	Ellobiida	Ellobiidae	Cassidula	Cassidula nucleus (Gmelin, 1791)	brackish, terrestri
			Ellobium	Ellobium gangeticum (L. Pfeiffer, 1855)	marine
			Pythia	Pythia plicata (Férussac, 1821)	brackish
		Trimusculidae	Trimusculus	Trimusculus species	marine
		Architectonicidae	Architectonica	Architectonica laevigata (Lamarck, 1816)	marine
				Architectonica perspectiva (Linnaeus, 1758)	marine
	Stylommatophora	Achatinidae	Achatina	Achatina achatina (Linnaeus, 1758)	terrestrial
	Systellommatophora	Onchidiidae	Peronia	Peronia verruculata (Cuvier, 1830)	marine
Neritimorpha	Cycloneritida	Neritidae	Clithon	Clithon oualaniense (Lesson, 1831)	brackish, fresh
			Neripteron	Neripteron violaceum (Gmelin, 1791)	brackish, fresh
			Nerita	Nerita albicilla Linnaeus, 1758	marine
Patellogastropoda		Nacellidae	Cellana	Cellana species	marine
				Cellana species	marine
Vetigastropoda	Lepetellida	Fissurellidae	Diodora	Diodora italica (Defrance, 1820)	marine
				Diodora species	marine
		Haliotidae	Haliotis	Haliotis ovina Gmelin, 1791	marine
	Trochida	Tegulidae	Rochia	Rochia nilotica (Linnaeus, 1767)	marine
		Trochidae	Astralium	Astralium semicostatum (Kiener, 1850)	marine
			Trochus	Trochus ochroleucus Gmelin, 1791	marine
			Turbo	Turbo bruneus (Röding, 1798)	marine
			Umbonium	Umbonium vestiarium (Linnaeus, 1758)	marine

Table: 4. Systematic Classification of Bivalves in the study area.

Class : Bivalvia					
Sub Class	**Order**	**Family**	**Genera**	**Species Name**	**Occurance**
Autobranchia	Adapedonta	Pharidae	Siliqua	Siliqua radiata (Linnaeus, 1758)	Marine
			Sinonovacula	Sinonovacula constricta (Lamarck, 1818)	Marine
	Anomalodesmata	Laternulidae	Exolaternula	Exolaternula spengleri (Gmelin, 1791)	Marine
	Arcida	Arcidae	Anadara	Anadara inaequivalvis (Bruguière, 1789)	Marine
				Anadara brasiliana (Lamarck, 1819)	Marine
				Anadara notabilis (Röding, 1798)	Marine
				Anadara pilula (Reeve, 1843)	Marine
				Anadara species	Marine
				Anadara species	Marine
				Anadara species	Marine
				Anadara trapezia (Deshayes, 1839)	Marine
			Barbatia	Barbatia obliquata (W. Wood, 1828)	Marine
			Mesocibota	Mesocibota bistrigata (Dunker, 1866)	Marine
			Trisidos	Trisidos tortuosa (Linnaeus, 1758)	Marine
			Tegillarca	Tegillarca rhombea (Born, 1778)	Marine
				Tegillarca granosa (Linnaeus, 1758)	Marine, Brackish
		Cucullaeidae	Cucullaea	Cucullaea labiata ([Lightfoot], 1786)	Marine
		Glycymerididae	Glycymeris	Glycymeris sp	Marine
				Glycymeris undata (Linnaeus, 1758)	Marine
	Cardiida	Cardiidae	Papyridea	Papyridea lata (Born, 1778)	Marine
			Vasticardium	Vasticardium elongatum (Bruguière, 1789)	Marine
			Vepricardium	Vepricardium asiaticum (Bruguière, 1789)	Marine

Class : Bivalvia					
Sub Class	Order	Family	Genera	Species Name	Occurance
Autobranchia	Cardiida	Donacidae	Donax	Donax faba Gmelin, 1791	Marine
			Hecuba	Hecuba scortum (Linnaeus, 1758)	Marine
			Latona	Latona cuneata (Linnaeus, 1758)	Marine
				Latona semisulcata semigranosa (Dunker, 1877)	Marine
		Psammobiidae	Asaphis	Asaphis deflorata (Linnaeus, 1758)	Marine
		Tellinidae	Eurytellina	Eurytellina lineata (W. Turton, 1819)	Marine
			Jitlada	Jitlada philippinarum (Hanley, 1844)	Marine
			Pharaonella	Pharaonella pharaonis (Hanley, 1844)	Marine
			Tellinimactra	Tellinimactra edentula (Spengler, 1798)	Marine
			Tellina	Tellina species	Marine
	Carditida	Carditidae	Cardites	Cardites bicolor (Lamarck, 1819)	Marine
				Cardites species	Marine
	Myida	Pholadidae	Pholas	Pholas orientalis Gmelin, 1791	Marine
	Mytilida	Mytilidae	Modiolus	Modiolus modulaides (Röding, 1798)	Marine
			Perna	Perna viridis (Linnaeus, 1758)	Marine
	Ostreida	Margaritidae	Pinctada	Pinctada chemnitzii (R. A. Philippi, 1849)	Marine
		Ostreidae	Magallana	Magallana bilineata (Röding, 1798)	Marine
			Saccostrea	Saccostrea cucullata (Born, 1778)	Marine
		Pinnidae	Atrina	Atrina serrata (G. B. Sowerby I, 1825)	Marine
	Pectinida	Anomiidae	Anomia	Anomia achaeus Gray, 1850	Marine
				Anomia ephippium Linnaeus, 1758	Marine
		Pectinidae	Amusium	Amusium pleuronectes (Linnaeus, 1758)	Marine

Class : Bivalvia					
Sub Class	Order	Family	Genera	Species Name	Occurance
Autobranchia	Pectinida	Pectinidae	Mimachlamys	Mimachlamys crassicostata (G. B. Sowerby II, 1842)	Marine
				Mimachlamys sanguinea (Linnaeus, 1758)	Marine
			Volachlamys	Volachlamys species	Marine
				Volachlamys tranquebaria (Gmelin, 1791)	Marine
		Placunidae	Placuna	Placuna placenta (Linnaeus, 1758)	Marine
	Unionida	Unionidae	Unio	Unio pictorum (Linnaeus, 1758)	Brackish, Fresh
	Venerida	Mactridae	Mactra	Mactra violacea Gmelin, 1791	Marine
				Mactra species	Marine
				Mactra turgida Gmelin, 1791	Marine
			Mactrella	Mactrella striatula (Linnaeus, 1767)	Marine
		Veneridae	Dosinia	Dosinia lupinus (Linnaeus, 1758)	Marine
			Irus	Irus irus (Linnaeus, 1758)	Marine
			Marcia	Marcia opima (Gmelin, 1791)	Brackish
			Meretrix	Meretrix casta (Gmelin, 1791)	Marine
				Meretrix lusoria (Röding, 1798)	Marine
				Meretrix meretrix (Linnaeus, 1758)	Marine
			Paratapes	Paratapes textile (Gmelin, 1791)	Marine
				Paratapes undulatus (Born, 1778)	Marine
			Protapes	Protapes gallus (Gmelin, 1791)	Marine
			Sunetta	Sunetta meroe (Linnaeus, 1758)	Marine
				Sunetta scripta (Linnaeus, 1758)	Marine
				Sunetta donacina (Gmelin, 1791)	Marine

Table: 5. Total number of orders, families and species distributed in Subclass of class Bivalvia in the study area

BIVALVIA				
Subclass	Orders	Families	Species	Species Percentage
Autobranchia	Adapedonta	1	2	3.03
	Anomalodesmata	1	1	1.52
	Arcida	3	16	24.24
	Cardiida	4	13	19.70
	Carditida	1	2	3.03
	Myida	1	1	1.52
	Mytilida	1	2	3.03
	Ostreida	3	4	6.06
	Pectinida	3	8	12.12
	Unionida	1	1	1.52
	Venerida	2	16	24.24

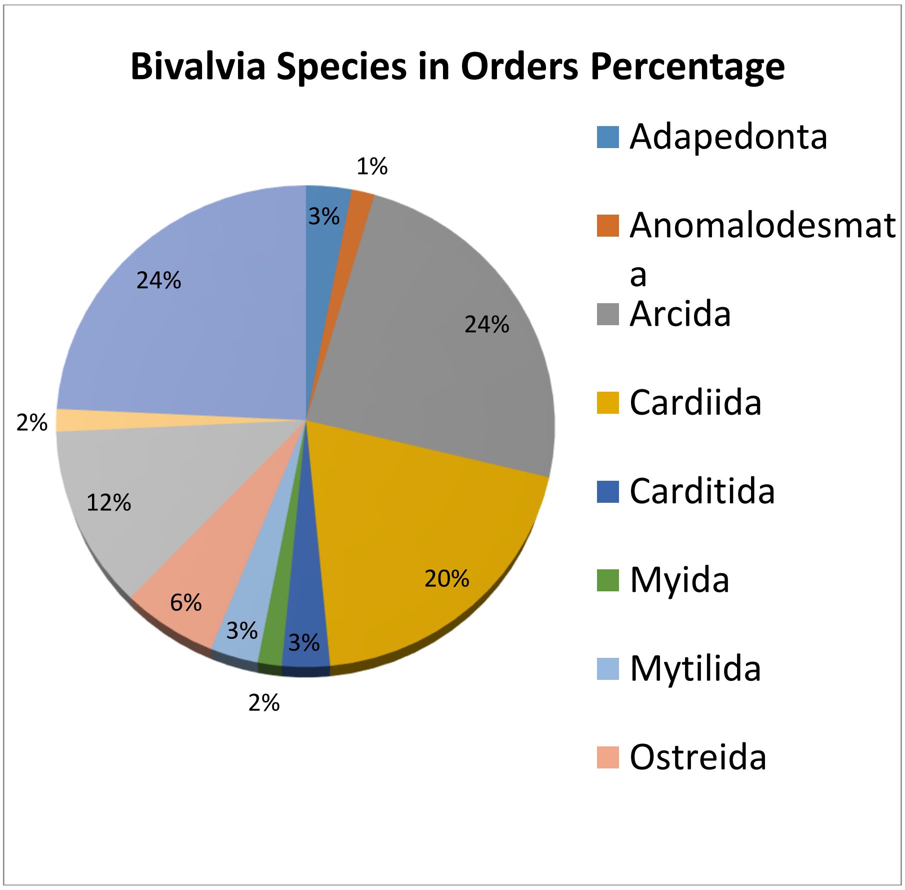


Fig.:5. Percentages of Species in the orders of Class Bivalvia

Overview of class Bivalvia in the study area:

Bivalves play a significant role in the ecological dynamics of Kakinada Bay and the Coringa Mangroves, remarkably contributing to the sustainability of these marine and estuarine ecosystems. As natural filter feeders, they help maintain water quality. This study identified 66 species of bivalves within the region belong to one subclass, Autobranchia. In the subclass Autobranchia, the orders Arcida and Venerida demonstrate the highest species diversity, with each order comprising 16 species, which collectively accounts for 24.24% of the total species recorded. Among the 11 orders in the class Bivalvia, (Tab 4&5, fig: 3) the order Cardiida showcases the greatest family diversity, consisting of 4 families. This is followed by the orders Arcida, Ostreida, and Pectinida, each containing 3 families. Of the 21 bivalve families examined, the family Arcidae is particularly noteworthy for its species richness, encompassing 13 species, while the family Veneridae closely follows with 12 species.

Felix et al. (2019) reported that the Andhra coast is home to several major bivalve species, including *Crassostrea madrasensis, Saccostrea cucculata, Meretrix meretrix, Meretrix casta, Marcia opima, Paphia malabarica, Tegillarca granosa, T. rhombea,* and *Perna viridis*. These species are primarily distributed along the shallow regions of the Godavari estuary. Satyanarayana and Krishna (2017) reported a total of 8 bivalve species from the East Godavari estuarine ecosystem and emphasized the importance of sustainable harvesting practices for shell collection. Chatla and Padmavathi (2017) documented a total of 23 species of molluscs, comprising 16 species of gastropods belonging to 12 families and 7 species of bivalves representing 5 families. Among these, bivalves like *Crassostrea madrasensis* and *Meretrix meretrix* were found to be the most dominant species in the Paleru and Moosy backwaters.

Narasimham et al. (1984) reported a significant abundance of bivalves in the region, including the window-pane oyster *Placenta placenta* (Linnaeus) and the blood-clam *Anadara granosa* (Linnaeus). These species were observed to thrive in habitats where over 50% of the sediment particles measured 0.125 mm, indicating a preference for this specific grain size. The study also documented other bivalve resources such as *Anadara rhombea, Meretrix meretrix, Paphia malabarica, Crassostrea madrasensis,* and *Perna viridis,* which were found to be diversified across several estuarine habitats rich in organic sediments. Raut et al. (2005) conducted a detailed study on the macro benthic community of Kakinada Bay, and reported that commercially valuable molluscs such as the blood clam, windowpane oyster, and saltwater clams have been replaced by smaller molluscs like *Pirenella cingulata,* along with various crustaceans and echinoderms. The authors attributed these significant changes to the transformation of the old port into a deep water port, which has dramatically altered the habitat. Additionally, they noted a marked decline in benthic faunal densities due to the ongoing dredging activities and the same was identified in our current studies on investigation of diversity of molluscan fauna in the region.

Table: 6. Systematic list of class Cephalopoda in the study area

Class : Cephalopoda					
Sub Class	**Order**	**Family**	**Genera**	**Species Name**	**Occurance**
Coleoidea	Myopsida	Loliginidae	Uroteuthis	Uroteuthis (Photololigo) duvaucelii (d'Orbigny [in Férussac & d'Orbigny], 1835)	Marine
				Uroteuthis (Photololigo) sibogae (Adam, 1954)	Marine
	Sepiida	Sepiidae	Acanthosepion	Acanthosepion pharaonis (Ehrenberg, 1831)	Marine
				Acanthosepion aculeatum (d'Orbigny, 1835)	Marine
			Rhombosepion	Rhombosepion prashadi (Winckworth, 1936)	Marine
			Sepia	Sepia brevimana Steenstrup, 1875	Marine
			Sepiella	Sepiella inermis (d'Orbigny, 1835)	Marine

Cephalopods are among the most significant classes of molluscs, with numerous species forms as a dominant fishery in Kakinada Bay. Within this class, the subclass Coleoidea is classified into the orders Myopsida and Sepiida. The order Myopsida includes the family Loliginidae, which comprises the genus Uroteuthis and having two species: *Uroteuthis (Photololigo) duvaucelii* and *Uroteuthis (Photololigo) sibogae*, both of which thrive in marine environments. In the order Sepiida, the family Sepiidae is further categorized into three genera: Acanthosepion, Rhombosepion, and Sepiella. The genus Acanthosepion includes *Acanthosepion pharaonis* and *Acanthosepion aculeatum*, while Rhombosepion is represented by *Rhombosepion prashadi*. (Tab: 6) The genus Sepia features *Sepia brevimana*, and the genus Sepiella includes *Sepiella inermis*. Collectively, these species highlight the rich diversity of genera and species within the subclass Coleoidea. According to Abdussamad and Somayajulu (2004), the fishery in Kakinada Bay is sustained by four species each of squids and cuttlefish. Among the squids, *Loligo duvauceli* stands out as the most dominant species in the catch, while other notable species contributing to the squid fishery include *Loligo uyii, Doryteuthes* spp., and *Loliolus* spp. The cuttlefish fishery is supported by *Sepia pharaonis, S. aculeata, S. brevimana*, and *Sepiella inermis.*

Conclusion:

Kakinada Bay and its associated mangrove regions harbours a rich diversity of molluscan fauna, with over 30 naturally occurring species of bivalves and gastropods. Remarkably, species such as *Tegillarca granosa* and *Placuna placenta* form a unique fishery in this region. The abundance of organic sediments in these areas fosters the proliferation of molluscs, which play an essential role in both ecological and economic contexts. Marine mollusc shells serve various purposes, from food sources to raw materials for products such as pearls, handicrafts, paper, buttons, ornaments, cement, lime, and poultry feed. The handicrafts and ornaments created from these shells are highly prized in both Indian and international markets (Appukuttan, 1996). The Coringa region, in particular, benefits from higher organic input, further boosting the economic value of its gastropod and bivalve populations, which are integral to industries like lime, paper, ornamental crafts, and cement.

However, growing threats to marine biodiversity and the overexploitation of mollusc shells have led to the inclusion of many marine species in the Wildlife (Protection) Act (WPA) of 1972. *Placuna placenta*, in particular, listed under Schedule IV of the WPA due to its decline caused by anthropogenic pressures and habitat disruption. Despite these protections, inadequate law enforcement and a lack of awareness continue to result in the illegal collection and sale of molluscan species, exacerbating their depletion. Therefore, concerted conservation efforts are urgently needed to protect these species, and stricter measures must be taken to curb illegal fishing practices, especially for species with dwindling populations.

Beyond their economic importance, molluscs especially gastropods and bivalves play a vital role as bio-indicators of environmental changes and human impacts (Fortunato, 2015). Filter-feeding bivalves such as oysters and clams accumulate contaminants and trace metals, making them sensitive to even minor changes in their habitats (Singh & Gupta, 2021). Studies have also shown the harmful effects of heavy metals and organochloride pesticides on gastropods, further underscoring their significance in monitoring ecosystem health. In conclusion, protecting molluscan species is crucial not only for maintaining biodiversity but also for sustaining local economies and ensuring the health of marine ecosystems.

References:

1. Oguh, C., Obiwulu, E., Umezinwa, O. J., Ameh, S., Ugwu, C., Sheshi, I., & Oguh, C. (2021). Ecosystem and ecological services: Need for biodiversity conservation - A critical review. Asian Journal of Biology, 11(4), 1-14.
2. Wang, Y.-S., & Gu, J.-D. (2021). Ecological responses, adaptation, and mechanisms of mangrove wetland ecosystems to global climate change and anthropogenic activities. International Biodeterioration & Biodegradation, 162, 105248.
3. Spalding, M. D., Blasco, F., & Field, C. D. (Eds.). (1997). World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp.
4. Odum, W.E. and E.J. Heald, 1972. Trophic analysis of an estuarine mangrove community. Bulletin Marine Science, 22: 671738.
5. Printrakoon, C., Wells, F., & Chitramvong, Y. (2008). Distribution of molluscs in mangroves at six sites in the upper Gulf of Thailand. The Raffles Bulletin of Zoology, 18, 247-257.
6. MolluscaBase eds. (2024). MolluscaBase. Accessed at https://www.molluscabase.org
7. Venkatraman, C. and K. Venkataraman, 2012. Diversity of Molluscan Fauna along the Chennai Coast. Marine Biodiversity: Uttar Pradesh State Biodiversity Board, pp: 29-35.
8. Ruppert, E. E., Fox, R. S., & Barnes, R. D. (2004). Invertebrate zoology: A functional evolutionary approach (7th ed.). Brooks/Cole.
9. Bouchet, P., & Rocroi, J.-P. (2005). Classification and nomenclature of gastropod families. Malacologia, 47(1), 1-397.
10. Narasimham, K. A. (1973). On the molluscan fisheries of the Kakinada Bay. Indian Journal of Fisheries, 20, 209-214.
11. Narasimham, K. A. (1980). Culture of blood clam at Kakinada. Marine Fisheries Information Service, Technical and Extension Series, 20, 7-9.
12. Narasimham, K. A. (1987). Fishery and Dynamics of the Window Pane Oyster, *Placenta placenta* (Linnaeus), from Kakinada Bay. Indian Journal of Fishery, 34(3), 277-282.
13. Narasimham, K. A. (2004). Molluscan fisheries of Kakinada Bay-Recent developments. Proceedings of the Seminar on Sir Arthur Cotton's vision on River water Management for Food security. Organised by SastriyaVignanaSamithi and SPICAM, Kakinada, 15th May 2004, 69-73.
14. Murthy, V. S., Narasimham, K. A., & Venugopalam, W. (1979). Survey of windowpane oyster (*Placenta placenta*) resources in the Kakinada Bay. Indian Journal of Fishery, 26(1 & 2), 125-132.
15. Radhakrishna, Y., & Ganapati, P. N. (1967). Fauna of the Kakinada Bay. Bulletin of the National Institute of Sciences of India, 38, 689-699.
16. Radhakrishna, Y., & Janakiram, R. (1975). The mangrove molluscs of Gadavari and Krishna estuary. In R. Natarajan (Ed.), Recent Researches in Estuarine Biology (pp. 177-184). Hindustan Publishing Corporation.
17. Laxmilatha, P. (2015). Status and conservation issues of window pane oyster Placuna placenta (Linnaeus 1758) in Kakinada Bay, Andhra Pradesh, India. Journal of Marine Biological Association of India, 57(1), 92-95.
18. Ramakrishna and Dey A., Barua, S. and Mukhopadhyaya, A. (2007) Marine Molluscs.Polyplacophora and Gastropoda. In: Fauna of Andhra Pradesh, State Fauna Series, Zoological Survey of India.5 (Part-7): 149- 260.

19. Raut, D., Ganesh, T., Murty, N. V. S. S., & Raman, A. V. (2005). Macrobenthos of Kakinada Bay in the Godavari delta, East coast of India: comparing decadal changes. Estuarine, Coastal and Shelf Science, 62(4), 609-620.
20. Gosliner, T. M. (1996). Diversity and distribution of tropical Indo-Pacific opisthobranch gastropods. Bulletin of Marine Science, 58(3), 701-719.
21. Silva, C. A., & Calheiros, D. F. (2004). Mollusc distribution in relation to the hydrodynamics of a mangrove estuary. Journal of Molluscan Studies, 70(4), 297-304.
22. Subba Rao, N.V. (2003). Indian Seashells part I. Polyplacophora and Gastropoda. ZSI, Kolkata, Occasional Paper, No. 192, 1–416.
23. Ramakrishna, D., & Dey, A. (2010). Annotated Checklist of Indian Marine Molluscs (Cephalopoda, Bivalvia and Scaphopoda): Part-I. Rec. zool. Surv. India, Occ. Paper No., 320, 1-357. (Published by the Director, Zool. Surv. India, Kolkata.
24. FAO. (2002). Species Identification Guide for Fishery purposes and American Society of Ichthyologists and Herpetologists special publication No. 5. The Living Marine Resources of the Western Central Atlantic Volume 1 Introduction, molluscs, crustaceans, hagfishes, sharks, batoid fishes and chimaeras.
25. Monolisha, S., & Patterson Edward, J. K. (2015). Biodiversity of marine molluscs from selected locations of Andhra Pradesh coast, South eastern India. Indian Journal of Geo-Marine Sciences, Vol. 44(6).
26. Subba Rao NV, Surya Rao KV, Maitra S (1991) Marine molluscs. Zoological Survey of India, State Fauna Series 1; Fauna of Orissa Part 3: 1–175.
27. Subba Rao, N. V., Dey, A., & Barua, S. (1992). Estuarine and marine molluscs of West Bengal. In Fauna of West Bengal, State Fauna series, 3 (Part 9), 129-268. Zoological Survey of India.
28. Vian, L. W., Nilamani, N., Sharuiddin, S. F. F., Woo, S. P., Ilias, N., Yasin, Z., & Hwai, A. T. S. (2022). Diversity and distribution of molluscs (Gastropoda and Bivalvia) in the seagrass beds at Pulau Gazumbo, Penang, Malaysia. Journal of Survey in Fisheries Sciences, 9(1), 79-95.
29. Rahmawati, Y. F., Putri, R. A., Prakarsa, T. B. P., Muflihaini, M. A., & Aliyani, Y. P. (2021). Diversity and distribution of molluscs in the intertidal zone of Nglambor Beach, Gunung Kidul, Yogyakarta. BIO Web of Conferences, 33, 01002. https://doi.org/10.1051/bioconf/20213301002.
30. Keerthana, M., Arisekar, U., Kingston, S. D., & Sudhan, C. (2023). Malacofaunal diversity (Gastropods and Bivalves) along the mangrove forest area of the Gulf of Mannar marine biosphere region, South India. *Regional Studies in Marine Science*, *67*, 103201. https://doi.org/10.1016/j.rsma.2023.103201
31. Appukuttan, K. K., (1996). *Marine mollusc and their conservation*. In Menon, N. G. and C. S. G. Pillai (Eds.) Marine biodiversity, Conservation and management, CMFRI, Cochin.4:66-77.
32. Felix, J., Dhanraju, K., Pattnaik, P., Kavita, M., R., V., & Sasikumar, G. (2019). Bivalve fisheries in Andhra Pradesh.
33. Satyanarayana, J. E, & Krishna, P. V. (2017). Species diversity and distribution of molluscan fauna from estuary and mangroves (Coringa Wildlife Sanctuary) of East Godavari estuarine ecosystem, Andhra Pradesh, India. International Journal of Advanced Research, 5(6), 2930-2937.
34. Chatla. D. & Padmavathi, P. (2017). Diversity of Malacofauna from the Paleru and Moosy backwaters of Prakasam district, Andhra Pradesh, India.
35. Abdussamad, E. M., & Somayajulu, K. R. (2004). Cephalopod fishery at Kakinada along the east coast of India: Resource characteristics and stock assessment of Loligo duvauceli. Bangladesh Journal of Fish Research, 8(1), 61-69.
36. Fortunato, H. (2015). Mollusks: Tools in environmental and climate research. American Malacological Bulletin, 33(1), 1-15.
37. Singh, P. P., & Gupta, S. M. (2021). Molluscs as biomonitors of heavy metal pollution: A review. Journal of Advanced Scientific Research, 12(2 Suppl 1), 35-42.