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A Comparative Study on Zooplankton Standing Stock at Ratnagiri-West Coast of India

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Abstract:

India has a considerably large coastline, 9.5% of which is comprised of Maharashtra. The coastal regions of Maharashtra support a rich fishery potential which directly or indirectly depends upon the secondary productivity of the coastal ecosystem. Zooplanktons are a vital link in the food chain between the primary and tertiary levels; furthermore, they are considered important indicators for assessing environmental changes. Ratnagiri, situated at the southern end of Maharashtra, is a minor port used for industrial cargo and fishing. The present study was performed at three locations in the coastal region of Ratnagiri. Herein, I compared zooplankton standing stock (biomass, population, and faunal density), Physico-chemical parameters, tidal variability, spatial and temporal variation, and feeding habits in detail for over one and a half decades. Data collected at three sampling locations in the years 1999, 2009, and 2015 were compared. Outcomes of the study revealed considerable changes in zooplankton biomass, population density, and variation in the faunal group. The community structure of the zooplankton showed the dominance of herbivores followed by omnivores and carnivores. These comparisons could not only help us to enhance our understanding of changes in zooplankton in the past 16 years but also serve as the baseline for future studies.

Keywords: *zooplankton, Standing stock, Ratnagiri, water quality*

1. Introduction

In the past few decades, coastal marine ecosystems are under increasing pressure from multiple drivers related to human-induced environmental changes including resource extraction, habitat modification and destruction, and the introduction of pollutants and nutrients (Halpern et al., 2008). Zooplanktons have a pivotal role in the food chain by facilitating the passage of nutrients to lower levels and guaranteeing food supply to upper levels (Lomartire et al., 2021, Calbet, 2001). Zooplanktons are important indicators for assessing environmental changes owing to their large population density, short lifespan, drifting nature, high group, and species diversity, and different tolerances to stress. Monitoring the abundance, faunal composition, and distribution of zooplankton populations is essential to detect ecological changes in the marine environment. Zooplankton abundance and community change in response to chemical parameters over a period of decade impart a more comprehensive perspective on factors influencing lower trophic level food web dynamics. (Ezhilarasan et al., 2018). In many countries, the failure of fishing is reportedly attributed to reduced zooplankton populations (Rajasegar et al., 2000; Robertson & Blabber, 1992).

Several studies on zooplankton have been performed at various locations in Ratnagiri (Goswami et al., 2000; Kharate et al., 2018; Kulkarni & Mukadam, 2015;). Mirya Bay is a fishing harbor that is contaminated with trash fish, fishing-related wastes, and bilge from trawlers. Although the bay is not directly polluted by any industrial effluents, untreated sewage from the town of Ratnagiri flows into the coastal waters. In addition, Ratnagiri is a small port where barges transport

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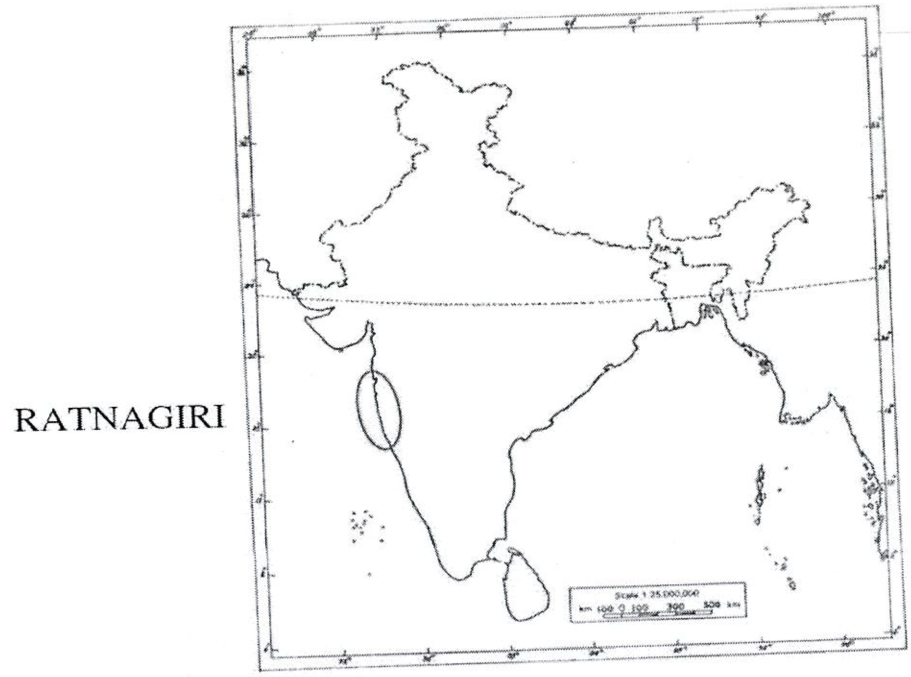
clinker for the cement plant. The quantum of waste released to this system remains unknown and the information on zooplankton diversity from Mirya Bunder, Ratnagiri, is limited. The present study, performed at Mirya Bay in Ratnagiri, reports results from a 16-year long time-series during which a sampling strategy for physicochemical and biological key variables was implemented. Long term plankton time series plays an essential role in detecting environmental changes (Hays et al., 2005; Mackas & Beaugrand, 2010; Perry et al., 2004). Therefore, the purpose of the present study was to provide an overview of the periodical variability of physicochemical parameters and the zooplankton abundance over two decades.

2. Material and Method

2.1 Station location: The present study was performed at Ratnagiri, which represents the marine environment off Mirya Bay and the surrounding regions. The following three sampling stations were chosen for the study: stations R1 (bay area,17°00'.36(N) 73°16'.77(E)), R2 (close to the Shore17°00'.27(N) 73°16'.11(E),), and R3 (3–5 km from the Shore,16°59'.90(N) 73°13'.33(E).



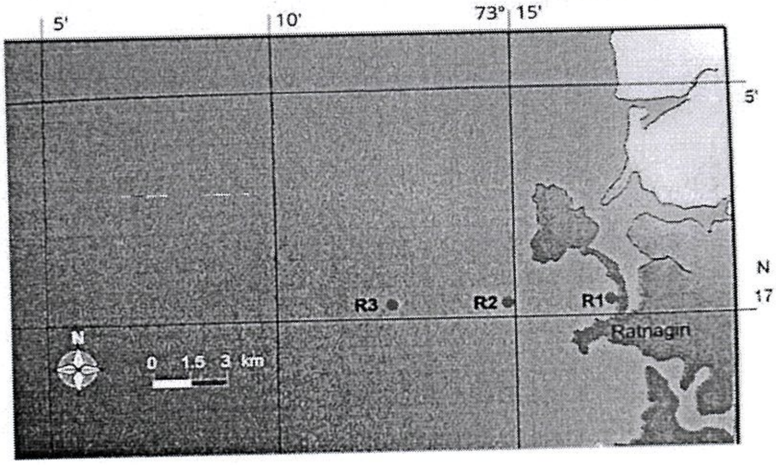


Fig 1: Sampling Location at Ratnagiri-West Coast of India

2.2 Sampling period and frequency:

Zooplankton and samples for water quality were collected once a year (premonsoon) in 1999, 2009, and 2015. The time gap of 10 (1999-2009) years and 6 years(2009-2015) was selected as changes in Physicochemical variables and zooplankton community can be vividly & clearly analyzed if a longer time horizon is selected. Wherever available, Physicochemical variables were also compared with the latest available data. However, comprehensive data for all parameters was available only till 2015. Diurnal collection for 12 hours was done at station R1. Samples for water quality were collected at 1-hour intervals, whereas samples for zooplankton were collected at 2-hour intervals. At station R2, samples were collected for 6 hours at 1-hour intervals for water quality and in 2-hour intervals for zooplankton and covering one high and low tide. At station R3, spot sampling was performed in duplicates.

2.3 Sampling procedure:

Samples were corrected using a Heron Tranter net (Tranter et al., 1972) with a mouth area of 0.25 m2 and mesh size of 0.33 mm attached with a calibrated tsk flowmeter. The zooplankton net was towed for approximately 5 minutes and an oblique haul was collected. (Achyutankutti & Kumar, 1974) The flow meter reading was used to calculate the volume of water filtered. The samples were preserved in 5% seawater buffered formalin and stored for biomass estimation and taxonomical observation.

2.4 Analysis:

In the laboratory, larger organisms such as jellyfish, prawns, and small fishes were removed before estimating the volume. The remaining zooplankton samples were filtered and excess water was drained on an absorbent paper. The volume of water filtered (V) through the net was calculated by adopting the following calibration formula provided with the flow meter:

$$V = [(0.157 \times N) - 0.003] \times A,$$

Where N = no of revolutions and
A = mouth area of the net.

The total volume of plankton was determined through the displacement method (Hansen, 1966; Sheaud, 1947), in which the displacement volume was expressed in terms of ml/100 m3. Zooplankton Sorting, identification and counting was performed under a Binocular microscope. (Olympus). The taxonomical identification up to the group level was carried out with the help of standard identification keys (Kasturirangan, 1963)

The organic carbon content of plankton was calculated as per the following formula (Nair et al., 1983a):

For station R1 and R2, 1 ml = 61.9 mg (dry weight).For station R3,1 ml is=81.7 mg (Nair, 1980a).

Organic carbon content is 34.5 % of the dry weight of the zooplankton at stations R1, and R2 and 41% for station R3. (Nair, 1980a). Physico chemical parameters such as atmospheric and surface water temperatures, and pH, were recorded during the sampling. Suspended solids, salinity, dissolved oxygen, biological oxygen demand, ammonia, and nutrients such as nitrate, and nitrite were analysed by adopting the standard methods. (APHA, 2005).

2.5 Statistical analysis:

For environmental parameters, the R software is used to perform non-parametric ANOVA (Kruskal-Wallis Test for ANOVA) Zooplankton data was treated with ANOVA, and Excel was used to calculate different statistical values and graphs.

3. Result and Discussion

3.1 Physicochemical variables:

In the duration of 16 years of the study and that found by Khandagale P. et.al (2022), Physico chemical parameters like atmospheric temperature, water temperature, and pH were comparable. Regarding salinity, no significant difference was observed during the study period. (Table 1) Average values for suspended load at Ratnagiri were 24.4, 13.2, and 17.9 mg/l for 1999, 2009, and 2015 respectively. The mean Dissolved oxygen (DO) in 2009(6.2 mg/l) and 2015(6.9 mg/l) was within range. A similar range of DO values (3.88- 6.4 mg/l) was also recorded by Khandagale P. et.al (2022). A Low DO value (2.8 mg/l) was observed in 1999, this could be due to port and fishing activities as well as sewage disposals from Ratnagiri town. High values of other parameters like ammonia(1.2 µmol/l),' and suspended load (24.4-highest in 1999 over 16 years) correspond to the low DO observed in 1999. DO concentration in the coastal water is primarily driven by various factors such as temperature organic matter degradation primary production and respiration. (Sarma et al., 2013) BOD values did not reflect a significant pattern recorded during the study period. (Table 1). A study by Khandagale P. et.al (2022) showed that BOD values have remained within the same range. NO_3–N varied without any trends. (mean 1999 -1.9 µmol/l, 2009 3.6 µmol/l, 2015- 0.1 µmol/l). Similarly, NO_2–N is found without any trend (mean 1999 -0.6 µmol/l, 2009 0.3 µmol/l, 2015- 0.9 µmol/l). The mean NH_4+-N values for the survey period were 1.2 µmol/l, 0.4 µmol/l, and 1.6 µmol/l.The overall results of water quality indicate good assimilation capacity of the water. Similar findings are noticed in NIO Technical Report (2018). Overall Kruskal-Wallis test indicates a p-value of less than 0.05 showing a significant difference over the years for all physicochemical parameters except salinity.

Table 1. Average values of the physicochemical parameters at stations R1, R2, and R3 of the Ratnagiri in 1999, 2009, and 2015, respectively.

mean ± std.dev.(range)).

	1999	2009	2015
AT(°C)	30.2 ± 1.5 (28.0-34.0)	28.9± 0.89 (28.8-29.0)	27.96±1.04 (26.0-30,5)
WT(°C)	29.5 ±0.9 (27.0-31.2)	28.7 ± 0.50 (28.0-29.9)	28.6±0.39 (27.5-29.4)
SS (mg/l)	24.4 ±8.9 (14.0-43.0)	13.2 ± 3.5 (8.6 -21.8)	17.9±2.93 (11.7-23.4)
pH	8.1 ±0.18 (7.8-8.4)	8.2 ± 0.02 (8.1-8.2)	8.2 ± 0.05 (8.0-8.3)
SAL(PPT)	35.1 ±1.0 (32.9-37.6)	34.7 ±0.26 (34.1-35.2)	34.2 ± 0.9 (33.0-35.3)
DO (mg/l)	2.8 ±1.1 (0.9-5.5)	6.2 ± 0.49 (4.2-6.9)	6.9 ± 0.23 (6.3-7.3)
BOD (mg/l)	1.2 ±0.5 (0.4-2.5)	2.5 ±1.5 (0.3-4.9)	1.8 ± 0.56 (1.0-2.9)
NO^{3-}-(µmol/l)	1.9 ±1.07 (0.1-4.1)	3.6± 0.5 (2.2-5.0)	0.1 ± 0.47 (0.1-0.2)
NO^{2-}-(µmol/l)	0.6 ±0.24 (0.1-1.6)	0.3±0.3 (0.1-1.0)	0.9 ±0.02 (0.2-2.0)
NH_4^+-(µmol/l)	1.2 ± 0.7 (0.3 -7.1)	0.4 ±0.21 (0.1-0.7)	1.6 ± 1.1 (0.4 -8.1)

AT: Atmospheric temp, WT: Water temp., SS: Suspended Solids, Sal: Salinity, DO: Dissolved Oxygen, BOD: Biological oxygen demand, NO^{2-}Nitrite, NO^{3-} Nitrate, NH_4^+- Ammonia.

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Table 2. P value calculated using Kruskal–Wallis Test for the physicochemical parameters.

	AT (°C)	WT (°C)	pH	SAL (PPT)	DO (mg/l)	BOD (mg/l)	NO^{2-} (µmol/l)	NO^{3-}- (µmol/l)	NH_4^+- (µmol/l)
P value	<.00001	.0022	.03452	.18042	<.00001.	< 0.00001	.00005	< .00001	< .00001

AT: Atmospheric Temp, WT: Water Temp, Sal: Salinity, DO: Dissolved Oxygen, BOD: Biological oxygen demand, NO^{2-}–Nitrite, NO^{3-} Nitrate, NH_4^+- Ammonia.

3.2 Zooplankton:

The zooplankton standing stock in terms of biomass was relatively high in 1999 (0.5–13.9 ml/100 m^3; mean, 4.3 ml/100 m^3) compared with that in 2015(0.1-4.8 ml/100 m^3; mean, 1.3 ml/100 m^3). In 2009, the increase in biomass was attributable to the ctenophores (100/100 m^3) and abundant cladocerans (37465/100 m^3). High biomass owing to ctenophores and cladocerans has also been reported by Santhakumari (1991). Furthermore, secondary productivity also shows similar results (1999: 90.9 mgC/100m^3/day, 2009: 363.0 mgC/100m^3/day, 2015: 29.5 mgC/100m^3/day). The abundance of cladocerans play important role in marine organic matter production is also reported by Marazzo & Valentin, (2004). The region showed no specific pattern for the zooplankton population(Table 3) and was highest during 2009(31.6 × 103–262.2 × 10^3/100m^3; mean, 122.4 × 103/100 m^3). Copepods and cladocerans are the main contributors to the high population in 2009, which was several times higher than the population in 1999 and 2015. ANOVA revealed the presence of a significant variation in the zooplankton biomass ($p < 0.05$; $F = 24.2$) and abundance ($p < 0.05$, $F = 7.9$) over the study period. Tidal variations for the years 1999 and 2015 show that the zooplankton biomass and population were higher during the flood tide than during the ebb. The faunal group was comparable between both flood and ebb tides. Jeyaraj et al (2014) found similar results.

In total, 27 zooplankton taxa were identified in the study area, in which copepods contributed to 75%, 62.7%, and 54.7% of the population during 1999, 2009, and 2015 respectively. Mestry et al. (2021) and Khandagale .P. et al (2022) also found Copepods in abundance at Ratnagiri. In the present study, Cladocerans was the second dominant taxa observed constituting 30.6% and 28.4% of total zooplanktons with an average population of 37465 individuals /100 m^3 and 7160 individuals/100 m^3 for the years 2009 and 2015. Similar Swarms of cladocerans associated with low salinity were examined and reported by Karwar by Santhakumari (1991). Another reason of abundance of cladocerans is the presence of fewer predator like chaetognaths (2009: 0.8%; 2015: 1.2%) and ctenophores (2009: 0.02%; 2015: 0.03%). Atienza et al. (2008) reported that the appearance of cladocerans is dominated by two factors, food availability, and predators. A similar observation was found by Socorrinha D'costa and Pai (2015). Notably, during 1999, the second dominant group appeared to be comprised of foraminiferans contributing 15.8% with an average abundance of 11051 individuals/100 m^3, whereas in 2009 and 2015 the foraminiferan was with very less numbers18 individuals/ 100 m^3 and 2 individuals /100 m^3 respectively. Planktonic foraminifera has the unique potential to substantially extend our view

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on plankton dynamics because their skeletal remains are preserved for millions of years in deep-sea sediments. Therefore, identifying links between sedimentary and modern time series offers great potential to study zooplankton dynamics across time scales that would have been inaccessible for direct observations. However, this link is rarely established and the potential of planktonic foraminifera for advancing our understanding of zooplankton dynamics warrants further research (Jonker et al, 2021). The order of abundance varied significantly for the study period showing fish eggs, decapod larvae, and chaetognaths as the most common groups for 1999. During 2009 and 2015 Siphonophores (av. 29291 individuals/100 m^3 in 2009 and 4882 individuals/100 m^3 in 2015) were numerically less abundant compared to copepods. However, as pure carnivores, their presence is noticed as they play a significant role in the food web. Santhakumari (1991).

The other groups recorded in 2009 were, chaetognaths (0.8%), lamellibranchs (0.7%), decapod larvae (0.3%), gastropods (0.3%), fish eggs (0.1%), appendicularian (0.4%) whose total contribution was 2.7%, similar group diversity was found by Goswami et al (2000). In 2015 decapods (3.2%), gastropods (3.0%), bivalve (2.5%) appendicularian (1.5%) Pteropod (0.5%) were found. The presence of these taxa indicates a positive influence on the fishery. (Table 4). Similar results in Mirya were found by Nair et al. (1980)

Table 3. Average values of the Zooplankton Biomass, Faunal Group, Population of the Ratnagiri in 1999-2009 and 2015.

(mean ± std. dev. (range)).

	1999	2009	2015
Biomass (ml/100 m^3)	4.3±3.7(0.5-13.9)	17.0± 5.4 (8.6-33.3)	1.38 ±1.3 (0.1-4.8)
Population (no x10^3/100 m3)	40.8±38.4(1.8-113.9)	122.4 ± 79.4(31.6-262.2)	25.1 ±18.9 (1.3-110.5)
Faunal group(no)	9± 1.75 (6-16)	17 ± 0.6 (15-18)	15 ± 1.7 (11-19)

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Table 4. List of Zooplankton Taxa, mean abundance, and frequency of occurrence (%) recorded at Ratnagiri during 1999,2009,2015.

Taxa	1999		2009		2015	
	Mean	Abundance (%)	Mean	Abundance (%)	Mean	Abundance (%)
Foraminifera	11051	15.8	18	.01	2	<0.1
Copepoda	30632	75.0	76809	62.7	13779	54.7
Decapod larva	910	2.2	367	0.3	808	3.2
Cumacea	-	-	-	-	-	<0.1
Mysida	265	0.3	-	-	2	<0.1
Stomatopods	1	<0.1	3	<0.1	-	-
Prawn larva	15	<0.1	-	-	-	-
Ostracoda	1	<0.1	1	<0.1	1	<0.1
Cladocera	1	<0.1	37465	30.6	7160	28.4
Isopod	-	-	1	<0.1	1	<0.1
Heteropod	-	-	37	0.03	1	<0.1
Polychaete larva	1	<0.1	19	0.2	25	0.1
Amphipoda	3	<0.1	34	0.03	4	<0.1
Chaetognatha	500	1.2	993	0.8	375	1.5
Ctenophore	4	<0.1	27	0.2	2	<0.1
Hydromedusae	-	-	8	0.1	4	<0.1
Siphonophorae	4	<0.1	4882	4.0	882	3.5
Doliolida	-	-	-	<0.1	-	
Appendicularia	73	0.1	480	0.4	382	1.5
Lucifer sp.	19	<0.1	5	<0.1	268	1.1
Bivalvia	307	0.3	832	0.7	631	2.5
Gastropoda	422	0.6	402	0.3	757	3.0
Pteropoda	-	-	4	<0.1	152	0.6
Marine Insect	1	<0.1	-	-	-	-
Fish Larvae	-	-	5	<0.1	31	<0.1
Fish egg	1789	4.4	98	0.1	20	<0.1

Community structure presented Significant change from 1999, to 2009. and 2015. The overall decrease in herbivores (71.7% to 32% and 35.9%) and carnivores' abundance (16.8%,4.8%, and 5.9%) was recorded. During the study period, omnivore zooplanktons gradually showed an increase in population (11.4%, 63.2,58.2) A shift in the pattern of abundance from Herbivores:Carnivores: Omnivores to Omnivores: Herbivores: Carnivores is noticed. This suggests that the nutritional requirement of the zooplankton community may shift to nonphytoplankton components and establish omnivorous and carnivorous taxa (Madhupratap et al., 1992).

4. Conclusion

Despite increased anthropogenic activities in the coastal waters under study, oxygen concentrations have not yet surfaced in these waters. However, the water quality will be affected if appropriate measures, including treatment of sewage water before releasing the same into the sea and proper fish discard, are not implemented. Zooplankton assemblages that were observed over the years showed significant differences; however, the diversity was comparable indicating that physicochemical arrows of more than one factor or unmeasured factors were likely to have been important controllers of abundance in these years of the study. In the present study, no distinct tendencies of zooplankton grouping depending on a particular environmental parameter were observed. The abundance of cladocerans in the zooplankton population is indirect evidence of potential fishery resources in the area. Additionally, cladocerans are known to have a positive influence on mackerel fishing; the Ratnagiri region is known for its abundance of mackerels. The presence of meroplankton, decapod, molluscan, and juveniles are indicators of the fishery potential in this area. Krishnamoorthy et al (1999). The present study on zooplankton provides the baseline information for future ecological assessment and monitoring; in addition, it may help in evaluating the fishery potential of the Mirya Bunder in the Ratnagiri coastal area.

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Authors statement

The author confirms sole responsibility for the study conception, data collection, analysis and result interpretation, and preparation of the manuscript.

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