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Exploring Marine Zooplankton Diversity In Mumbai's Coastline, Maharashtra, India.

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Abstract

In the present work, we carried out the diversity of Zooplankton in some selected coastal areas of Mumbai coasts like Aksa beach, Versova beach, Manori beach, Girgaon Chowpatty and Elephanta caves from 22 September 2022 to 26 February 2023. The Zooplanktons were collected in the interval of 10-15 days from each site. As Zooplankton are present on the surface during the day, the collections were done during the day by using a Zooplankton hand net. Each site had different geographical condition, which includes high current, sandy and muddy shore, and different tide levels. A total of 28 species were found during the study of these 5 stations; we found 6 orders and 17 families of Zooplankton. Among these species, copepods and foraminifera are the most dominant groups of holoplankton. The highest diversity of Zooplankton was seen in Aksa, Versova, Manori, while the lowest observed at Elephanta Caves and Girgaon.

Keywords: Marine, Zooplankton, Diversity, Mumbai, Pollution, Beaches.

Introduction:

Zooplankton are heterotrophic creatures and play a vital role in aquatic ecosystems by cycling organic materials, transferring energy in the food web, and transferring energy from primary producers to secondary consumers, which is the most significant trophic link in the food chain. (Steinberg & Robert, 2009). Other than that, some of the zooplankton species may be able to identify the effect of pollution or eutrophication on water quality. (Mahajan 1981). The survival and development of fish are directly associated with zooplankton because the animals are fed on by them, while also playing a vital role in feeding chains and food webs throughout aquatic ecosystems (Venkataramana 2013 & Miah *et al.* 2013, Shivashankar). Zooplankton are a valuable indicator of changes in water quality and thus may be used to estimate the state of water pollution, due to their capability to respond quickly to environmental change as well as chemical and physical conditions within aquatic bodies (Contreras *et al.* 2009). The occurrence and spread of plankton fauna are influenced by a number of issues, such as biotics and climate change, physicochemical properties of habitats. (Richardson 2008, Rajagopal *et al.* 2010, Ahmad *et al.* 2011, Alexander 2012). Water temperature is an important factor that affects the growth and development of animals, which helps to control their death rates. (Andrulewicz *et al.* 2008, Hall & Burns 2001, Tunowski 2009). Another environmental factor that also has an impact on the organism is salinity, as animals have to adapt their body's saline levels with respect to the external environment. (Ojaveer *et al.* 2010, Lawrence *et al.* 2004). These environmental parameters are important for the composition and density of zooplankton in promoting their breeding. (Greenwood *et al.* 2001). Present-day, in all the oceans of the globe, zooplankton corresponds to organisms adrift in the water. In addition to a large amount of taxonomic diversity and dimensions, they range in size

from one micrometre to several metres. (de Vargas *et al.,* 2015; Stemmann and Boss, 2012; Karsenti *et al*., 2011). Zooplankton play an important role in the carbon cycle by contributing to the biological pump that drives the export of photosynthetically fixed organic carbon from the surface to the intermediate and deep oceans. (Longhurst and Glen Harrison, 1989; Turner, 2015; Turner, 2002; Steinberg and Landry, 2017). A key connection between primary producers and the higher levels of the food chain (Ikeda, 1985), Zooplankton have a central role to play in environmental and biogeochemical matters as well as socioeconomic interests. The impact of plankton on the world's economy can be positive, like its role as a fish food source. (van der Lingen *et al.,* 2006; Lehodey *et al.,* 2006) or as an indicator of water quality (Suthers *et al.,* 2019). It may also have a negative impact on different human activities, such as aquaculture and fisheries, for example, due to blooms of jellyfish. (Richardson *et al.,* 2009). The variety of zooplankton is highest near the equator, and it decreases steadily as you move toward the poles around the globe. (Rombouts *et al.,* 2009; Ibarbalz *et al.*, 2019). In contrast, the biomass for zooplankton occurs to be little in tropical regions and increases at latitudes that have frequent seasonal fluctuations between temperate as well as Arctic areas (Moriarty *et al.,* 2012; Soviadan *et al.,* 2022; Ikeda, 1985). Zooplankton species exhibit varied feeding behaviors influenced by the time of day, whether it's day or night, and these habits can also shift depending on the presence of surface or bottom-dwelling species. The diversity of zooplankton taxa in a particular habitat, especially when various fish of different trophic levels are present, is closely linked to the overall health of the ecosystem. (Robertson and Howard 1978). Research indicates that aquaculture operations near seagrass meadows can impact zooplankton populations and affect their interactions with fish. This, in turn, may disrupt the balance of predator-prey dynamics and the overall food web. (Jaxion-Harm *et al.* 2013, Metillo *et al.* 2019).

For instance, variations in zooplankton species are caused by environmental fluctuations from one geographic area to another, as is noted for the crustaceans of Korea's seagrass beds (Park *et al.* 2020). Copepods are a key group of zooplankton that serve as primary consumers, playing an essential role in the flow of nutrients and energy within marine ecosystems and seagrass meadows. They create an important trophic connection between phytoplankton, the primary producers, and planktivorous fish, which are at the tertiary level of production. (De Young *et al.* 2004). The presence of phytoplankton and other nutrients influences the diversity of copepod species across different locations. (Kassim *et al.* 2015, Matias-Peralta and Yusoff 2015, Shuaib *et al* 2019). Zooplankton are small organisms that float in the water and can't hold their position when the currents move. The community of zooplankton is an assemblage of different animals that includes many taxonomic groups, mainly the invertebrates. Zooplankton constitute an efficient trophic level in the utilization of the habitat and transfer of energy from primary to secondary level, forming an important link in the food chain and are thus significant in assessing the productivity of the sea as secondary producers (Nair, 2001). Seasonal variations resulting from monsoons and upwelling are primarily responsible for zooplankton production in coastal waters. (Nair, 2001). The quantity and makeup of zooplankton populations are influenced by fluctuations in water quality parameters. (Gaonkar *et al.,* 2010). The zooplankton is a major food source for both omnivorous and carnivorous fish. (Alam *et al.,* 1987) The young carps primarily consume zooplankton for their nourishment. (Bardach *et al.,* 1972). A wide range of disturbances, including nutrient loading, are dealt with by the zooplankton community (Dadson, 1992) and play a key role in the aquatic food chains (Sharma, 1998). Zooplankton react rapidly to changes of the aquatic environment, e. g. pH, colour, odour, and taste, to be able to indicate overall health or condition of the water body for their brief life cycle (Carriack and Schelskek, 1977).

Materials & Methods

Zooplankton Sampling & Sites

Mumbai features an extensive coastline that stretches an impressive 149 kilometers, with 16 kilometers of beautiful beaches running from Colaba in the south all the way up to Madh and Marve in the north. To conduct sampling, five sites were chosen based on their topography and extensive coastlines, namely Aksa, Manori, Girgaon, Versova, and Elephanta. Aksa Beach is situated at 19°07'45.8"N latitude and 72°48'49.5"E longitude, while Manori Beach is located at 19°12'35.3"N latitude and 72°46'50.8"E longitude. Girgaon Beach is situated at 18°57'11.3"N latitude and 72°48'48.4"E longitude, Versova Beach at 19°07'45.8"N latitude and 72°48'49.5"E longitude, and Elephanta Caves at 18°57'34.8"N latitude and 72°56'15.4"E longitude.

All these areas fall under the Mumbai suburban region. The temperature in these regions is moderate, ranging from 26°C - 32°C, with the sampling primarily conducted during the winter season when the

temperature is between 20°C and - 24°C. These sites offer ample space and favorable topography for the collection of samples.The topographic data was gathered utilizing a GPS map camera application on a mobile device. Simultaneously, the samples were collected employing a plankton net. The collected samples were transferred into a bottle after being placed in a beaker. The zooplankton was collected in a circular manner at three different levels and horizontally by towing the plankton net. The net was trailed horizontally for 5-6 minutes each time along the waves at varying depths, covering an area of 50 meters. After collection, the samples were temporarily preserved in 5% formaldehyde for 2 hours and then observed under a light microscope. The collection of zooplankton depended on the time of collection, water depth, and the strategy employed for collecting the samples. A 12 standard silk bolting cloth plankton net was employed, featuring a mesh size of 125 meshes per square inch and measuring 89 cm in length. The net was supported by a muslin reinforcement connected to a 24 cm Die ring. Three braided leaders were affixed to swivels at both the front and tail of the bag, each measuring 2 cm. Zooplankton collection was conducted during the daytime as these organisms surface for feeding on phytoplankton during this time. At night, they tend to go to the bottom of the sea, making it difficult to capture and reducing the diversity available for sampling. Identification books and a key specifically designed for the common planktonic copepoda found in Indian coastal waters were utilized to identify the zooplankton samples. Overall, the collection and identification methods employed were well-suited for the purpose of the study.

Table No. 2.1 Sampling sites along with GPS location.

Sr. No.	Sampling sites	Latitudinal	Longitudinal
1	Versova Beach	19°07'45.8"N	72°48'49.5"E
2	Aksa Beach	19°10'33.1"N	72°47'38.3"E
3	Girgaon Chowpatty	18°57'11.3"N	72°48'48.4"E
4	Manori Beach	19°12'35.3"N	72°46'50.8"E
5	Elephanta caves	18°57'34.8"N	72°56'15.4"E

Fig. no. 1 Versova Beach

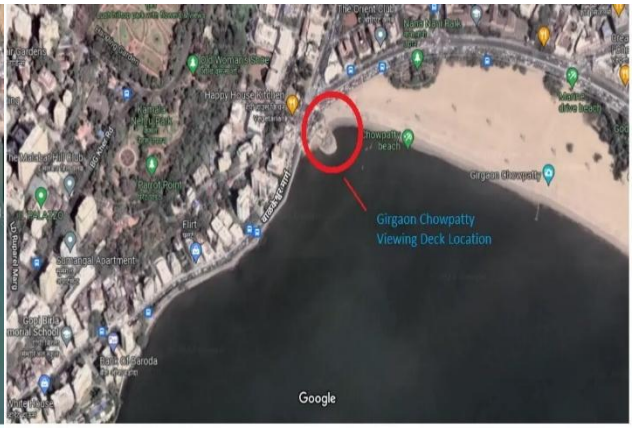


Fig. no. 2 Girgaon Chowpatty

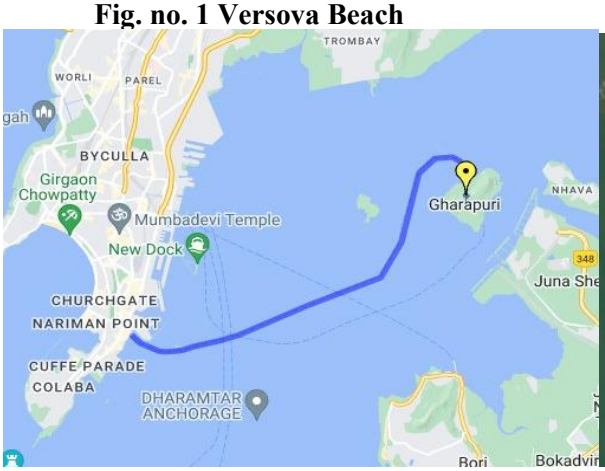


Fig. no. 3 Elephanta caves

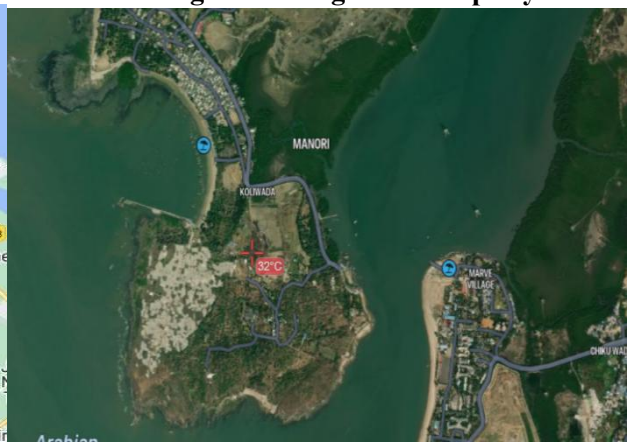


Fig. no. 4 Manori Beach

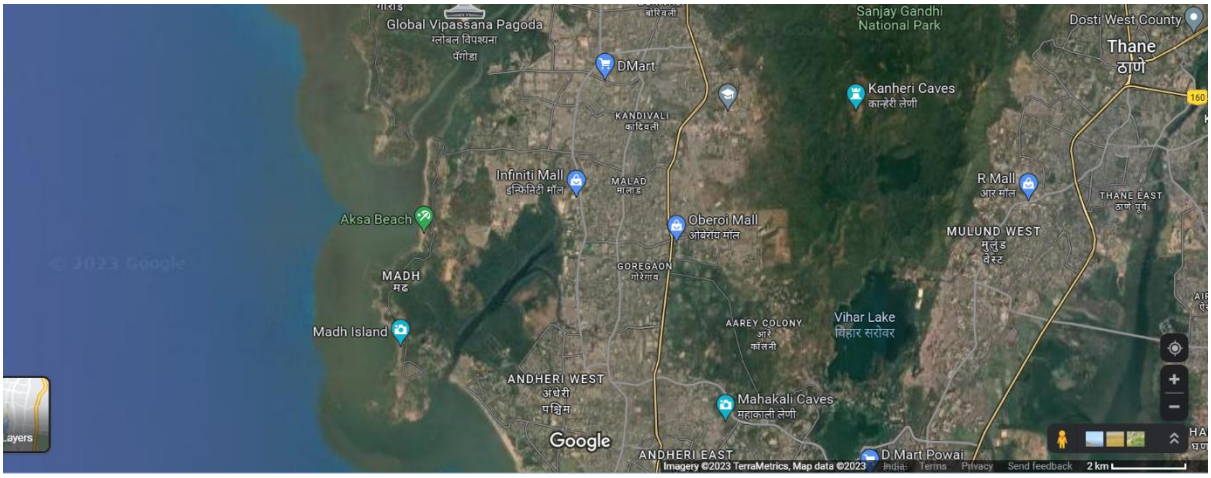


Fig. no. 5 Aksa Beach

Table No. 2.2 Visit details of Selected Beaches along with tide details.

Sr. No.	Sampling sites	Date	Time	Low tide/ Height
1	Versova Beach	22 Oct 2022	16:00	1.61m
2	Aksa Beach	18 Nov 2022	13:00	2.39m
3	Girgaon chow patty	15 Dec 2022	10:00	1.99m
4	Manori Beach	31 Jan 2023	13:00	2.17m
5	Elephanta caves	26 Feb 2023	10:30	0.95m

Results and Discussion:

The marine ecosystem is a fascinating tapestry of various organisms, each essential in their roles as consumers or producers. At the heart of this ecosystem are phytoplankton, the primary producers that thrive in our water bodies. Zooplankton, on the other hand, play a crucial role by feeding on these phytoplankton, transferring energy and nutrients up the food chain to larger marine creatures. Understanding the diversity of zooplankton in a particular area is vital, as it helps clarify the local food web dynamics. A recent study explored the abundance and diversity of marine zooplankton across five distinct locations: Aksa, Versova, Manori, Girgaon, and the Elephanta Caves. The study identified a total of 28 species of marine zooplankton, with Aksa, Versova, and Manori showing the greatest diversity. The dominant species identified were copepods, and other species, such as foraminifera, Metanauplius of Semibalanus balanoides, tadpole larvae of tunicates, and veligers with 44-lobed velum, were also observed in water samples from these sites. Out of 28 species identified, 9 species belonged to the family Cibicididae in the order Rotaliida, 2 species belonged to the family Paracalanidae in the order Calanoida, 1 species belonged to the family Sapphirinidae in the order Cyclopoida, 1 species belonged to the family Calanidae in the order Calanoida, 2 species belonged to the family Balanidae in the order Balanomorpha, 1 species belonged to the family Eucalanidae in the order Calanoida, 1 species belonged to the family Tachidiidae in the order Harpacticoida, 1 species belonged to the family Diaptomidae in the order Calanoida, 3 species belonged to the family Micraciidae in the order Harpacticoida, 1 species belonged to the family Cyclopidae in the order Cyclopoida, 1 species belonged to the family Mysidae in the order Mysida, 2 species belonged to the family Oithonidae in the order Cyclopoida, 1 species belonged to the family Temoridae in the order Calanoida, 1 species belonged to the family Tortanidae in the order Calanoida, and 1 species belonged to the family Ectinosomatidae in the order Harpacticoida. In summary, the study provides valuable insight into the diversity and abundance of marine zooplankton in the sampled stations, which can aid in understanding the ecological dynamics of these ecosystems.

The identification of zooplankton is crucial in understanding their role in the marine ecosystem. In the current study, copepods were found in large numbers, indicating a decline in water quality and a potential increase in nutrient content in the fish. Copepods, commonly known as the "sea cows of the oceans," are unable to swim in water and rely on ocean currents for movement, aided by their two antennae. In most copepod species, females are larger than males.

The abundance of zooplankton is highly influenced by temperature, as they are poikilothermic organisms. Temperature affects their respiration, ingestion, and reproduction, making it a crucial factor in their growth.

The study was conducted during the winter season in Mumbai, where the average temperature ranges from 20°C to 24°C, providing an ideal condition for the growth of zooplankton. The number of individual zooplankton observed at Manori was lower than at Versova, and Aksa had the highest number of individual zooplankton.

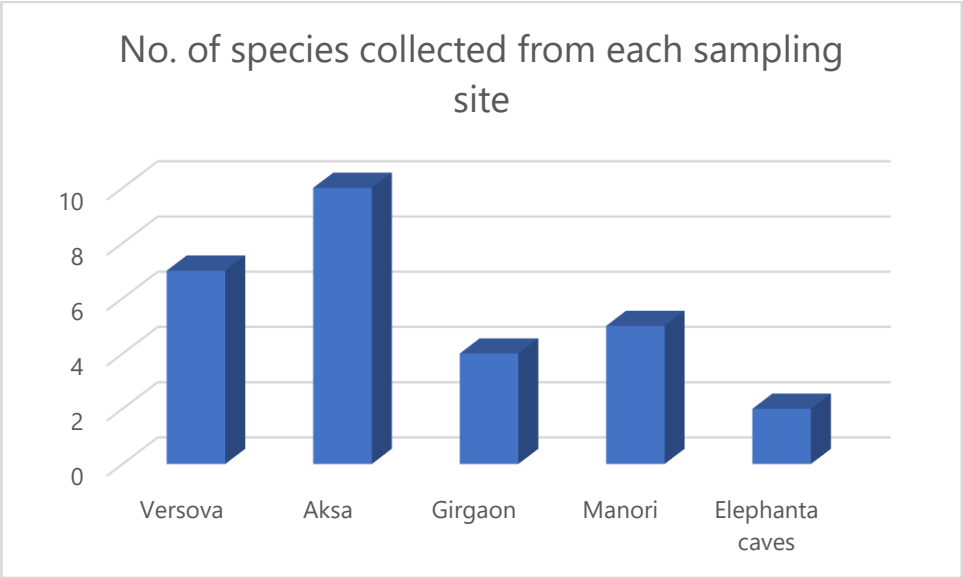
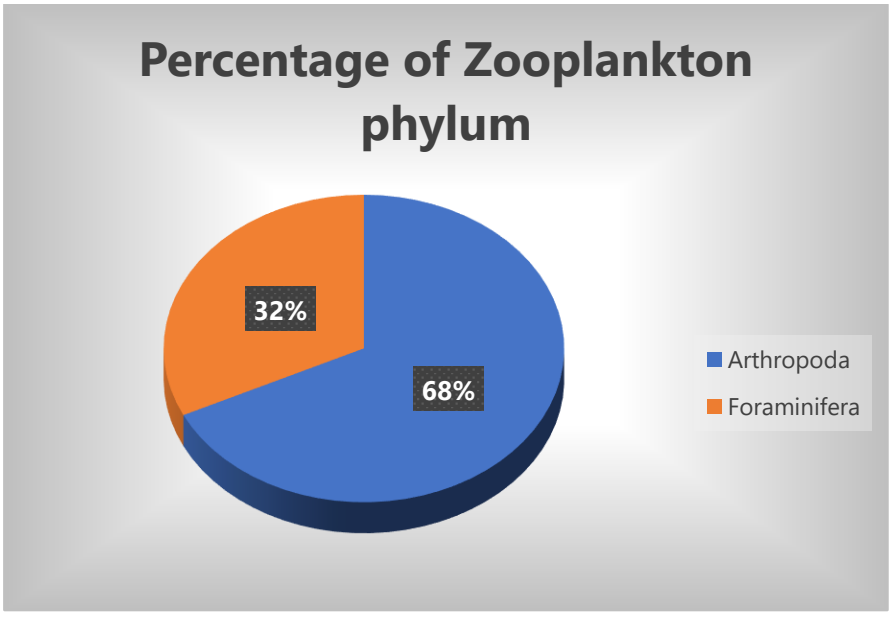


Fig. No.6: Number of collected zooplankton species from selected sites

The study showed that Aksa had the highest number of individuals, with a count of 75. Out of the observed zooplankton, 20 different genera of holoplankton were identified, while no meroplankton genera were observed. In this study, we identified zooplankton from two main phyla: Arthropoda and Foraminifera. Arthropoda stands out as the largest group of marine zooplankton, found throughout the ocean and thriving in various oceanic zones. Characterized by their segmented bodies and protective chitin coverings, this phylum exhibited a notable dominance in our findings, with 19 distinct species identified, the majority being copepods. Foraminifera, the second most prevalent phylum in our collection, comprised 9 identified species. These organisms primarily feed on diatoms, algae, and bacteria, and can be located in nearly every marine environment, whether in the benthic or planktonic stages. Overall, the zooplankton community was predominantly made up of Arthropoda, accounting for 68% of the total identified species, while Foraminifera represented 32% of the species observed.



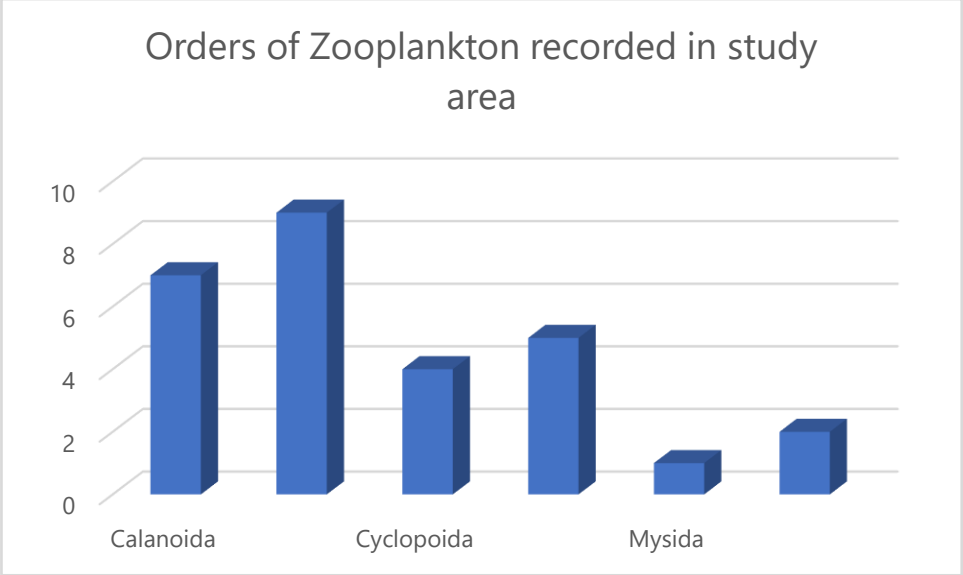


Figure 7. Order of zooplankton seen in samples

The collected samples revealed the presence of 19 species belonging to the phylum Arthropoda, which are further classified into five different orders, namely Calanoida, Rotaliida, Cyclopoida, Harpacticoida, and Balanomorpha. Among these orders, Calanoida was the most dominant, containing 7 species of copepods. Acrocalanus gibber and Paracalanus aculeatus were the most abundant species of marine zooplankton in the Calanoida order, and they were found in all the sampling sites. The Rotaliida order had 9 species, which were observed in the water samples of Girgaon, Elephanta, and Versova, as well as in the water samples of Manori and Aksa. Additionally, the order Harpecticoida had one species, Microsetella norvegica, while the order Cyclopoida had one species, Oithona fallax, which were found in large numbers in the samples.

Table no. 3.1 Checklist of Marine Zooplanktons from Mumbai coast.

Sr. No	Classification	Scientific Name	Image reference
	Order -1. Calanoida		
	Family-1. Paracalanidae		
1		*Acrocalanus gibber*	-
2		*Paracalanus aculeatus*	Plate No. 1-N
	Family-2. Calanidae		
3		*Cosmocalanus darwinii*	Plate No. 1-V
	Family-3. Eucalanidae		
4		*Eucalanus bungii*	-
	Family-4. Diaptomidae		
5		*Heliodiaptomus viduus*	Plate No. 1-E
	Family-5. Temoridae		
6		*Temora turbinata*	Plate No. 1-H
	Family-6. Tortanidae		
7		*Tortanus forcipatus*	Plate No. 1-P
	Order – 2. Rotaliida		
	Family-7. Cibicididae		
8		*Cibicidoides alazanensis*	Plate No. 1-B
9		*Cibicidoides bradyi*	Plate No. 1-R
10		*Cibicidoides dohmi*	Plate No. 1-S
11		*Cibicidoides eocaenus*	-
12		*Cibicidoides guazumalensis*	Plate No. 1-Y
13		*Cibicidoides incrassatus*	-
14		*Cibicidoides lamontdohertyi*	-
15		*Cibicidoides mexicanus*	Plate No. 1-T
16		*Cibicidoides grimsdalei*	-
	Order- 3. Cyclopoida		

	Family-8. Sapphirinidae		
17		*Copilia mirabilis*	Plate No. 1-A
	Family-9. Cyclopidae		
18		*Thermocyclops hyalinus*	-
	Family-10. Oithonidae		
19		*Oithona fallax*	Plate No. 1-L
20		*Oithona pseudofrigida*	Plate No. 1-M
	Order- 4. Harpacticoida		
	Family-11. Tachidiidae		
21		*Euterpina acutifrons*	Plate No. 1-D
	Family-12. Miraciidae		
22		*Macrosetella gracilis*	Plate No. 1-G
23		*Oculosetella gracilis*	Plate No. 1-K
24		*Distioculus minor*	-
	Family-13. Ectinosomatidae		
25		*Microsetella norvegica*	Plate No. 1-C
	Order- 5. Mysida		
	Family-13. Mysidae		
26		*Mysis sp.*	-
	Order- 6. Balanomorpha		
	Family- 14. Balanidae		
27		*Balanus balanus*	Plate No. 1-U
28		*Semibalanus balanoides*	Plate No. 1-I, J

In 2018, Takar conducted a study on the diversity of marine zooplankton in mangroves along the Mumbai coast. They studied two estuaries and one enclosed mangrove at Lokhandwala and found copepods to be abundant in all three locations. In addition to copepods, they also observed larval stages of polychaetes at Lokhandwala and decapods, gastropods, and bivalve larvae at Bhayandar and Dharamtar. The researchers analyzed the water parameters of all three stations to observe how they affected the population of zooplankton. They found that high temperatures during the summer season resulted in a high number of copepods in the area. The current study also observed a large number of copepods at Versova beach, likely due to the ideal temperature in the area.

In 2018, Sadasivan studied the abundance and seasonal distribution of zooplankton in Patalganga estuaries. They found 14 groups of zooplankton, with copepods and copepod nauplii dominating the population, followed by barnacle nauplii and foraminifera. The numerical distribution of marine zooplankton was highly dependent on the abundance of phytoplankton in the area. They observed a high number of zooplankton from May to August and a low number during the winter season. The current study, conducted during winter, observed 28 species of zooplankton, indicating a decrease in the zooplankton population in Patalganga.

In 2008, Patil studied the distribution of zooplankton in the estuaries of Bhayandar and Naigaon for one year. They found 37 species of marine zooplankton, with Maxillopoda dominating the group with a total of 17 species, along with cypris larvae. However, in the current study, only 28 species were observed within four months, indicating a lower abundance of zooplankton in the creek areas of Bhayandar and Naigaon due to poor water quality.

Upon analyzing the Girgaon chawpatty samples, we observed a significantly lower abundance of zooplankton compared to other samples. This discrepancy can be attributed to the time of sampling. While the other samples were collected during the morning, the Girgaon sample was collected during the night. This observation suggests that zooplankton are present on the water's surface during the day and migrate to the deep sea during the night.

Zooplankton's presence on the water's surface is linked to the abundance of phytoplankton during the day. Phytoplankton perform photosynthesis and produce food, which zooplankton consume. In turn, these zooplankton are preyed upon by larger fish, underscoring their crucial role in the marine food chain.

Summary & Conclusion:

A recent study on marine zooplankton across five locations in Mumbai has uncovered a remarkable diversity within this group, identifying 28 species spanning two phyla and six distinct orders. Zooplankton, found in

both freshwater and marine environments worldwide, are highly adaptable organisms that thrive even in extreme conditions. Their study is crucial as they play an important role in the aquatic food web, feeding on phytoplankton and serving as a nutrient source for larger fish and their larvae. Additionally, the presence and abundance of zooplankton can serve as an indicator of water pollution levels. Seasonal variations significantly influence their growth patterns. The current research was conducted during winter, a period that offers optimal temperatures for their development. This resulted in the identification of 28 species, with copepods and foraminifera being the most prevalent. Overall, these findings underscore the significance of exploring the diversity of marine zooplankton.

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