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First report of three benthic foraminifera from the waters of Andaman Islands, India

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ABSTRACT The living benthic foraminifera *Nevillina coronata* (Millet, 1898), *Sigmoihauerina involuta* (Cushman, 1946) and *Loxostomina limbata* (Brady, 1881) are reported for the first time from the inner shelf regions of Andaman Islands, India. *Nevillina coronata*, very common in the north east, was observed to favorably flourish in the low temperature of rainy season, during monsoon period, whereas the remaining two species were abundant in the non rainy months. Although, in Andaman and Nicobar islands, the mega diversity for Foraminifera has not been studied in details yet, our findings suggest that the three species may be considered as indicators of monsoon and non monsoon periods.

KEY WORDS Wandoor; Andaman Sea; *Nevillina*; Shelled Protozoa and Climate.

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INTRODUCTION

The Andaman Nicobar Islands are tropical islands lying in the Bay of Bengal (6–14° N Lat; 92–94° E Long). The mean summer and winter temperatures often vary because of tropical conditions. Humid climate is a consequence of the annual rainfall ranging from 2900 to 3100 mm. Dry months from January to April show high evaporation since the islands are situated near the Equator and, therefore, solar radiations are more intensive (Velmurugan et al., 2015). These islands are also prone to seismicity as being placed between the subduction and emergence zone of the plate.

Foraminifera are a group of marine Protozoa, ubiquitously distributed throughout the world's marine habitats. They are unicellular (i.e. comprising of a single cell) eukaryote organisms that likely evolved from an amoeba-like ancestor. Foraminifera are usually encased by the protective shell or test that may be composed of organic, agglutinated or calcareous materials. The test may show one or more chambers; chamber arrangement and aperture style, with many slight variations around a few basic themes, are important features for classifying these animals. Various benthic foraminifera are often used for different kinds of biological, environmental and pollution monitoring studies. Microfossils, especially foraminifera, became the prime source to address the environmental issues (Nigam, 2005).

Generally, the larger benthic foraminifera are used to monitor the coral reef environmental changes. Indicator species are used to predict the deposition of oil and natural gas products. The larger symbiont-bearing benthic foraminifera are efficient recyclers and generally require warm clear oligotrophic waters to flourish, and are also important contributors to carbonate budgets (Harney et al., 1999). The meiobenthic community of fo-

raminifera played an important role in the carbon cycle of the sediments (Moodley et al., 2000). The benthic foraminifera group Miliolida was very important as indicator of past and present environmental conditions (Haynes, 1981). According to Wilson (2007), a guild is a group of species having a very similar ecological role within a community, exploiting the same kinds of resources in comparable ways. Live organisms forming a guild may have similar spatial and temporal distribution. Sugihara (1980) observed that such a communities can be divided into smaller and more strongly related functional groups of species. Bandy (1954) reported that temperature is the main factor to determine the different faunal zones at 100 m depth for benthic foraminifera. Changes in abundance of marker species, the introduction of new species or serious loss of previously existing species, changes in species diversity, dominance or abundance may be useful tools to document the extent of environmental changes (Murray, 2000).

Foraminifera distribution is related to water depth, sediment texture and sedimentation rate (Guimerans & Currado, 1999). *Globigerina bulloides* is abundant in the upwelling environment (Kroon et al., 1991). The benthic foraminifera *Stainforthia fusiformis* (Williamson, 1848) is an opportunistic species which may cope with environmental stress (Alve, 2003). Agglutinated species are favored in the low marsh environment and *Miliammina fusca* (Brady, 1870) is dominant in low saline conditions (Moreno et al., 2005). The opportunistic species such as *Nonionella iridea* Heron-Allen et Earland, 1932, *Cassudulina carinata* and *Bolivina dilatata* are very reactive to the phytodetritus deposits. *Nonionella iridea* is dominant with the spring coccolithophore bloom (Duchemin et al., 2008). Low-energy environments are dominated by the families Soritacea and Miliolacea with less percentages of Rotaliacea (Madkour, 2013). Even though the studies on fossil Foraminifera have a long history, the knowledge on live benthic organisms is meager due to the paradigm shift of geology and biological sciences. Hence, it is the time to explore live foraminifera, including benthic communities in order to understand their sensitiveness to the environment to predict future changes on climate.

In particular, in Andaman and Nicobar Islands, only 11 research papers were published about foraminifera, and none of them about living organisms (see Khare et al., 2007). So, an attempt was made to study live foraminifera of Andaman Sea and eastern side of Bay of Bengal and their response to physico-chemical-environmental factors.

MATERIAL AND METHOD

Surface sediment samples were collected by a Van veen Grab from a depth of 10–20 m and the collected sediment transferred into plastic covers; then the samples were preserved with 10 % formaldehyde and 2 % Rose Bengal to distinguish the living fauna (Schonfeld et al., 2012). All samples were carefully stored in laboratory without disturbances. After 14 days of preservation, approximately 100 ml of sediments were sieved through 500 µm and 63 µm standard sieves. The samples retained in the 63 µm sieve were utilized for faunal analysis under a Nikon Binocular Stereoscopic Microscope. The sorted living benthic foraminifera were identified and mounted in cardboard micropaleontological slides.

The area of study is located in South, Middle and North Andaman group of islands, in the Andaman Sea. It comprises: 1) Wandoor station, located in Port Blair, the South Andaman, headquarter of Andaman and Nicobar Islands; 2) Mayabunder, in Middle Andaman, which is also a headquarter for Middle and North Andaman district; and 3) Diglipur, in the North Andaman district. Wandoor is a coral reef environment with coral sand deposits located in the western side of the Island and in the eastern side of Bay of Bengal. The coral sand is covered with the seaweed *Sargassum* sp.; Mayabunder station is located in a coral reef environment near Avis Island with a steep slope and coral sand deposits; and, finally, Diglipur shows sandy deposits near the western approach of Ross and Smith Islands.

RESULTS AND DISCUSSION

During this study we found three species, *Nevillina coronata* (Millet, 1898) **(**Figs. 1, 2), *Loxostomina limbata* (Brady, 1881) (Figs. 3, 4) and *Sigmoihauerina involuta* (Cushman, 1946) (Figs. 5, 6) not previously reported as living foraminifera for

this area. Their habitat and local environmental parameters are discussed herewith (Table 1).

Systematic

The following scheme is according to Loeblich & Tappan (1987).

Order FORAMINIFERIDA Eichwald, 1830
Sub Order MILIOLINA Delage et Herouard, 1896
Family HAUERINIDAE Schwager, 1876
Genus *Nevillina* Sidebottom, 1905

Nevillina coronata (Millet, 1898)
Biloculina coronata Millet, 1989

DESCRIPTION. Test elongate, calcareous, porcellaneous, imperforate. Test surface smooth and very delicate, the earlier chambers are clearly visible. The latest chamber envelopes the older chambers; Earliest chambers are triloculine and the final chamber biloculine. The aperture consists in the terminal end of the final chamber and is arranged at each opposite end of the test. The opening is elongated, with more than six arched ribs joining in a ring around the central opening (Figs. 1–4).

Family HAUERINIDAE Schwager, 1876
Genus *Sigmoihauerina* Zheng, 1979

Sigmoihauerina involuta (Cushman, 1946)
Hauerina involuta Cushman, 1946
Pseudohauerina occidentalis subsp. *involuta* (Cushman, 1946)

DESCRIPTION. The test is calcareous, porcellaneous, ovate to sub-circular, showing five chambers with and a planispiral one. In adult specimens, three chambers can be observed in the final whorl, with 25–28 radial septa. Test may show numerous longitudinal striae on the surface. The aperture is in the terminal end of the final chamber showing a typical trematophore plate with many small openings (Figs. 5–8).

Sub Order ROTALINA Lankester, 1885
Family BOLIVINITIDAE Cushman, 1927
Genus *Loxostomina* Sellier De Civrieux,1969

Loxostomina limbata (Brady, 1881)
Bolivina limbata Brady, 1881
Bulimina limbata Brady, 1881
Euloxostomum limbatum (Brady, 1981)
Loxostoma limbatum (Brady, 1881)
Loxostomoides limbatum (Brady, 1881)
Loxostomum limbatum (Brady, 1881)
Rectobolivina limbata (Brady, 1881)
Loxostomina limbata (Brady, 1881)

DESCRIPTION. The elongated test consists of eight pairs of chambers as biserial, and the last two uniserial. In the first part, the shell shows one chamber increasing its size in the terminal part, and becomes narrower at the end of the aperture side. Longitudinal striae may be present and the test shows a coarse perforation; adult specimens are twisted or slightly depressed. The aperture, in the terminal end of the final chamber, is oval with outer lip; in immature specimens is linear. The shell is made of calcareous hyaline materials (Figs. 9–11).

Discussion

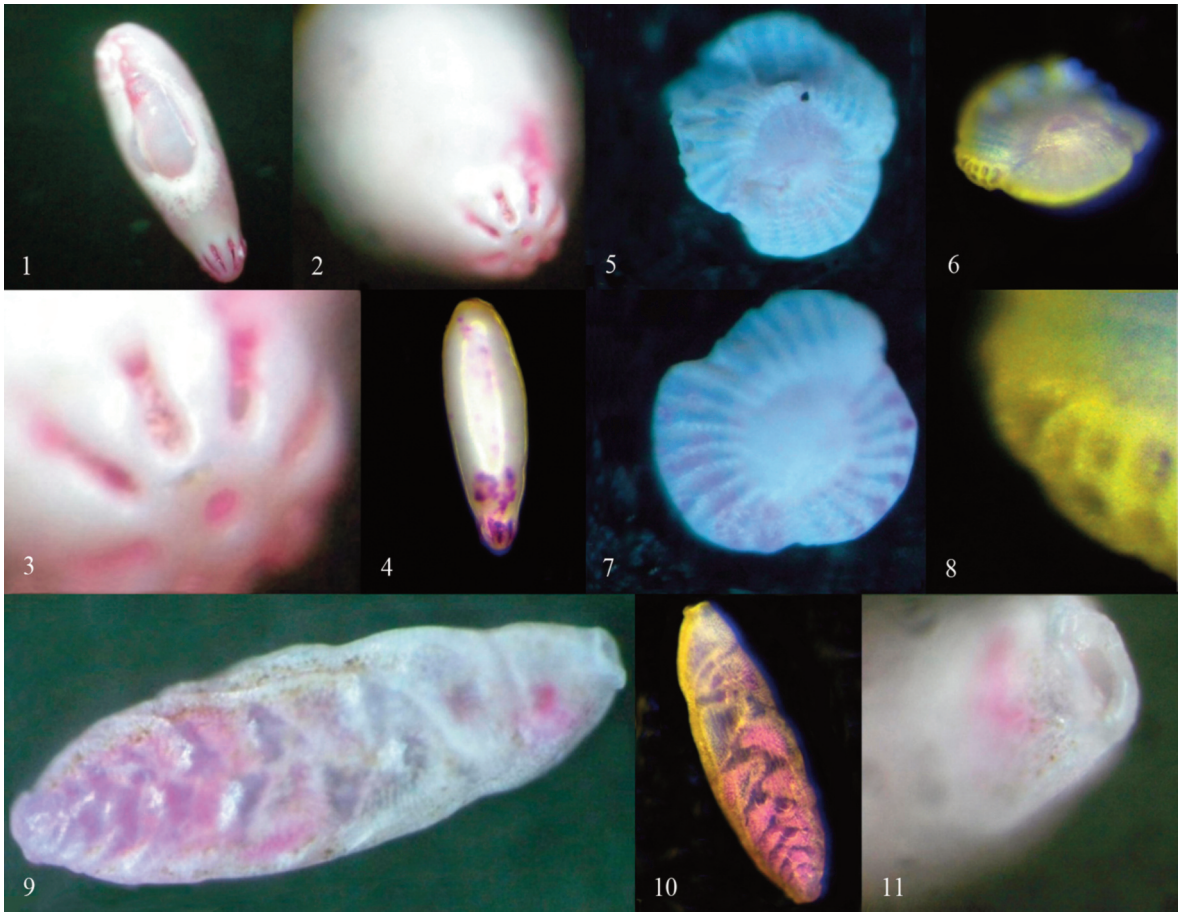
Nevillina coronata and *S. involuta*, belong to Miliolida, whereas *L. limbata* to Bolivinida. *Nevillina coronata* flourished in Wandoor, in the month of September when the south west monsoons play a role of modest change in the environmental parameters (27.5 °C 35.9 PSU, pH 8.3, see Table 1). *Sigmoihauerina involuta* and *L. limbata* flourished in the month of March, in Mayabunder and Diglipur, where the temperature was 28.2°C with salinity of 33.4 PSU and pH of 8.6 (Table 1). The above parameters seem to indicate that *N. coronata* need low temperature, and high salinity (35.9 PSU), whereas the other two species needed higher temperature (28.2°C), and lower salinity (33.4 PSU). But, above all, the three species have never been reported as live foraminifera in any earlier reports from Andaman and Nicobar Islands and this occurrence may be considered as the first time report in these waters. It is also noteworthy to say that, according to available literature, *N. coronata* was never reported from the Indian Ocean, after Millet (1898). On the contrary, it was reported from New South Wales, Pacific Ocean (Albani, 1979) and New Zealand (Hayward et al., 1999), all environments with warm-temperate waters. Recently (2008) it was also reported from Chinese Exclusive Economic zone (WORMS, Foraminifrea Data Base).

	Wandoor, - Bay of Bengal - South Andaman	Mayabunder - Andaman Sea - Middle Andaman	Diglipur – Andaman Sea – Middle Andaman
Latitude and Longitude	11°35'49.17N 092°36'42.05E	13°17'44.69N 093°03'20.76E	12°55'06.11N 092°56'03.84E
Nevillina coronata	Yes	No	No
Sigmoihauerina involuta	No	Yes	Yes
Loxostomina limbata	No	Yes	Yes
Water Depth (m)	10 m	20 m	20 m
Period	September-2013 September-2014	March-2012 April-2014	March-2012 April-2014
Temperature ° C	27.5C	28.2C	28.2C
Salinity PSU	35.9	33.3	33.3
pH	8.3	8.6	8.5
Dissolved Oxygen (ml/L)	5.5	5.8	5.8
Turbidity (NTU)	5.9	80	102
Sediment character	Sandy	Sandy	Sandy

Table 1. Presence/absence of the three species and environmental parameters observed in the three study areas.

	Nevillina coronata	***Sigmoihauerina involuta***	***Loxostomina limbata***
Type Level	Recent	Recent	Recent
Type Locality	Malay Archipelago, Indian Ocean	Rongelab Atoll, Marshall Islands	Not Designated quotes in Holburn et al. (2013)
Bathymetry as Reported Earlier and Current Observation(*)	Neritic Zones* 0-10 m Depth	Neritic to Upper Bathyl Zones, *15-20 m Depth	Neritic to Upper Bathyl Zones, *15-20 m Depth
Size of the Studied specimen	746.31 µm , length and 308.49 µm width	313.54 µm Dia	847.31 µm length and 266.15 µm width
Chronostratigraphy	Holocene to Recent	Oligocene to Recent	Middle Miocene to Recent
Biogeography	Indo-Pacific Regions	Indo-Pacific Regions	World Wide
References	Loeblich & Tappan, 1994; Albani, 1979; Hayward et al., 1999	Loeblich & Tappan, (1987), 1994; Debenay, 2012	Cushman, 1942; Loeblich & Tappan, 1994; Holburn et al., 2013

Table 2. Species-related oceanographical information.



Figures 1–4. *Nevillina coronata*. Fig. 1: side view, Fig. 2: apertural view, Fig. 3: close view of aperture, Fig. 4: adult specimen. Figures 5–8. *Sigmoihauerina involuta*. Fig. 5: dorsal view, Fig. 6: apertural view, Fig. 7: ventral view, Fig. 8: close view of aperture. Figures 9–11. *Loxostomina limbata*. Fig. 9: ventral side, Fig. 10: dorsal side, Fig. 11: apertural view.

CONCLUSIONS

In the present study we encountered for the first time three species of foraminifera (*N. coronata*, *S. involuta* and *L. limbata*) in the Andaman Archipelago. In particular, *N. coronata* was encountered in September, with rains and low temperature, which might suggest that this species can be considered as an indicator for the rainy season, while the other two species, *S. involuta* and *L. limbata*, more often flourished in the spring-summer months, which would make them as possible non-rainy season indicators.

On this basis, further studies are needed to monitor the occurrence of the very same species with respect to other environmental parameters which may, perhaps, also be helpful to future paleontology and paleocological studies.

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