

Building evidence for conservation globally

Journal of Threatened Taxa

10.11609/jott.2023.15.4.22927-23138

www.threatenedtaxa.org

26 April 2023 (Online & Print)

15(4): 22927-23138

ISSN 0974-7907 (Online)

ISSN 0974-7893 (Print)



Open Access





ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

EDITORS

Founder & Chief Editor

Dr. Sanjay Molur

Wildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO),
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India

Deputy Chief Editor

Dr. Neelesh Dahanukar

Noida, Uttar Pradesh, India

Managing Editor

Mr. B. Ravichandran, WILD/ZOO, Coimbatore, Tamil Nadu 641006, India

Associate Editors

Dr. Mandar Paingankar, Government Science College Gadchiroli, Maharashtra 442605, India

Dr. Ulrike Streicher, Wildlife Veterinarian, Eugene, Oregon, USA

Ms. Priyanka Iyer, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India

Dr. B.A. Daniel, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India

Editorial Board

Dr. Russel Mittermeier

Executive Vice Chair, Conservation International, Arlington, Virginia 22202, USA

Prof. Mewa Singh Ph.D., FASC, FNA, FNAsc, FNAPsy

Ramanna Fellow and Life-Long Distinguished Professor, Biopsychology Laboratory, and
Institute of Excellence, University of Mysore, Mysuru, Karnataka 570006, India; Honorary
Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; and Adjunct
Professor, National Institute of Advanced Studies, Bangalore

Stephen D. Nash

Scientific Illustrator, Conservation International, Dept. of Anatomical Sciences, Health Sciences
Center, T-8, Room 045, Stony Brook University, Stony Brook, NY 11794-8081, USA

Dr. Fred Pluthero

Toronto, Canada

Dr. Priya Davidar

Sigur Nature Trust, Chadapatti, Mavinhalla PO, Nilgiris, Tamil Nadu 643223, India

Dr. Martin Fisher

Senior Associate Professor, Battcock Centre for Experimental Astrophysics, Cavendish
Laboratory, JJ Thomson Avenue, Cambridge CB3 0HE, UK

Dr. John Fellowes

Honorary Assistant Professor, The Kadoorie Institute, 8/F, T.T. Tsui Building, The University of
Hong Kong, Pokfulam Road, Hong Kong

Prof. Dr. Mirco Solé

Universidade Estadual de Santa Cruz, Departamento de Ciências Biológicas, Vice-coordenador
do Programa de Pós-Graduação em Zoologia, Rodovia Ilhéus/Itabuna, Km 16 (45662-000)
Salobrinho, Ilhéus - Bahia - Brasil

Dr. Rajeev Raghavan

Professor of Taxonomy, Kerala University of Fisheries & Ocean Studies, Kochi, Kerala, India

English Editors

Mrs. Mira Bhojwani, Pune, India

Dr. Fred Pluthero, Toronto, Canada

Mr. P. Ilangoan, Chennai, India

Ms. Sindhura Stothra Bhashyam, Hyderabad, India

Web Development

Mrs. Latha G. Ravikumar, ZOO/WILD, Coimbatore, India

Typesetting

Mrs. Radhika, ZOO, Coimbatore, India

Mrs. Geetha, ZOO, Coimbatore India

Fundraising/Communications

Mrs. Payal B. Molur, Coimbatore, India

Subject Editors 2020–2022

Fungi

Dr. B. Shivaraju, Bengaluru, Karnataka, India

Dr. R.K. Verma, Tropical Forest Research Institute, Jabalpur, India

Dr. Vatsavaya S. Raju, Kakatiya University, Warangal, Andhra Pradesh, India

Dr. M. Krishnappa, Jnana Sahyadri, Kuvempu University, Shimoga, Karnataka, India

Dr. K.R. Sridhar, Mangalore University, Mangalagangothri, Mangalore, Karnataka, India

Dr. Gunjan Biswas, Vidyasagar University, Midnapore, West Bengal, India

Plants

Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India

Dr. N.P. Balakrishnan, Ret. Joint Director, BSI, Coimbatore, India

Dr. Shonil Bhagwat, Open University and University of Oxford, UK

Prof. D.J. Bhat, Retd. Professor, Goa University, Goa, India

Dr. Ferdinando Boero, Università del Salento, Lecce, Italy

Dr. Dale R. Calder, Royal Ontario Museum, Toronto, Ontario, Canada

Dr. Cleofas Cervancia, Univ. of Philippines Los Baños College Laguna, Philippines

Dr. F.B. Vincent Florens, University of Mauritius, Mauritius

Dr. Merlin Franco, Curtin University, Malaysia

Dr. V. Irudayaraj, St. Xavier's College, Palayamkottai, Tamil Nadu, India

Dr. B.S. Kholia, Botanical Survey of India, Gangtok, Sikkim, India

Dr. Pankaj Kumar, Department of Plant and Soil Science, Texas Tech University, Lubbock, Texas, USA.

Dr. V. Sampath Kumar, Botanical Survey of India, Howrah, West Bengal, India

Dr. A.J. Solomon Raju, Andhra University, Visakhapatnam, India

Dr. Vijayasankar Raman, University of Mississippi, USA

Dr. B. Ravi Prasad Rao, Sri Krishnadevaraya University, Anantpur, India

Dr. K. Ravikumar, FRLHT, Bengaluru, Karnataka, India

Dr. Aparna Watve, Pune, Maharashtra, India

Dr. Qiang Liu, Xishuangbanna Tropical Botanical Garden, Yunnan, China

Dr. Noor Azhar Mohamed Shazili, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia

Dr. M.K. Vasudeva Rao, Shiv Ranjani Housing Society, Pune, Maharashtra, India

Prof. A.J. Solomon Raju, Andhra University, Visakhapatnam, India

Dr. Mandar Datar, Agharkar Research Institute, Pune, Maharashtra, India

Dr. M.K. Janarthanam, Goa University, Goa, India

Dr. K. Karthigeyan, Botanical Survey of India, India

Dr. Errol Vela, University of Montpellier, Montpellier, France

Dr. P. Lakshminarasimhan, Botanical Survey of India, Howrah, India

Dr. Larry R. Noblick, Montgomery Botanical Center, Miami, USA

Dr. K. Haridasan, Pallavur, Palakkad District, Kerala, India

Dr. Analinda Manila-Fajard, University of the Philippines Los Banos, Laguna, Philippines

Dr. P.A. Sinu, Central University of Kerala, Kasaragod, Kerala, India

Dr. Afroz Alam, Banasthali Vidyapith (accredited A grade by NAAC), Rajasthan, India

Dr. K.P. Rajesh, Zamorin's Guruvayurappan College, GA College PO, Kozhikode, Kerala, India

Dr. David E. Boufford, Harvard University Herbaria, Cambridge, MA 02138-2020, USA

Dr. Ritesh Kumar Choudhary, Agharkar Research Institute, Pune, Maharashtra, India

Dr. A.G. Pandurangan, Thiruvananthapuram, Kerala, India

Dr. Navendu Page, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand, India

Dr. Kannan C.S. Warrior, Institute of Forest Genetics and Tree Breeding, Tamil Nadu, India

Invertebrates

Dr. R.K. Avasthi, Rohtak University, Haryana, India

Dr. D.B. Bastawade, Maharashtra, India

Dr. Partha Pratim Bhattacharjee, Tripura University, Suryamaninagar, India

Dr. Kailash Chandra, Zoological Survey of India, Jabalpur, Madhya Pradesh, India

Dr. Ansie Dippenaar-Schoeman, University of Pretoria, Queenswood, South Africa

Dr. Rory Dow, National Museum of Natural History Naturalis, The Netherlands

Dr. Brian Fisher, California Academy of Sciences, USA

Dr. Richard Gallon, Llandudno, North Wales, LL30 1UP

Dr. Hemant V. Ghatge, Modern College, Pune, India

Dr. M. Monwar Hossain, Jahangirnagar University, Dhaka, Bangladesh

Mr. Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope

For Article Submission Guidelines, visit <https://threatenedtaxa.org/index.php/JoTT/about/submissions>

For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: Mauve Stinger *Pelagica noctiluca* by Swaathi Na. Medium used is soft pastels and gelly roll.



Recent Foraminifera from the coast of Mumbai, India: distribution and ecology

Ganapati Ramesh Naik¹ , Manisha Nitin Kulkarni² & Madhavi Manohar Indap³

^{1,3} Department of Zoology, Central Research Laboratory, D.G. Ruparel College of Arts, Science & Commerce, Senapati Bapat Marg, Mahim, Mumbai, Maharashtra 400016, India.

² Department of Zoology, The Institute of Science, 15, Madam Cama Road, Mumbai, Maharashtra 400032, India.

¹ gnsrnaik@gmail.com, ² harmonium.mnk@gmail.com, ³ madhaviindap@yahoo.com (corresponding author)

Abstract: Foraminifera have been used in biostratigraphy and paleoenvironmental research. They are useful environmental indicators for monitoring the marine environment. Intertidal sediment samples were analysed for their diversity in relation to physicochemical parameters and sediment characteristics along the Mumbai coast of India. Thirty-five species were found, divided into five orders and 18 families. The orders Rotaliida and Miliolida were identified to be dominant. Foraminifera were observed to be inversely related to sand particle size in relation to sediment and physicochemical parameters of water. Canonical correlation analysis explained the relationship between species abundance and water physicochemical parameters.

Keywords: Abundance, anthropological activities, environmental indicators, foram, grain size, marine coastal area, physicochemical factors, Protista

Abbreviations: CCA—Canonical correlation analysis | DO—Dissolved oxygen | MON—Monsoon | MPCB—Maharashtra Pollution Control Board | OC—Organic carbon | OM—Organic matter | POM—Post-monsoon | PRM—Pre-monsoon | TFN—Total foraminifera number | WNT—Winter.

Editor: Rajashekhar K. Patil, Mangalore University, Mangalore, India.

Date of publication: 26 April 2023 (online & print)

Citation: Naik, G.R., M.N. Kulkarni & M.M. Indap (2023). Recent Foraminifera from the coast of Mumbai, India: distribution and ecology. *Journal of Threatened Taxa* 15(4): 23101–23113. <https://doi.org/10.11609/jott.7813.15.4.23101-23113>

Copyright: © Naik et al. 2023. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

Funding: There is no Government funding. Partially funded by Fine Envirotech Engineers, Mumbai.

Competing interests: The authors declare no competing interests.

Author details: MR. GANAPATI RAMESH NAIK, PhD research scholar at D G Ruparel College's Department of Zoology, Central Research Laboratory. Has spent the last six years working in the subject of marine ecology. DR. MANISHA NITIN KULKARNI is currently a professor in the Department of Zoology at The Institute of Science in Mumbai. Her scientific interests include biodiversity and endocrinology. DR. MADHAVI MANOHAR INDAP is an emeritus professor. Adjunct faculty at D G Ruparel College's Central Research Laboratory in Mumbai. Her areas of interest in study include biodiversity, ecology, and marine biotechnology.

Author contributions: Madhavi Indap (MI) had conceptualized the study, directed and finalized the manuscript. Ganapati Naik (GN) collated in the information, evaluated the data and wrote the manuscript. Manisha Kulkarni (MK) had supervised the manuscript.

Acknowledgements: We are thankful to National Centre for Nano-sciences and Nanotechnology, University of Mumbai (NCNNUM) for providing us the facility of scanning electron microscopy (SEM) for our work. We are grateful to Fine Envirotech Engineers, Mumbai for providing financial help to carry out this work.



INTRODUCTION

Mumbai, the state capital of Maharashtra, has a population of about 22 million people. It is also the largest and busiest port on India's west coast. Intertidal zone of Mumbai represents the peak of adaptability by most types of marine life to harsh environmental circumstances such as wave action, desiccation and other associated aspects generated by the tides of the sea (Kameswara & Srinath 2002). Among marine microorganisms, foraminifera are exceptionally varied and widely spread (Cushman et al. 1928). They are distinguished as protists by having an external test and streaming granular ectoplasm. Their tests are composed of calcium carbonate or agglutinated sediments, which are well preserved after death (Vidya & Patil 2014). They are considered good ecological indicators for detection and monitoring of coastal pollution (Pravasini & Patra 2012). According to Fabrizio et al. (2013), *Ammonia tepida* has a high resistance to environmental stress while *Ammonia parkinsoniana* is sensitive to pollution. These are the most widely used fossil species for biostratigraphy, sediment correlation and palaeoenvironmental research (Murray 2006) and their usage as bio-indicators in offshore oil drilling operations is well documented (Mariéva et al. 2010). Abninath & Biswas (1954), Devi & Rajashekhar (2009), and Subhadra & Patil (2012) conducted intertidal studies of foraminifera from the Mumbai coast on diversity studies in the intertidal region. Coastal water is vulnerable to contamination since 38% of the world's population lives within 100 kilometres of the coast (Pravasini & Patra 2012). Coastal pollution is caused by point and non-point wastewater sources from cities, which include sewage water, waste from industry and harbours, beach tourism and fishing crafts activities. Pollution has a negative impact on organisations at all levels, from the organism to the community and the environment (Francisco et al. 2011).

The current study was undertaken to document the Foraminifera at several sites along the Mumbai coast. The objective was to determine the relationship between forum abundance and various physicochemical factors, as well as anthropological activities. This information will aid in the creation of a database of foraminifera along Mumbai's coastline and contribute to understanding the effects of natural and anthropogenic events on Foraminifera.

Study Area

Mumbai is located at 19.0760° N & 72.8777° E, with an overall coast length of 149 km. Four coastal locations with distinct ecology were chosen for sampling. These sites range from north to south along the Mumbai shoreline (Figure 1). Gorai beach (M1) is located in Mumbai's northwestern outskirts. It is regarded as one of Mumbai's cleanest beaches. Juhu beach (M2) has a five-kilometre coastline. Dadar beach (M3) is situated on the south-west side of Mahim Island. Girgaon beach (M4) is located on Mumbai Island's south-west coast. M2, M3, and M4 are well-known tourist attractions. Mumbai's water quality is deteriorating as a result of pollutants from wastewater treatment facilities, sewage discharges, and discharges from point and non-point sources in the creek and along the shore (Ritesh et al. 2015).

MATERIAL AND METHODS

Sediment samples were collected in two phases: September 2013–August 2014 and December 2016–November 2017, from four stations: M1, M2, M3, and M4. The sampling was divided into four seasons: pre-monsoon (March–May), monsoon (June–August), post-monsoon (September–November), and winter (December–February).

Using a scientific spatula, the upper one cm layer of sand sediment was collected in duplicates between the intertidal zone during low tide. Forams were stained using Rose Bengal solution and stored in 70% isopropyl alcohol (Walton et al. 1952). The materials were washed through a 63 µm sieve and oven-dried at 60°C for analysis. A stereo microscope was used to examine one gram of sand from each station. The total number of specimens (live + dead) was used to calculate abundance. Forum tests were hand-picked and put on micro-paleontological slides using a foram sorting brush. 'JEOL JSM - 5800VS' scanning electron microscope (SEM) was used to image selected specimens. The Loeblich & Tappan (1988) classification system and the e-site "World Foraminifera Database" (Hayward et al. 2022) were used for taxonomic analysis.

Temperature, pH, salinity, dissolved oxygen (DO), phosphates and nitrates were chosen as water physicochemical parameters. A digital thermometer was used to record the temperature of the water at sample sites. pH, salinity and DO were measured with a "Thermo Scientific Eutech PCD-650 multi-parameter metre." Nutrients nitrate and phosphate were estimated

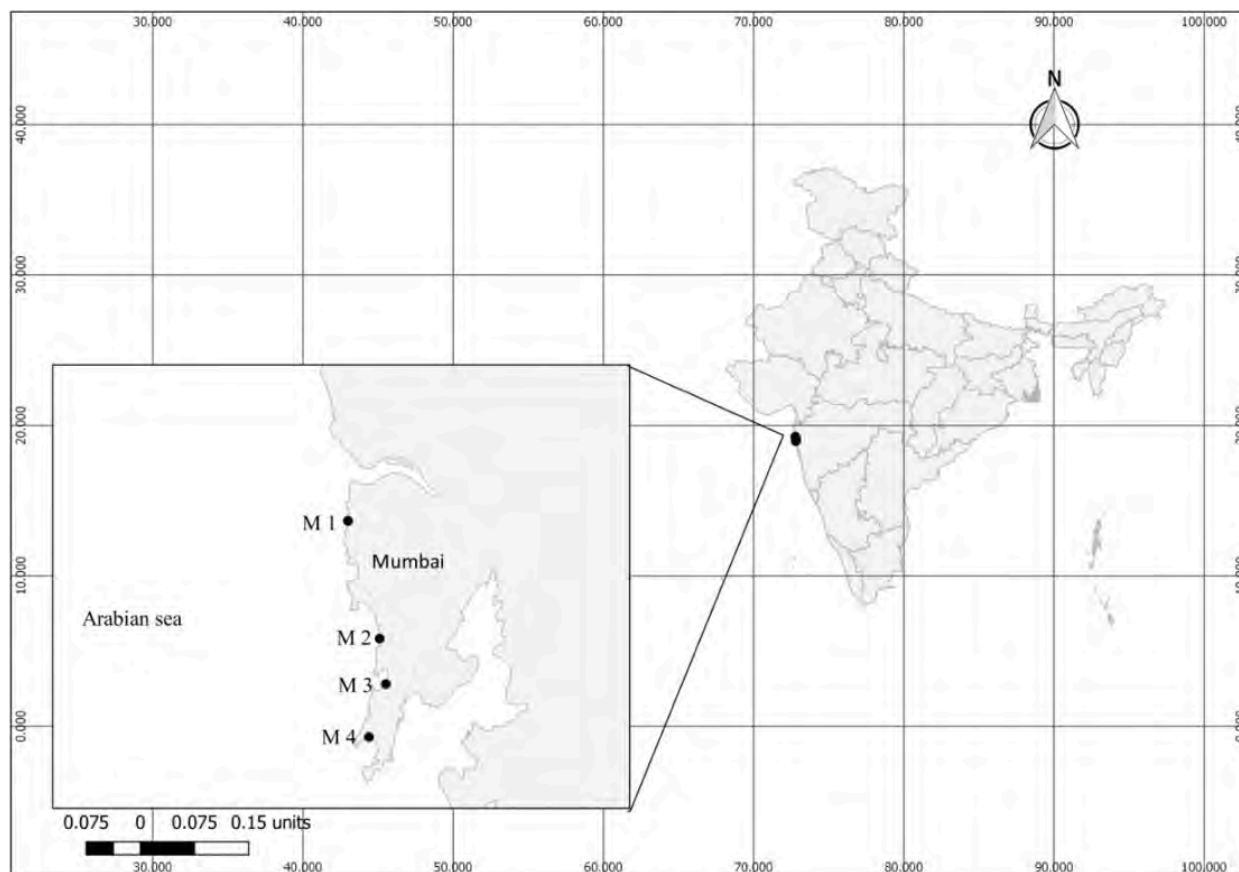


Figure 1. Map depicting the study area with sampling sites.

using standard methods given in the APHA manual (Lenore et al. 1999).

Another batch of sand sediment was collected for measurement of organic carbon by titration with ammonium ferrous sulphate using the Walkley-Black technique with suitable modification (Syed et al. 2011). To determine the texture of sand sediment, samples were sieved through multiple mesh sizes. The soil textural triangle approach (Derek et al. 2015) was used to determine their type. Past 3 v4.03 software was used to calculate diversity indices including the Shannon index, Simpson index, Evenness, Margalef index, canonical correlation, and Q-mode cluster.

RESULTS AND DISCUSSION

Foraminifera Assemblage & Physicochemical Parameters

The current study revealed the existence of 35 species from four orders, 18 families and 21 genera (Table 1). These 35 species were divided into 33 benthic

and two planktonic species. M1, M2, M3, and M4 stations revealed the presence of 34, 32, 33, and 22 species, respectively. Order Rotaliida was dominant with 19 species, followed by order Miliolida, which had 11 species. The dominant species identified along Mumbai's shore were *Nonion scaphum* (17.8%), *Ammonia beccarii* (15.7%), *A. dentata* (12%), *Elphidium hispidulum* (8.9%), and *Bolivina striatula* (5.7%). Table 2 has a Foraminifera checklist. Images 1 (1–20) and 2 (1–19) displays SEM images that illustrate the morphological trait of species.

The total Foraminifera number (TFN) is the total number of individuals found in one gram of sediment. TFN values in samples ranged from 590 at M2 to 178 at M4 per gram. Northern Mumbai stations (M1, M2) showed greater values, whereas southern Mumbai stations recorded lesser values (M3, M4).

Shannon index (H) represented both species abundance and evenness in areas ranging from 2.06 (M4) to 2.77 (M2). Simpson index of dominance (D) revealed the dominance of cosmopolitan species with values 0.08 (M2) to 0.21 (M4). Equitability index revealed species evenness (e^H/S) with values ranging from 0.41 (M3)

to 0.67 (M4). The Margalef index of species richness ranged from 2.09 (M4) to 5.04 (M1), and is directly related to taxonomic numbers 12 (M4) and 32 (M1). Table 3 presents the diversity indices.

The water parameters including pH, temperature, salinity, dissolved oxygen, phosphate, and nitrate were considered for study of various seasons including, pre-monsoon, monsoon, post-monsoon, and winter, which are represented in Table 4.

The pH ranged from 6.54 at M2 during post-monsoon to 7.89 at M4 during monsoon. Water temperatures in the intertidal zone ranged from 25°C reflecting monsoon at M4 to 29°C representing pre-monsoon at M1. Salinity at all sites varied with the seasons, ranging from 17 during the monsoon at M1 to 41 during the pre-monsoon at M2.

Dissolved oxygen, phosphate and nitrate showed variations in its concentrations. DO levels were highest during the pre-monsoon (7.4 mg/l) and lowest during the winter (3.1 mg/l) at M1. Similarly, in monsoon, M4 station had the lowest phosphate and nitrate levels, viz., 0.14 mg/l and 0.1 mg/l and M3 in winter revealed the greatest phosphate and nitrate ranges 0.56mg/l to 1.5mg/l, respectively.

The sediment type study revealed that silt type occurred at the M1 and M2, loamy sand at the M3 and sandy loam at the M4. The organic carbon percentage of sediment varied between stations, ranging from 0.28% to 0.37% (Table 4).

Pearson Correlation & Canonical Correlation Analysis (CCA)

For the water parameters and diversity indices, a Pearson correlation matrix was calculated (Table 5). The pH and dissolved oxygen correlated positively with species evenness but negatively with the other indices. Temperature correlated positively with the number of taxa, the H index and the Margalef index. Salinity only correlated positively with species dominance. Phosphate and nitrate had a significant negative correlation with species evenness.

CCA defined a relationship between species, stations and environmental parameters (Figure 2). For this analysis, species having a total population more than 1% was chosen, which included population of 18 species. Phosphate and dissolved oxygen defined axis one, whereas nitrate, pH, salinity, and temperature defined axis two. According to CCA analysis nitrate, pH and salinity correlated positively, but temperature correlated negatively with all other physicochemical parameters. All of the water parameters were found to have a significant

correlation with 12 species.

Ammonia beccarii, *E. repandus*, *A. dentata*, and *S. raphana* were abundant at three sample stations displayed in the top-right quadrant of the graph. *T. oblonga*, *A. intricata*, *T. tricarinata*, and *E. hispidulum* peaked at five stations in the bottom right quadrant of the graph. *Q. vulgaris*, *U. senticosa*, *N. scaphum*, and *B. pseudoplicata* showed the highest abundance at five stations represented at top-left quadrant of graph and species *B. marginata*, *R. globularis*, *B. striatula*, *C. lobatulus*, *Q. tropicalis*, and *E. advenum* were most abundant at three stations represented at bottom-left quadrant of graph.

A. beccarii and *A. dentata* are mainly found in waters with high nitrate levels. *N. scaphum* was well associated with ambient temperature and phosphate concentration. *B. striatula*, *C. lobatulus* and *Q. tropicalis* held the average positions for all parameters. *E. hispidulum* and *T. tricarinata* were significantly correlating with DO, pH, and salinity.

Species-ecological Relationship

This research attempted to investigate the relation of foraminifera to intertidal benthic ecology at different stations. Data from physicochemical parameters were correlated with dominant species using specific indices.

At M1 TFN ranged from 533 to 450 individuals per gram, it was represented by 34 species. *N. scaphum* (28.33%), *A. dentata* (12.3%), *E. hispidulum* (8%) and *A. beccarii* (7.64%) were dominant species representing the area. According to Kumar & Manivannan (2001) *N. scaphum* has shown positive correlation to an increase in temperature and DO, our data support this statement. During the winter, the Simpson's index 0.14 is correlating with nitrate value. There is cumulative impact of nitrate and temperature with bleaching response on foraminifera (Martina et al. 2017), allowing only tolerant species to thrive. Thirty-one species have been identified at M2, with a maximum foraminifera test count of 590 in pre-monsoon. Here major taxa were again *N. scaphum* (21%), *A. dentata* (10.82%), and *A. beccarii* (10.59%). Phosphate has long been recognized as a calcite formation inhibitor, adsorbing onto the calcite surface and inhibiting active crystal growth sites (Aldridge et al. 2011), which might account for lower test numbers than M1. After *A. beccarii*, the dominant species was *B. striatula* (8.12%). *Lagena*, *Fissurina*, *Bolivina*, *Bulimina*, and *Uvigerina* species are found in finer sediments and exist in the shelf to slope area, according to Rajiv et al. (1986); however their prevalence in the study area

Table 1. Foraminiferal taxa composition along with the stations of Mumbai coast.

	Order	Family	Genus	Species
1	Rotaliida	Nonionidae	<i>Nonion</i>	<i>Nonion scaphum</i>
2		Ammoniididae	<i>Ammonia</i>	<i>Ammonia beccarii</i>
3				<i>Ammonia dentata</i>
4		Bolivinitidae	<i>Bolivina</i>	<i>Bolivina striatula</i>
5				<i>Bolivina pseudoplicata</i>
6		Siphogenerinoididae	<i>Spiroloxostoma</i>	<i>Spiroloxostoma glabra</i>
7			<i>Siphogenerina</i>	<i>Siphogenerina raphana</i>
8				<i>Siphogenerina</i> sp.
9		Elphidiidae	<i>Elphidium</i>	<i>Elphidium hispidulum</i>
10				<i>Elphidium advenum</i>
11				<i>Elphidium</i> sp.
12		Rosalinidae	<i>Rosalina</i>	<i>Rosalina globularis</i>
13		Eponididae	<i>Eponides</i>	<i>Eponides repandus</i>
14		Cibicididae	<i>Cibicides</i>	<i>Cibicides lobatulus</i>
15		Discorbinellidae	<i>Discorbinella</i>	<i>Discorbinella</i> sp.
16		Buliminidae	<i>Bulimina</i>	<i>Bulimina marginata</i>
17		Uvigerinidae	<i>Uvigerina</i>	<i>Uvigerina senticosa</i>
18		Globigerinidae	<i>Globigerina</i>	<i>Globigerina bulloides</i>
19			<i>Globigerinoides</i>	<i>Globigerinoides</i> sp.
20	Miliolida	Hauerinidae	<i>Quinqueloculina</i>	<i>Quinqueloculina tropicalis</i>
21				<i>Quinqueloculina porterensis</i>
22				<i>Quinqueloculina vulgaris</i>
23				<i>Quinqueloculina polygona</i>
24				<i>Quinqueloculina agglutinans</i>
25		<i>Triloculina</i>	<i>Triloculina</i>	<i>Triloculina tricarinata</i>
26				<i>Triloculina oblonga</i>
27		Spiroloculinidae	<i>Spiroloculina</i>	<i>Spiroloculina antillarum</i>
28				<i>Spiroloculina communis</i>
29		Cribrulinoididae	<i>Adelosina</i>	<i>Adelosina intricata</i>
30		Cornuspiridae	<i>Cornuspira</i>	<i>Cornuspira involvens</i>
31	Nodosariida	Lagenidae	<i>Lagena</i>	<i>Lagena vulgaris</i>
32				<i>Lagena sulcata</i>
33				<i>Lagena laevis</i>
34	Polymorphinida	Ellipsolagenidae	<i>Fissurina</i>	<i>Fissurina cucullata</i>
35				<i>Fissurina</i> sp.

may be due to wave action. M3 receives water runoff from the Mithi River and had low salinity during the monsoon due to monsoon water, in addition to large amount of sewage and industrial garbage from the Mithi (Jayasiri et al. 2014). At the M3, 33 distinct taxa were present. *A. beccarii* (24.18%), *A. dentata* (15.2%), and *E. hispidulum* (12.21%) dominated the station. M4 had taxa count 20 with a maximum of 198 individuals. The

dominant species representing the area were *A. beccarii* (32.67%), *T. tricarinata* (15.02%), and *E. hispidulum* (11.55%).

The distribution of benthic Foraminifera is influenced by organic carbon (OC) and sediment type (Elakkiya & Manivannan 2013). Benthic foram have been shown to be closely associated with variations in percent gravel, organic carbon flux, temperature and salinity (Alexandra

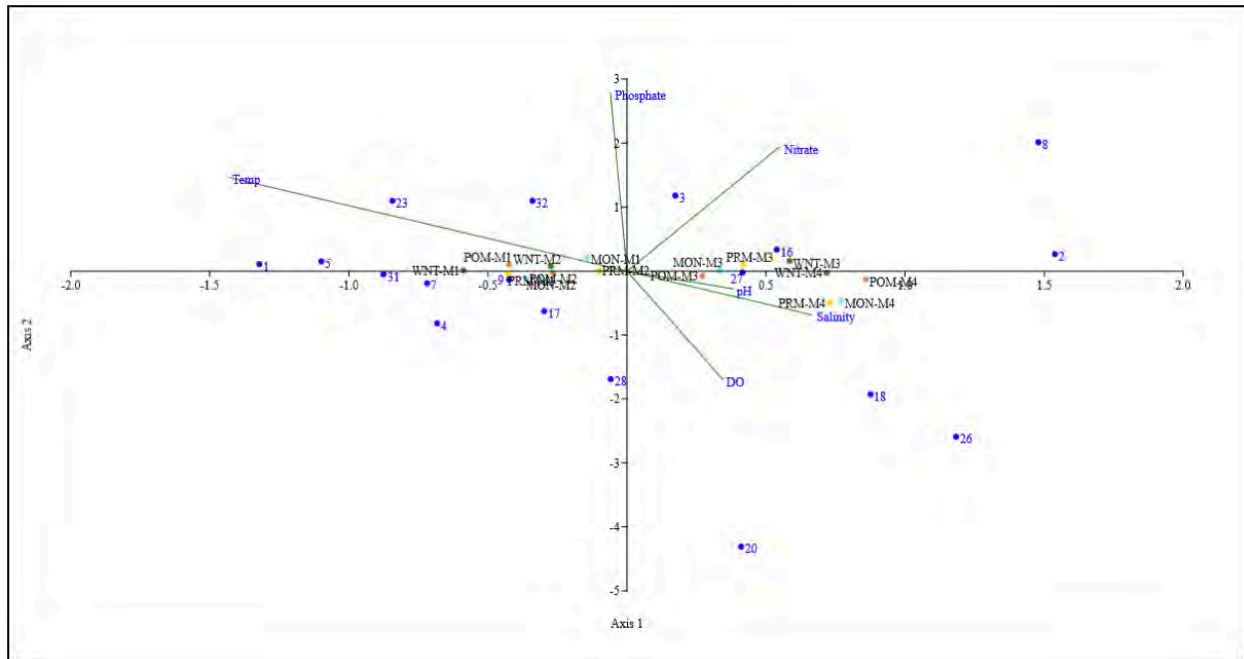


Figure 2. Canonical correlation analysis (CCA) of abundant species with relation to physico-chemical parameters of water and station distribution.

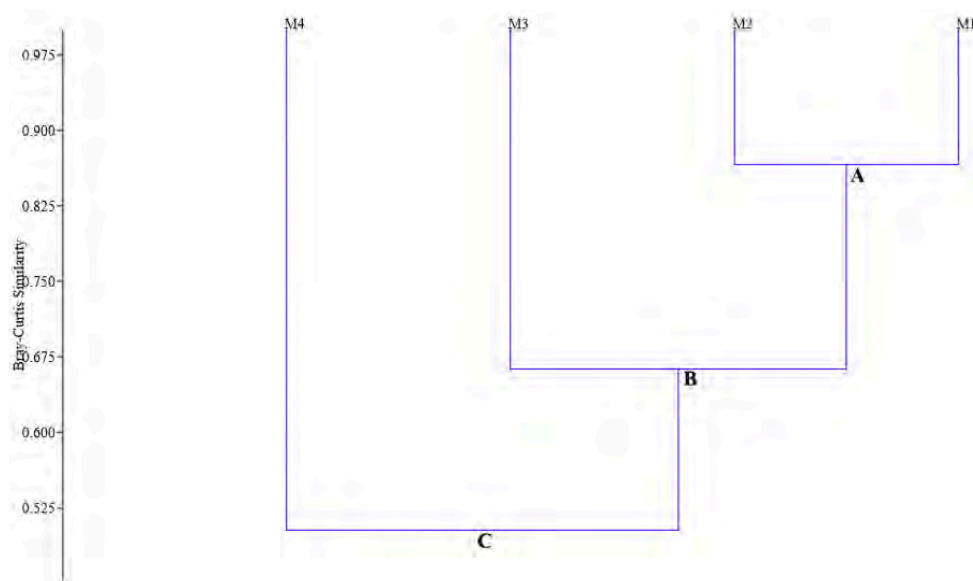


Figure 3. Bray-Curtis hierarchical cluster analysis for sampling stations.

et al. 2007). The sediment at stations M1 and M2 was silt type, with 0.34% and 0.28% organic carbon, respectively. At M1 Margalef index of 5.04 and at M2 Shannon value of 2.77 were both positively correlated with sediment type, as sand mixed with shelly fragments and silt or clay support the richest standing crop of foraminifera (Chaturvedi et al. 2000). Station M3 had loamy sand with the highest organic carbon content of 0.37% of

all stations. Water discharge from Mahim Creek has the highest percentage of organic carbon, as the creek is the largest sink for the most of waste created by residential complexes and small-scale industry (Singare et al. 2015). Station M4 is associated with 0.31% organic carbon with sediment particle size larger than other stations. According to Elena et al. (2019) stations exposed to the open sea and intensified currents were

Table 2. Distribution of Foraminifera species along four stations of Mumbai coast.

	Species	M1	M2	M3	M4
1	<i>Nonion scaphum</i>	+	+	+	+
2	<i>Ammonia beccarii</i>	+	+	+	+
3	<i>Ammonia dentata</i>	+	+	+	+
4	<i>Bolivina striatula</i>	+	+	+	+
5	<i>Bolivina pseudoplicata</i>	+	+	+	+
6	<i>Spiroloxostoma glabra</i>	+	+	+	-
7	<i>Siphogenerina raphana</i>	+	+	+	+
8	<i>Siphogenerina</i> sp.	+	+	+	-
9	<i>Elphidium hispidulum</i>	+	+	+	+
10	<i>Elphidium advenum</i>	+	+	+	+
11	<i>Elphidium</i> sp.	+	-	+	+
12	<i>Rosalina globularis</i>	+	+	+	+
13	<i>Eponides repandus</i>	+	+	+	+
14	<i>Cibicides lobatulus</i>	+	+	+	+
15	<i>Discorbinella</i> sp.	-	-	+	-
16	<i>Bulimina marginata</i>	+	+	+	+
17	<i>Uvigerina senticosa</i>	+	+	+	+
18	<i>Globigerina bulloides</i>	+	+	+	-
19	<i>Globigerinoides</i> sp.	+	+	+	-
20	<i>Quinqueloculina tropicalis</i>	+	+	+	+
21	<i>Quinqueloculina portensis</i>	+	+	+	-
22	<i>Quinqueloculina vulgaris</i>	+	+	+	+
23	<i>Quinqueloculina polygona</i>	+	+	+	+
24	<i>Quinqueloculina agglutinans</i>	+	-	-	-
25	<i>Triloculina tricarinata</i>	+	+	+	+
26	<i>Triloculina oblonga</i>	+	+	+	+
27	<i>Spiroloculina antillarum</i>	+	+	+	+
28	<i>Spiroloculina communis</i>	+	+	+	+
29	<i>Adelosina intricata</i>	+	+	+	+
30	<i>Cornuspira involvens</i>	+	+	+	-
31	<i>Lagena vulgaris</i>	+	+	+	-
32	<i>Lagena sulcata</i>	+	+	+	-
33	<i>Lagena laevis</i>	+	+	-	-
34	<i>Fissurina cucullata</i>	+	+	+	-
35	<i>Fissurina</i> sp.	+	+	+	-

defined by coarser sediments. As M4 had sandy loam type of sediment suggesting good wave action due to its association with open sea. The moderate value of OC at this station is associated with sediment type, since in coarse-grained sand, interstitial water may travel easily through pore spaces, resulting in less organic particle settling (Hiroshi 1994).

A. beccarii and *A. dentata* correlated negatively with DO values from all stations, making them adaptable to anoxic conditions (Fatin et al. 2012; Sundara et al. 2016). *B. striatula* which thrived well in low oxygen stations (Abhijit & Nigam 2014) and was positively associated to salinity since it is an opportunistic species that can thrive in both high and low salinity conditions (Patricia et al. 2019). The dominance of *Ammonia* sp. and *Elphidium* sp. in study area indicated that they are resistant to decreased salinity, pH or a combination of the two factors (Laurie et al. 2018).

N. scaphum adapted to environments characterized by high organic matter (OM) quality and it indicates affinity for OM-rich sediments (Pierre et al. 2016), so its distribution is well associated with M1 and M2 as compared to M4 which had more coarse type of sediment. *A. dentata* and *E. hispidulum* was abundant at M1, M2 and M3 as silt sand is preferred by the species over coarse sandy sediment (Elakkiya & Manivannan 2013), with affinity for larger amount of organic carbon values (Maria et al. 2012). However, based on our understanding of above work on foraminifera, we may conclude that the cosmopolitan species *A. beccarii*, *A. dentata*, *B. striatula*, *N. scaphum*, and *E. hispidulum* thrive well in Mumbai waters.

Hierarchical Cluster Analysis

Foraminifera species were tested to a Bray-Curtis cluster analysis in relationship to stations (Figure 3). It divided stations into three groups: Cluster A (M1 + M2), Cluster B (Cluster A + M3), and Cluster C (Cluster B + M4).

Cluster A consists of two stations (M1 + M2) that share 32 species. It had a similar type of sediment, silt with physicochemical properties. CCA analysis showed these stations near to one other on the middle and left sides of Axis one. The main representatives of this cluster were *N. scaphum* (21–28.3%), *A. beccarii* (7.6–10.5%), *A. dentata* (10.8–12.3%), *B. striatula* (6.6–8.1%), *B. pseudoplicata* (5.5–5.6%), *C. lobatulus* (4.7–5.5%), *Q. tropicalis* (3.5–6.4%), *E. hispidulum* (6.5–8%), *U. senticosa* (2.9–3.7%), *T. tricarinata* (1.8–3.5%) and *B. marginata* (2.8–3.1%). Species like *N. scaphum*, *A. dentata*, and *B. striatula* have more affinity for fine sediment like silt than coarse type of sediment.

Cluster B comprised of three stations (Cluster A + M3) with 31 species in common. In this cluster M3 is having more similarity with M2 than M1. The cluster had silt and loamy sand sediment which showed a little correlation with one another. The main species represented by the cluster were *N. scaphum* (8.2–28.3%), *A. beccarii* (7.6–24.1%), *A. dentata* (10.8–15.2%), *E. hispidulum*

Table 3. Biodiversity indices of Foraminifera for Mumbai coast.

Station	Season	Taxa	Individuals	Dominance	Shannon	Evenness	Margalef
M1	Pre-monsoon	32	467	0.1249	2.646	0.4407	5.044
	Monsoon	28	533	0.1224	2.529	0.4479	4.3
	Post-monsoon	29	476	0.1203	2.585	0.4575	4.541
	Winter	28	450	0.1474	2.525	0.446	4.42
M2	Pre-monsoon	29	590	0.1039	2.671	0.4983	4.389
	Monsoon	27	431	0.087	2.776	0.5945	4.286
	Post-monsoon	28	414	0.08698	2.757	0.5625	4.481
	Winter	27	486	0.1057	2.625	0.5113	4.203
M3	Pre-monsoon	27	363	0.1259	2.528	0.4638	4.411
	Monsoon	29	385	0.1069	2.681	0.5035	4.703
	Post-monsoon	26	328	0.09856	2.644	0.5411	4.316
	Winter	29	389	0.1413	2.484	0.4132	4.695
M4	Pre-monsoon	19	193	0.1416	2.317	0.5339	3.42
	Monsoon	12	192	0.1593	2.086	0.6711	2.092
	Post-monsoon	17	178	0.2122	2.064	0.4632	3.088
	Winter	20	198	0.1662	2.297	0.4971	3.593

(6–12.2%), *T. tricarinata* (1.8–6.2%), *E. repandus* (0.9–3.3%), *C. lobatulus* (3.2–5.5%), *B. striatula* (3.1–8.1%), and *Q. tropicalis* (3.2–6.4%).

Cluster C comprised of all four stations (Cluster B + M4) that share 22 species in common. In this cluster M4 had more similarity with M3 as compared with Cluster A. As M3 and M4 had loamy sand and sandy loam sediment, which had more similarity with each other. Having a more coarse type of sediment was responsible for more resistant taxa to sediment particle movements by wave action. The main species represented by the cluster were *A. beccarii* (1.9–28.3%), *T. tricarinata* (1.8–15%), *E. hispidulum* (6.5–11.5%), *A. dentata* (8.5–15.2%), *E. repandus* (0.9–5.2%), *E. advenum* (1.6–4.1%), *T. oblonga* (0.8–3.1%), and *R. globularis* (1.1–2.3%).

Test Deformity

Environmental stress induced by large fluctuations in environmental factors such as salinity, DO, temperature, pH, sedimentation, pollution and hydrodynamics has been connected to a significant percentage of abnormal tests in foraminiferal assemblages (Rehab et al. 2011). Mumbai is India's economic hub, and increased urbanization and industrialization have resulted in an increase in marine discharges to coastal areas (Jayasiri et al. 2014). According to Maharashtra Pollution Control Board (MPCB) data on Maharashtra's water quality

condition, water at stations Juhu (M2), Dadar (M3), and Girgaon (M4) had a bad water quality index (MPCB 2013–14, 2016–17). In the present study *Quinqueloculina* sp. (M3), *Triloculina* sp. (M3), *Siphogenerina raphana* (M2, M3) and an Undetermined taxa showed the abnormal formation of shells. These deformed tests have been shown in Image 2 (15–19).

Quinqueloculina sp. (M3) showed reduced chambers, *Triloculina* sp. (M3) had twisted chambers, *Siphogenerina raphana* (M2, M3) represented by enlarged chambers and uneven costae lines, and the undetermined taxa had unusually extended chambers. These abnormalities imply that environmental conditions and industrialization have had a negative impact on foraminiferal diversity. All of these abnormalities were associated predominantly with M3 station. According to studies conducted by Shamrao & Kadam (2003), Jayasiri et al. (2014), and Ritesh et al. (2015), Dadar beach is extremely contaminated owing to effluents carried in by the Mithi River, with low-energy hydrodynamics generated by the lagoon region. According to MPCB publications (MPCB 2013–14, 2016–17), the water quality index for M3 is also rated as bad to very-bad. According to Suresh & Sonia (2012) morphological abnormalities are induced by pollution, strongly in shallow waters than deep seas. According to Jayaraju et al. (2008), heavy metal contamination has a greater negative impact on

Table 4. Physico-chemical parameters of water, organic carbon, and sediment type from sampling stations.

Station	Season	pH	Temperature (°C)	Salinity (‰)	Dissolved oxygen (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)	Organic carbon %	Sediment type
M1	Pre-monsoon	7.52	29	30	7.4	0.2181	0.2	0.34	Silt
	Monsoon	7.61	28	17	7.2	0.327	0.5		
	Post-monsoon	7.33	28	35	6.2	0.349	0.44		
	Winter	7.11	27	38	3.1	0.315	0.648		
M2	Pre-monsoon	7.65	27	41	6.04	0.1455	0.95	0.28	Silt
	Monsoon	7.6	27	32	7.1	0.269	0.513		
	Post-monsoon	6.54	28	37	6.4	0.328	0.465		
	Winter	7.42	28	38	3.45	0.413	0.782		
M3	Pre-monsoon	7.43	28	38	5.8	0.264	0.65	0.37	loamy sand
	Monsoon	7.06	27	25	6.7	0.261	0.38		
	Post-monsoon	7.81	27	36	6.1	0.352	0.425		
	Winter	7.39	28	38	3.42	0.563	1.5		
M4	Pre-monsoon	7.09	29	39	6.1	0.214	0.687	0.31	Sandy loam
	Monsoon	7.89	25	29	7.4	0.1454	0.1		
	Post-monsoon	7.05	27	37	6.7	0.361	0.456		
	Winter	7.45	27	39	4.6	0.289	0.663		

Table 5. Pearson correlation analysis for diversity indices and physico-chemical parameters of water.

	pH	Temperature	Salinity	Dissolved oxygen	Phosphate	Nitrate	Taxa	Individuals	Dominance	Shannon	Evenness	Margalef
pH												
Temperature	-0.3695											
Salinity	-0.2218	0.092786										
Dissolved oxygen	0.16147	-0.10486	-0.559									
Phosphate	-0.2266	0.27571	0.1359	-0.58298								
Nitrate	-0.0683	0.26441	0.4791	-0.70243	0.57205							
Taxa	-0.127	0.53909	-0.093	-0.17265	0.27933	0.2728						
Individuals	0.08318	0.29869	-0.193	-0.093673	0.083084	0.2117	0.85011					
Dominance	-0.0449	-0.22792	0.1315	-0.10616	0.057666	-0.012	-0.6639	-0.663				
Shannon	-0.0992	0.3675	-0.073	-0.028479	0.090162	0.1115	0.87788	0.78129	-0.9176			
Evenness	0.20239	-0.58162	-0.059	0.39673	-0.49099	-0.458	-0.5564	-0.3568	-0.2039	-0.1202		
Margalef	-0.1953	0.59841	-0.038	-0.19832	0.3278	0.2943	0.98356	0.74471	-0.614	0.85002	-0.6019	

foraminiferal test morphology than agricultural and aquacultural wastes. From these damaged shells it may be concluded that they act as a sensitive taxon to environmental and anthropogenic conditions.

CONCLUSION

The present study revealed diversity and distribution of Foraminifera along Mumbai coast with presence of

35 species belonging to four orders, 18 families, and 21 genera. The orders Rotaliida and Miliolida dominated the taxa. *A. beccarii*, *N. scaphum*, *A. dentata*, and *E. hispidulum* were the most opportunistic species present at all stations. Due to similarities in sediment and species distribution, CCA and Bray-Curtis similarity analysis revealed that M1-M2 and M3-M4 were more associated with each other. *N. scaphum* served as sensitive taxa by showing affinity for oxygen and finer sediment type. *A. beccarii* and *E. hispidulum* acted

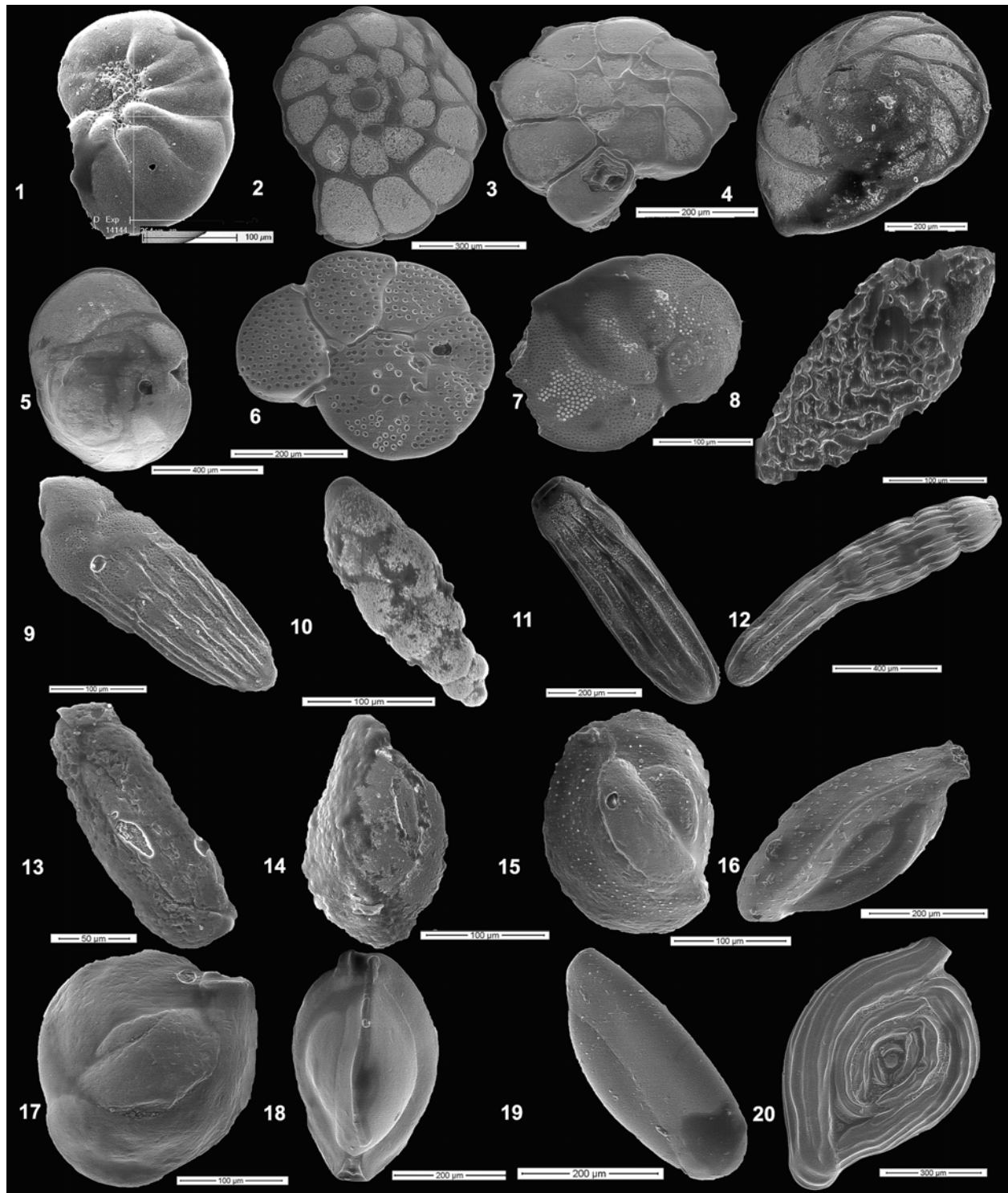


Image 1. 1—*Nonion scaphum* | 2—*Ammonia beccarii* | 3—*Ammonia dentata* | 4—*Eponides repandus* | 5—*Rosalina globularis* | 6—*Cibicides lobatulus* | 7—*Discorbinella* sp. | 8—*Bolivina pseudoplicata* | 9—*Bolivina striatula* | 10—*Spiroloxostoma glabra* | 11—*Siphogenerina raphana* | 12—*Siphogenerina* sp. | 13—*Quinqueloculina tropicalis* | 14—*Quinqueloculina agglutinans* | 15—*Quinqueloculina vulgaris* | 16—*Quinqueloculina polygona* | 17—*Quinqueloculina porterensis* | 18—*Triloculina tricarinata* | 19—*Triloculina oblonga* | 20—*Spiroloculina antillarum*. © SEM image is created and edited by Ganapati Naik.

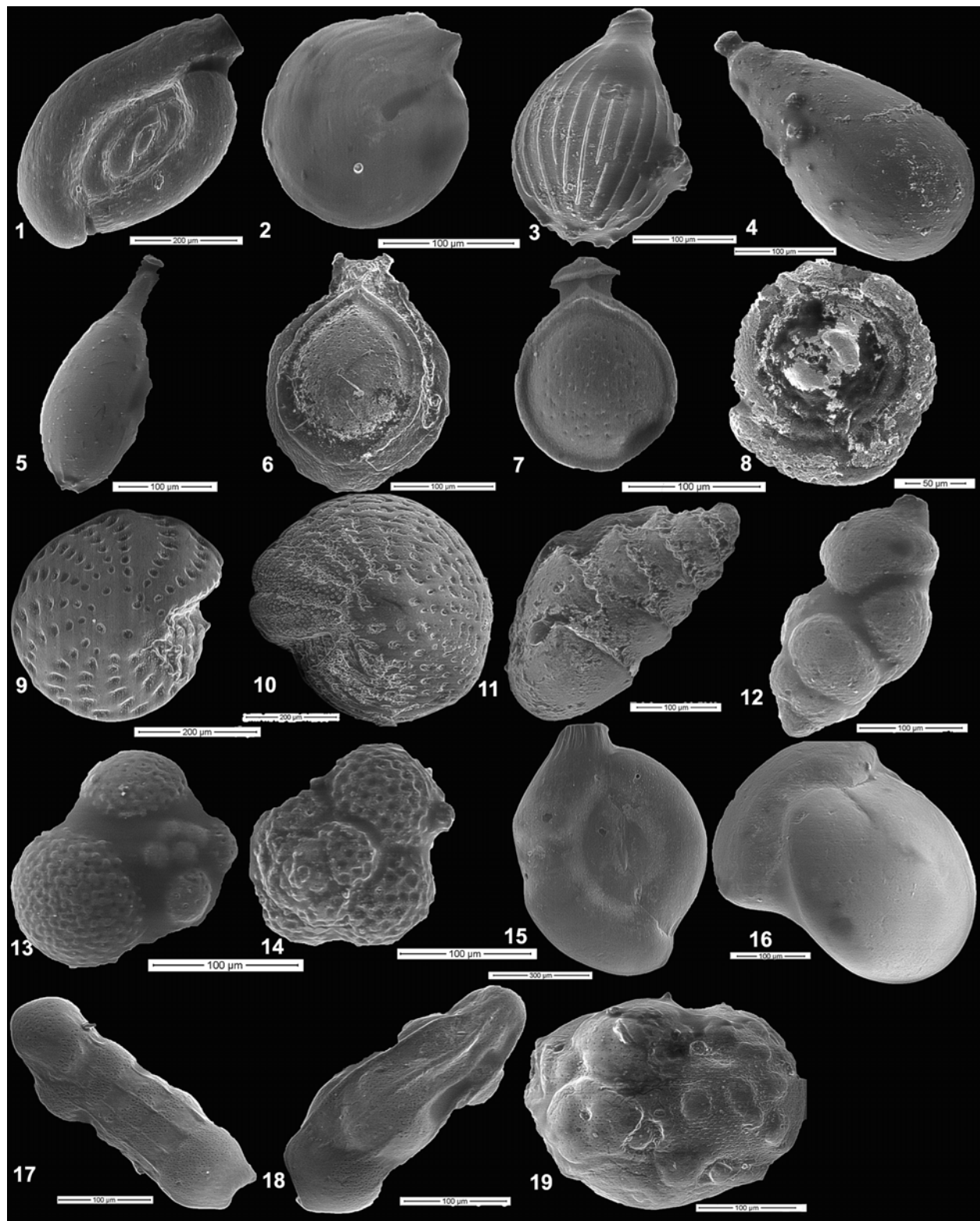


Image 2. 1—*Spiroloculina communis* | 2—*Adelosina intricata* | 3—*Lagena sulcata* | 4—*Lagena vulgaris* | 5—*Lagena laevis* | 6—*Fissurina cucullata* | 7—*Fissurina* sp. | 8—*Cornuspira involvens* | 9—*Elphidium advenum* | 10—*Elphidium hispidulum* | 11—*Bulimina marginata* | 12—*Uvigerina senticosa* | 13—*Globigerina bulloides* | 14—*Globigerinoides* sp. | 15—*Quinqueloculina* sp. | 16—*Triloculina* sp. | 17—*Siphogenerina raphana* | 18—*Siphogenerina raphana* | 19—Undetermined taxa. © SEM image is created and edited by Ganapati Naik.

as stress tolerant taxa flourishing well in fine as well as coarse sediment type. The presence of *B. striatula* indicated the hypoxic condition of water and sediment during winter season. The study found that finer to medium grain sand was associated with more species than coarse sand. Organic carbon concentrations correlated directly with fine sediment type and stations with low-energy hydrodynamic circumstances (M1, M3), allowing more organic carbon to trap between sand particles. The presence of deformed tests suggested that Mumbai's coastal water had physicochemical parameter fluctuations and received contaminated water from industrial areas. It symbolized the potential use of foraminifera in understanding the effects of urbanization and industrialization on coastal water. This creates a great need to construct foraminifera study models to comprehend long-term consequences of changing environmental and anthropogenic activities along urban coasts, since we cannot halt industrialization, but such research will assist to limit the impact of pollution on the marine environment.

REFERENCES

- Abhijit, M. & R. Nigam (2014). Bathymetric preference of four major genera of rectilinear benthic foraminifera within oxygen minimum zone in Arabian Sea off central west coast of India. *Journal of Earth System Science* 123(3): 633–639. <https://doi.org/10.1007/s12040-014-0419-y>
- Abninath, C. & B. Biswas (1954). Recent Perforate Foraminifera from Juhu Beach, Bombay. *The Micropaleontology Project, Inc.* 8(4): 30–32.
- Aldridge, D., C.J. Beer & D.A. Purdie (2011). Calcification in the planktonic foraminifera *Globigerina bulloides* linked to phosphate concentrations in surface waters of the North Atlantic Ocean. *Biogeosciences Discussions* 8: 6447–6472. <https://doi.org/10.5194/bgd-8-6447-2011>
- Alexandra, L.P., L. Saffi, V. Passlow & D.C. Collins (2007). Benthic Foraminifera as Environmental Indicators in Torres Strait–Gulf of Papua. Mapping the Seafloor for Habitat Characterization: Geological Association of Canada, 47: 329–347.
- Chaturvedi, S.K., R. Nigam & N. Khare (2000). Ecological Response of Foraminiferal Component in the Sediments of Khari Creek, Kachchh (Gujarat), West Coast of India. *ONGC Bulletin* 37(2): 55–64.
- Cushman, J. (1928). Chapter 1: The living animal. In: *Foraminifera: Their Classification and Economic Use*. Sharon, Massachusetts, USA, 3 pp.
- Derek, G.G., T.P.A. Ferré, K.R. Thorp & A.K. Rice (2015). Hydrologic-Process-Based Soil Texture Classifications for Improved Visualization of Landscape Function. *PLoS ONE* 10(6): e0131299. <https://doi.org/10.1371/journal.pone.0131299>
- Devi, G.S. & K.P. Rajashekhar (2009). Intertidal Foraminifera of Indian coast - a scanning electron photomicrograph-illustrated catalogue. *Journal of Threatened Taxa* 1(1): 17–36. <https://doi.org/10.11609/JOTT.01977.17-36>
- Elakkiya, P. & V. Manivannan (2013). Recent benthic foraminifera from off the coast of Arkattuthurai (near Nagapattinam), south east coast of India. *Indian Journal of Geo-marine Sciences* 42(7): 877–887
- Elena, L.G.C., J.L. Clarke, C. Smeaton, K. Davidson & W.E.N. Austin (2019). Organic carbon rich sediments: benthic foraminifera as bioindicators of depositional environments. *Biogeosciences* 16: 4183–4199. <https://doi.org/10.5194/bg-16-4183-2019>
- Fabrizio, F., G. Margaritelli, F. Francescangeli, R. Rettori, E.A.D. Châtelet & R. Coccioni (2013). Benthic foraminiferal assemblages and biotopes in a coastal lake: the case study of lake Varano (southern Italy). *ACTA Protozoologica* 52: 147–160. <https://doi.org/10.4467/16890027AP.13.0014.1111>
- Fatin, I.M., K. Yahya, A. Talib & O. Ahmad (2012). Benthic Foraminiferal Assemblages as Potential Ecological Proxies for Environmental Monitoring in Coastal Water. 2nd International Conference on Environment and BioScience 2012, IACSIT Press, Singapore, IPCBEE 44. <https://doi.org/10.7763/IPCBE.2012.V44.13>
- Francisco, S.P.J.V. d. Brink & R.M. Mann (2011). Chapter 8: Impact of Pollutants on Coastal and Benthic Marine Communities, pp 165., In: Ángel, B., M.J. Belzunce & J.M. Garmendia (eds.). *Ecological Impacts of Toxic Chemicals*, Bentham Science Publishers.
- Hayward, B., L.F. Coze, D. Vachard & O. Gross (2022). World foraminifera Database. (<http://www.marinespecies.org/foraminifera/>) Electronic version accessed 13 December 2022
- Hiroshi, K. (1994). Foraminiferal microhabitats in four marine environments around Japan. *Marine Micropaleontology* 24: 29–41. [https://doi.org/10.1016/0377-8398\(94\)90009-4](https://doi.org/10.1016/0377-8398(94)90009-4)
- Jayaraju, N., B.C.S.R. Reddy & K.R. Reddy (2008). The response of benthic foraminifera to various pollution sources: A study from Nellore Coast, East Coast of India. *Environmental Monitoring and Assessment* 142: 319–323. <https://doi.org/10.1007/s10661-007-9931-8>
- Jayasiri, H.B., A. Vennila & C.S. Purushothaman (2014). Spatial and temporal variability of metals in inter-tidal beach sediment of Mumbai, India. *Environmental Monitoring and Assessment* 186: 1101–1111. <https://doi.org/10.1007/s10661-013-3441-7>
- Kameswara, K.R. & M. Srinath (2002). Foraminifera from beach sands along Saurashtra coast, north-west India. *Journal of the Marine Biological Association of India* 44(1&2): 22–36.
- Kumar, V. & V. Manivannan (2001). Benthic foraminiferal responses to bottom water characteristics in the Palk Bay, off Rameswaram, southeast coast of India. *Indian Journal of Marine Sciences* 30: 173–179.
- Laurie, M.C., H.L. Filipsson, Y. Nagai, S. Kawada, K. Ljung, E. Kritzbeg & T. Toyofuku (2018). Decalcification and survival of benthic foraminifera under the combined impacts of varying pH and salinity. *Marine Environmental Research* 138: 36–45. <https://doi.org/10.1016/j.marenvres.2018.03.015>
- Lenore, C., G. Arnold & E. Andrew (1999). *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, American Water Works Association and Water Environment Federation, 20th edition, 1254 pp.
- Loeblich, A. & H. Tappan (1988). *Foraminiferal genera and their classification*. Springer science, Business media, New York, 2031 pp.
- MPCB (2013–2014). Water Quality Status of Maharashtra, pp. 113–114. Maharashtra Pollution Control Board
- MPCB (2016–2017). Water Quality Status of Maharashtra. Maharashtra Pollution Control Board, 74 pp.
- Maria, C.M., L. Bergamin, M.G. Finioia, G. Pierfranceschi, F. Venti & E. Romano (2012). Correlation between textural characteristics of marine sediments and benthic foraminifera in highly anthropogenically-altered coastal areas. *Marine Geology* 315–318: 143–161. <https://doi.org/10.1016/j.margeo.2012.04.002>
- Martina, P., T.E. Roberts & J.M. Pandolfi (2017). Variation in sensitivity of large benthic Foraminifera to the combined effects of ocean warming and local impacts. *Scientific Reports* 7: 45227.
- Mariéva, D., F.J. Jorissen, D. Martin, F. Galgani & J. Miné (2010). Comparison of benthic foraminifera and macro faunal indicators of the impact of oil-based drill mud disposal. *Marine Pollution Bulletin* 60(11): 2007–2021. <https://doi.org/10.1016/j.marpolbul.2010.07.024>
- Murray, J. (2006). Chapter 10: Application. *Ecology and Applications of Benthic Foraminifera*. Cambridge University Press, England, 281 pp.
- Patricia P.B.E., A.R. Rodrigues, M.P. Gomes & H. Vital (2019). Benthic

- foraminifera as indicators of river discharge in the Western South Atlantic continental shelf. *Marine Geology* 415: 105973. <https://doi.org/10.1016/j.margeo.2019.105973>
- Pierre, A.D., J. Bonnin, J.H. Kim, S. Bichon, B. Deflandre, A. Grémare & J.S.S. Damsté (2016). Impact of organic matter source and quality on living benthic foraminiferal distribution on a river-dominated continental margin: a study of the Portuguese margin. *Journal of Geophysical Research: Biogeosciences* 121(6): 1689–1714. <https://doi.org/10.1002/2015JG003231>
- Pravasini, P. & P.K. Patra (2012). Benthic foraminiferal responses to coastal pollution: a review. *International Journal of Geology, Earth and Environmental Sciences* 2(1): 42–56.
- Rajiv, N. (1986). Foraminiferal assemblages and their use as indicators of sediment movement: a study in the shelf region off Navapur, India. *Continental Shelf Research* 5(4): 421–431.
- Rehab, E., M.I. Ibrahim, Y. Milker, G. Schmiedl, N. Badr, S.E.A. Kholeif & K.A.F. Zonneveld (2011). Anthropogenic impact on benthic foraminifera, Abu-Qir bay, Alexandria, Egypt. *Journal of Foraminiferal Research* 41(4): 326–348. <https://doi.org/10.2113/gsjfr.41.4.326>
- Ritesh, V., V.K. Kushwaha, N. Pandey, T. Nandy & S.R. Wate (2015). Extent of sewage pollution in coastal environment of Mumbai, India: an object-based image analysis. *Water and Environment Journal* 29: 365–374. <https://doi.org/10.1111/wej.12115>
- Shamrao, A.I. & A.N. Kadam (2003). Pollution of some recreation beaches of Mumbai, Maharashtra. *Journal of Indian Association of Environmental Management* 30: 172–175.
- Singare, P.U., S.E.L. Ferns & E.R. Agharia (2015). Studies on Toxic Heavy Metals in Sediment Ecosystem of Mahim Creek near Mumbai, India. *International Letters of Chemistry, Physics and Astronomy* 43: 62–70. <https://doi.org/10.18052/www.scipress.com/ILCPA.43.62>
- Subhadra, D.G. & R.K. Patil (2012). Comparative study on foraminifera of east and west coast of India. *Journal of Environmental Biology* 33: 903–908.
- Sundara, R.R.B.C., N. Jayaraju, G. Sreenivasulu, U. Suresh & A.N. Reddy (2016). Heavy metal pollution monitoring with foraminifera in the estuaries of Nellore coast, East coast of India. *Marine Pollution Bulletin* 113(1–2): 542–551. <https://doi.org/10.1016/j.marpolbul.2016.08.051>
- Suresh, M.G. & A.N. Sonia (2012). Benthic foraminifera and geochemical studies with influence on pollution studies along the coast of Cuddalore, Tamil Nadu-ITS, India. *Arabian Journal of Geosciences* 7: 917–925. <https://doi.org/10.1007/s12517-012-0775-3>
- Syed, A.K., K.G.M.T. Ansari & P.S. Lyla (2011). Organic matter content of sediments in continental shelf area of southeast coast of India. *Environmental Monitoring and Assessment* 184: 7247–7256.
- Vidya, P. & R.K. Patil (2014). Mangrove sediment core analysis of foraminiferal assemblages - a study at two sites along the western coast of India. *Journal of Threatened Taxa* 6(2): 5485–5491. <https://doi.org/10.11609/JOTT.o3653.5485-91>
- Walton, W.R. (1952). Techniques for recognition of living foraminifera. *Contributions from the Cushman Foundation for Foraminiferal Research* 3: 56–60.



Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK
Dr. George Mathew, Kerala Forest Research Institute, Peechi, India
Dr. John Noyes, Natural History Museum, London, UK
Dr. Albert G. Orr, Griffith University, Nathan, Australia
Dr. Sameer Padhye, Katholieke Universiteit Leuven, Belgium
Dr. Nancy van der Poorten, Toronto, Canada
Dr. Kareen Schnabel, NIWA, Wellington, New Zealand
Dr. R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India
Dr. Manju Siliwal, WILD, Coimbatore, Tamil Nadu, India
Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India
Dr. P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India
Dr. R. Varatharajan, Manipur University, Imphal, Manipur, India
Dr. Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain
Dr. James Young, Hong Kong Lepidopterists' Society, Hong Kong
Dr. R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India
Dr. M. Nithyanandan, Environmental Department, La Ala Al Kuwait Real Estate. Co. K.S.C., Kuwait
Dr. Himender Bharti, Punjabi University, Punjab, India
Mr. Purnendu Roy, London, UK
Dr. Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan
Dr. Sanjay Sondhi, TITLI TRUST, Kalpavriksh, Dehradun, India
Dr. Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam
Dr. Nitin Kulkarni, Tropical Research Institute, Jabalpur, India
Dr. Robin Wen Jiang Ngiam, National Parks Board, Singapore
Dr. Lionel Monod, Natural History Museum of Geneva, Genève, Switzerland.
Dr. Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India
Dr. Rosana Moreira da Rocha, Universidade Federal do Paraná, Curitiba, Brasil
Dr. Kurt R. Arnold, North Dakota State University, Saxony, Germany
Dr. James M. Carpenter, American Museum of Natural History, New York, USA
Dr. David M. Claborn, Missouri State University, Springfield, USA
Dr. Kareen Schnabel, Marine Biologist, Wellington, New Zealand
Dr. Amazonas Chagas Júnior, Universidade Federal de Mato Grosso, Cuiabá, Brasil
Mr. Monsoon Jyoti Gogoi, Assam University, Silchar, Assam, India
Dr. Heo Chong Chin, Universiti Teknologi MARA (UiTM), Selangor, Malaysia
Dr. R.J. Shiel, University of Adelaide, SA 5005, Australia
Dr. Siddharth Kulkarni, The George Washington University, Washington, USA
Dr. Priyadarsanan Dharma Rajan, ATREE, Bengaluru, India
Dr. Phil Alderslade, CSIRO Marine And Atmospheric Research, Hobart, Australia
Dr. John E.N. Veron, Coral Reef Research, Townsville, Australia
Dr. Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany.
Dr. Yu-Feng Hsu, National Taiwan Normal University, Taipei City, Taiwan
Dr. Keith V. Wolfe, Antioch, California, USA
Dr. Siddharth Kulkarni, The Hormiga Lab, The George Washington University, Washington, D.C., USA
Dr. Tomas Ditrich, Faculty of Education, University of South Bohemia in Ceske Budejovice, Czech Republic
Dr. Mihaly Foldvari, Natural History Museum, University of Oslo, Norway
Dr. V.P. Uniyal, Wildlife Institute of India, Dehradun, Uttarakhand 248001, India
Dr. John T.D. Caleb, Zoological Survey of India, Kolkata, West Bengal, India
Dr. Priyadarsanan Dharma Rajan, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Bangalore, Karnataka, India

Fishes

Dr. Neelesh Dahanukar, IISER, Pune, Maharashtra, India
Dr. Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México
Dr. Heok Hee Ng, National University of Singapore, Science Drive, Singapore
Dr. Rajeev Raghavan, St. Albert's College, Kochi, Kerala, India
Dr. Robert D. Sluka, Chiltern Gateway Project, A Rocha UK, Southall, Middlesex, UK
Dr. E. Vivekanandan, Central Marine Fisheries Research Institute, Chennai, India
Dr. Davor Zanella, University of Zagreb, Zagreb, Croatia
Dr. A. Biju Kumar, University of Kerala, Thiruvananthapuram, Kerala, India
Dr. Akhilesh K.V., ICAR-Central Marine Fisheries Research Institute, Mumbai Research Centre, Mumbai, Maharashtra, India
Dr. J.A. Johnson, Wildlife Institute of India, Dehradun, Uttarakhand, India
Dr. R. Ravinesh, Gujarat Institute of Desert Ecology, Gujarat, India

Amphibians

Dr. Sushil K. Dutta, Indian Institute of Science, Bengaluru, Karnataka, India
Dr. Annemarie Ohler, Muséum national d'Histoire naturelle, Paris, France

Reptiles

Dr. Gernot Vogel, Heidelberg, Germany
Dr. Raju Vyas, Vadodara, Gujarat, India
Dr. Pritpal S. Soorae, Environment Agency, Abu Dhabi, UAE.
Prof. Dr. Wayne J. Fuller, Near East University, Mersin, Turkey
Prof. Chandrashekher U. Rivonker, Goa University, Taleigao Plateau, Goa. India
Dr. S.R. Ganesh, Chennai Snake Park, Chennai, Tamil Nadu, India
Dr. Himansu Sekhar Das, Terrestrial & Marine Biodiversity, Abu Dhabi, UAE

Birds

Dr. Hem Sagar Baral, Charles Sturt University, NSW Australia
Mr. H. Byju, Coimbatore, Tamil Nadu, India
Dr. Chris Bowden, Royal Society for the Protection of Birds, Sandy, UK
Dr. Priya Davidar, Pondicherry University, Kalapet, Puducherry, India
Dr. J.W. Duckworth, IUCN SSC, Bath, UK
Dr. Rajah Jayapal, SACON, Coimbatore, Tamil Nadu, India
Dr. Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, Haryana, India
Dr. V. Santharam, Rishi Valley Education Centre, Chittoor Dt., Andhra Pradesh, India
Dr. S. Balachandran, Bombay Natural History Society, Mumbai, India
Mr. J. Praveen, Bengaluru, India
Dr. C. Srinivasulu, Osmania University, Hyderabad, India
Dr. K.S. Gopi Sundar, International Crane Foundation, Araboo, USA
Dr. Gombobaatar Sunde, Professor of Ornithology, Ulaanbaatar, Mongolia
Prof. Reuven Yosef, International Birding & Research Centre, Eilat, Israel
Dr. Taej Mundkur, Wetlands International, Wageningen, The Netherlands
Dr. Carol Inskipp, Bishop Auckland Co., Durham, UK
Dr. Tim Inskipp, Bishop Auckland Co., Durham, UK
Dr. V. Gokula, National College, Tiruchirappalli, Tamil Nadu, India
Dr. Arkady Lelej, Russian Academy of Sciences, Vladivostok, Russia
Dr. Simon Dowell, Science Director, Chester Zoo, UK
Dr. Mário Gabriel Santiago dos Santos, Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, Vila Real, Portugal
Dr. Grant Connette, Smithsonian Institution, Royal, VA, USA
Dr. P.A. Azeez, Coimbatore, Tamil Nadu, India

Mammals

Dr. Giovanni Amori, CNR - Institute of Ecosystem Studies, Rome, Italy
Dr. Anwaruddin Chowdhury, Guwahati, India
Dr. David Mallon, Zoological Society of London, UK
Dr. Shomita Mukherjee, SACON, Coimbatore, Tamil Nadu, India
Dr. Angie Appel, Wild Cat Network, Germany
Dr. P.O. Nameer, Kerala Agricultural University, Thrissur, Kerala, India
Dr. Ian Redmond, UNEP Convention on Migratory Species, Lansdown, UK
Dr. Heidi S. Riddle, Riddle's Elephant and Wildlife Sanctuary, Arkansas, USA
Dr. Karin Schwartz, George Mason University, Fairfax, Virginia.
Dr. Lala A.K. Singh, Bhubaneswar, Orissa, India
Dr. Mewa Singh, Mysore University, Mysore, India
Dr. Paul Racey, University of Exeter, Devon, UK
Dr. Honnavalli N. Kumara, SACON, Anaikatty P.O., Coimbatore, Tamil Nadu, India
Dr. Nishith Dharaiya, HNG University, Patan, Gujarat, India
Dr. Spartaco Gippoliti, Socio Onorario Società Italiana per la Storia della Fauna "Giuseppe Altobello", Rome, Italy
Dr. Justus Joshua, Green Future Foundation, Tiruchirappalli, Tamil Nadu, India
Dr. H. Raghuram, The American College, Madurai, Tamil Nadu, India
Dr. Paul Bates, Harison Institute, Kent, UK
Dr. Jim Sanderson, Small Wild Cat Conservation Foundation, Hartford, USA
Dr. Dan Challender, University of Kent, Canterbury, UK
Dr. David Mallon, Manchester Metropolitan University, Derbyshire, UK
Dr. Brian L. Cypher, California State University-Stanislaus, Bakersfield, CA
Dr. S.S. Talmale, Zoological Survey of India, Pune, Maharashtra, India
Prof. Karan Bahadur Shah, Budhanilakantha Municipality, Kathmandu, Nepal
Dr. Susan Cheyne, Borneo Nature Foundation International, Palangkaraja, Indonesia
Dr. Hemanta Kafley, Wildlife Sciences, Tarleton State University, Texas, USA

Other Disciplines

Dr. Aniruddha Belsare, Columbia MO 65203, USA (Veterinary)
Dr. Mandar S. Paingankar, University of Pune, Pune, Maharashtra, India (Molecular)
Dr. Jack Tordoff, Critical Ecosystem Partnership Fund, Arlington, USA (Communities)
Dr. Ulrike Streicher, University of Oregon, Eugene, USA (Veterinary)
Dr. Hari Balasubramanian, EcoAdvisors, Nova Scotia, Canada (Communities)
Dr. Rayanna Hellem Santos Bezerra, Universidade Federal de Sergipe, São Cristóvão, Brazil
Dr. Jamie R. Wood, Landcare Research, Canterbury, New Zealand
Dr. Wendy Collinson-Jonker, Endangered Wildlife Trust, Gauteng, South Africa
Dr. Rajeshkumar G. Jani, Anand Agricultural University, Anand, Gujarat, India
Dr. O.N. Tiwari, Senior Scientist, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India
Dr. L.D. Singla, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India
Dr. Rupika S. Rajakaruna, University of Peradeniya, Peradeniya, Sri Lanka
Dr. Bahar Baviskar, Wild-CER, Nagpur, Maharashtra 440013, India

Reviewers 2020–2022

Due to pausity of space, the list of reviewers for 2018–2020 is available online.

The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the host, and the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64



OPEN ACCESS



The Journal of Threatened Taxa (JoTT) is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/) unless otherwise mentioned. JoTT allows unrestricted use, reproduction, and distribution of articles in any medium by providing adequate credit to the author(s) and the source of publication.

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

April 2023 | Vol. 15 | No. 4 | Pages: 22927–23138

Date of Publication: 26 April 2023 (Online & Print)

DOI: 10.11609/jott.2023.15.4.22927-23138

www.threatenedtaxa.org

Articles

Inventory and abundance of non-volant mammals and birds in the unprotected regions of the Mount Apo Range, Philippines

– Jhonnell P. Villegas, Jireh R. Rosales, Giovanna G. Tampus & Jayson C. Ibañez, Pp. 22927–22939

Floral biology of *Baccaurea courtallensis* – an endemic tree species from peninsular India

– Karupiah Nandhini, Vincent Joshuva David, Venugopal Manimekalai & Perumal Ravichandran, Pp. 22940–22954

Plant species diversity in the riparian forests of the Moyar River in southern India

– Muthu Karthick Nagarajan & Avantika Bhaskar, Pp. 22955–22967

Diversity of bracket fungi (Basidiomycota: Agaricomycetes: Polyporaceae) in Jammu Division, Jammu & Kashmir, India

– Brij Bala, Pp. 22968–22989

Identification, prioritization, and management of biodiversity hot spots: a case study of Western Ghats of Maharashtra, India

– Shivam Trivedi & Erach Bharucha, Pp. 22990–23004

Communications

Mammalian diversity of Debrigarh Wildlife Sanctuary, Odisha, India

– Nimain Charan Palei, Bhakta Padarbinda Rath & Sudeep Nayak, Pp. 23005–23015

Vertebrate road kills on State Highway 26 in Khandwa Forest Division, central India

– Kamran Husain & Prachi Mehta, Pp. 23016–23028

Terrestrial vertebrate and butterfly diversity of Garbhanga Landscape, Assam, India

– Pranjal Mahananda, Shah Nawaz Jelil, Sanath Chandra Bohra, Nilutpal Mahanta, Rohini Ballave Saikia & Jayaditya Purkayastha, Pp. 23029–23046

The avian diversity of Chemmattamvayal Wetlands and adjacent areas of Kasaragod District, Kerala, India

– Sreehari K. Mohan, R. Anjitha & K. Maxim Rodrigues, Pp. 23047–23060

Westward range extension of Burmese Python *Python bivittatus* in and around the Ganga Basin, India: a response to changing climatic factors

– Pichaimuthu Gangaiamaran, Aftab Alam Usmani, C.S. Vishnu, Ruchi Badola & Syed Ainul Hussain, Pp. 23061–23074

First record of *Tanaorhinus viridiluteata* Walker, 1861 (Lepidoptera: Geometridae: Geometrinae) from Mizoram, India

– B. Lalnghahpuii, Lalruatthara & Esther Lalhmingliani, Pp. 23075–23082

The giant clam commensal shrimp *Anchistus miersi* (de Man, 1888) (Decapoda: Palaemonoidae) new to Lakshadweep Sea, India

– Manu Madhavan, Purushothaman Paramasivam, S. Akash, T.T. Ajith Kumar & Kuldeep Kumar Lal, Pp. 23083–23090

Earthworm (Annelida: Clitellata) fauna of Chhattisgarh, India

– M. Nurul Hasan, Shakoor Ahmed, Kaushik Deuti & Nithyanandam Marimuthu, Pp. 23091–23100

Recent Foraminifera from the coast of Mumbai, India: distribution and ecology

– Ganapati Ramesh Naik, Manisha Nitin Kulkarni & Madhavi Manohar Indap, Pp. 23101–23113

Short Communications

Additional breeding records of Hanuman Plover *Charadrius seebohmii* E. Hartert & A.C. Jackson, 1915 (Aves: Charadriiformes: Charadriidae) from southeastern coast of India

– H. Byju, N. Raveendran, S. Ravichandran & R. Kishore, Pp. 23114–23118

A study on the breeding habits of Red-wattled Lapwing *Vanellus indicus* Boddaert, 1783 (Aves: Charadriiformes: Charadriidae) in the agricultural landscape of Muzaffarnagar District, Uttar Pradesh, India

– Ashish Kumar Arya, Kamal Kant Joshi, Deepak Kumar & Archana Bachheti, Pp. 23119–23122

Rediscovery and redescription of *Urolabida nilgirica* Yang (Hemiptera: Heteroptera: Urostylidae) from India

– Pratik Pansare, H. Sankararaman & Hemant V. Ghate, Pp. 23123–23130

The perception of bee and wasp fauna (Hymenoptera: Aculeata) by the inhabitants of Mangdi Valley, central Bhutan

– Kinley Tenzin, Pp. 23131–23135

Note

Breeding record of Little Ringed Plover *Charadrius dubius jerdoni* Legge, 1880 (Charadriidae: Charadriiformes) from Tamil Nadu, India

– H. Byju, Yoganathan Natarajan, N. Raveendran & R. Kishore, Pp. 23136–23138

Publisher & Host

