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Distribution of Benthic Foraminifera Around Six Coral Islands off Tuticorin, Bay of Bengal

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Abstract: Coral reef ecosystems have been subjected to unprecedented degradation over the past few decades. Disturbances affecting coral reefs include both anthropogenic and natural events. Six coral Islands namely – van Island, kaasuvar Island, kaariyachalli Island, vilaanguchalli Island, puzhivinichalli Island and upputhani Island from the gulf of mannar biosphere reserve were choosen to study the distribution of benthic foraminifers. About 169 benthic foraminiferal species belonging to 77 genera were identified. The occurrence of *amphistegina lessonii* and *amphistegina radiata* was relatively higher.

Key words: Anthropogenic · Gulf of Mannar · Benthic · Sediments

INTRODUCTION

Coral reefs are aragonite structures produced by living organisms, found in marine waters containing few nutrients and have certain zones of tolerance to water temperature, salinity, ultraviolet (UV) radiation, opacity and nutrient quantities. They are referred to as the "Tropical Rainforests of the Oceans". Globally, coral reefs are under threat from climate change, ocean acidification, overuse of reef resources and harmful land-use practices. Foraminifera are single-celled Protists and among the most abundant unicellular organisms in the ocean. To date, more than 2,140 benthic (ocean ?oor-dwelling) species have been recognized [1], while some 40–50 modern species of planktic (water column-dwelling) foraminifera have been described [2]. Benthic foraminifera are commonly found in all ocean sediments, inhabiting vast ranges of environments from the coastal zone to the deep ocean trenches and have been extensively studied by geologists due to their good fossilization potential. Their calcareous shells contribute to the carbonates formed in coral reef environments and are therefore, potential indicators of ancient reef environments [3]. In many coastal areas, especially in industrialized countries, pollution has severely affected foraminiferal microhabitats. Many foraminiferal species have adapted to extreme natural environments, such as habitats of high salinity, areas near hydrothermal vents [4], bacterial mats at hydrocarbon vents [5], or in silled basins [6]. As the irradiation levels are too high in shallow waters, the amount of light reaching the symbionts i.e. foraminiferans is needed to be decreased. These symbionts therefore, respond by either moving towards less irradiated regions within the test or by thickening its test. The scenario is completely different in deeper waters; as light intensity is very low, the foraminifers react by flattening their tests or by producing inter-septal piles; the latter not only enhance test strength but also serve as lenses to concentrate wherever light is available [7]. In spite of their ecological significance, the coral Islands of the Gulf of Mannar Biosphere Reserve (GoMBR) have not been studied from the benthic foraminiferal perspective. An attempt has therefore, been made to investigate the current status of benthic foraminiferans and their distribution.

MATERIALS AND METHODS

Study Area: Six Islands were selected for the collection of Foraminiferans, from the Gulf of Mannar region. The islands sampled were Vaan Theevu (08° 49' N; 78° 11' E), Kasuvar Theevu (08° 49' N; 78° 14' E), Vilaanguchalli Theevu (08° 56' N; 78° 16' E), Kariyachalli Theevu (08° 57' N; 78° 15' E), Upputhanni Theevu (09° 05' N; 78° 29' E) and Puluvinichalli Theevu (09° 06' N; 78° 32' E). The first four islands are a part of the Tuticorin Group, while the last two fall under the Vembar Group of coral islands (Fig. 1).

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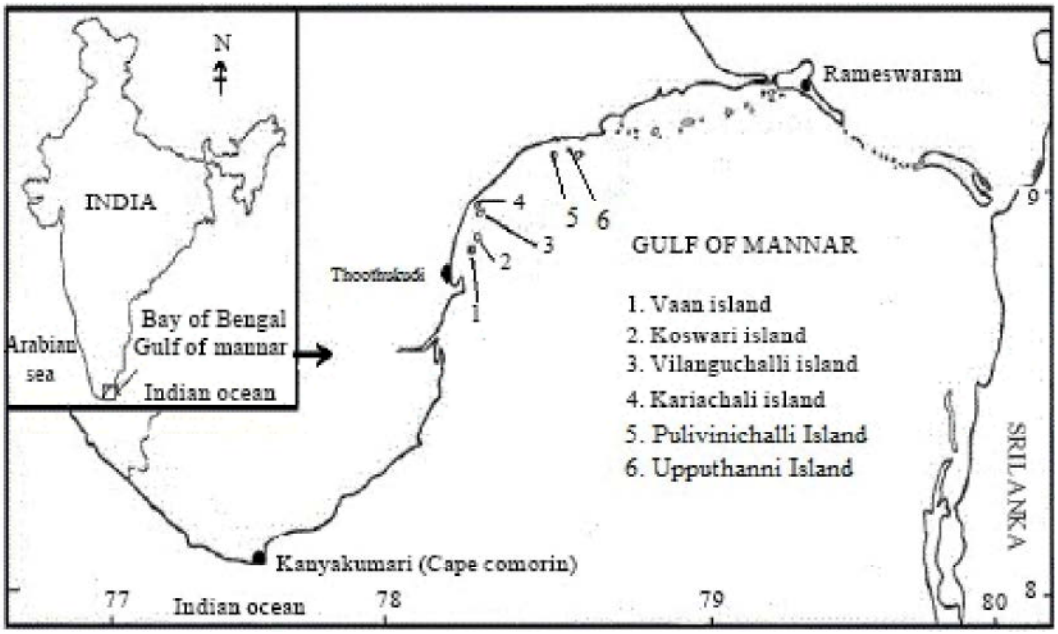

Fig. 1: Study area map representing the sampling sites

Methods: Forty-eight surface sediment and 48 bottom water samples (from the sediment-water interface) were collected in the vicinity of six coral Islands. Both the samples were collected manually with the help of divers from Tuticorin. Underwater photographs were taken using a CANON Powershot digital SLR camera (Model: S45). The collected water samples were preserved by adding a few ml of chloroform, whereas the Sediment samples were preserved in a mixture of one part of buffered formalin in nine parts of water (4% solution) with a pinch of $CaCl_2$.

The preserved sediment samples were subjected to the rose Bengal staining technique and subsequently oven-dried at 50° C. Each dried sediment sample was reduced to 25 g after coning and quartering and then sub-divided into 5 fractions using ASTM 35, 70, 100 and 120 sieves. The relatively finer fractions were subjected to floatation using carbon tetrachloride (CCl_4) [8] and the tests were separated from the filter paper to be mounted on 24-chambered micro paleontological slides. The different genera and species were identified and living and dead populations of all the taxa were counted. Type specimens of each species were selected and transferred to single round punch micro paleontological slides with cover slips. To obtain lucid illustrations, light microscopy photographs of different views of all the foraminiferal species present were taken using a CMEX camera (DC-5000) mounted on a EUROMEX-NOVEX trinocular stereo zoom microscope.

RESULT AND DISCUSSION

As mentioned earlier, water and sediment samples were collected during each season (July 2009 and February 2010). The living and total populations were counted for all the 169 species identified (consolidated from the six Islands sampled). The data has been presented in Table 1. The highest foraminiferan diversity was evidenced at the Upputhanni Theevu, followed by Vilaanguchalli Theevu. The lowest diversity of foraminiferans was recorded at the Kasuvar Theevu. The relative proportion of Foraminiferans found in the Six Islands has been depicted in Figure 2.

Vaan Theevu (VT): This Island has accounted for about 14.99% of the foraminiferan species found in all the six Islands. The minimum and maximum water depths recorded around this Island were 2.2 m and 16.1 m respectively. *Quinqueloculina lamarckiana* has been reported from this Island is also found in several localities worldwide and is a cosmopolitan species [9]. The following benthic foraminiferal species were observed to be present only in this Island, namely: *Cibicidella variablis, Cymbaloporella tabelliformis, Millettana milletti, Pseudoschlumbergerina ovata, Quinqueloculina reticulata, Quinqueloculina rhodiensis, Rosalina dencitiva and Spirillina denticulogranulata.*

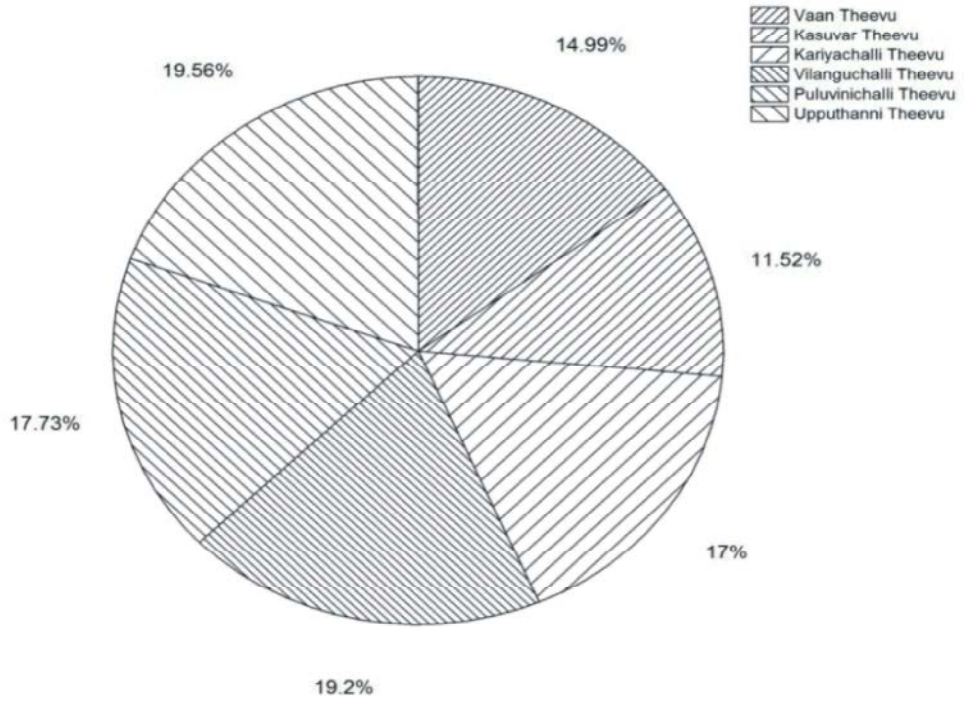

Fig. 2: The relative proportion of Foraminiferans found in the Six Islands

Table 1: Shows recorded Formanifera species from the various study area

S.No	Name of the Species	VT	KVT	KCT	VCT	PVT	UTT
1	*Acervulina mahabeti*	-	-	v	-	-	-
2	*Adelosina elegans*	v	v	v	v	-	
3	*Adelosina laevigata*	v	v	v	v	-	-
4	*Affinetrina planciana*	-	-	v	-	-	-
5	*Agglutinella compressa*	-	-	v	-	-	-
6	*Alveolinella quoyii*	-	-	v	-	-	-
7	*Ammoglobigerina globigeriniformis*	v	-	v	v	v	v
8	*Ammonia beccarii*	v	v	v	v	v	v
9	*Ammonia convexa*	-	-	v	v	v	v
10	*Ammonia dentate*	v	v	v	v	v	v
11	*Ammonia tepida*	v	v	v	v	v	v
12	*Amphistegina lessonii*	v	v	v	v	-	v
13	*Amphistegina lobifera*	-	-	-	-	v	v
14	*Amphistegina papillosa*	-	v	-	-	-	-
15	*Amphistegina radiata*	v	v	v	-	v	v
16	*Asterorotalia inflata*	v	v	v	v	v	-
17	*Asterorotalia trispinosa*	-	-	v	v	-	-
18	*Borelis schlumbergeri*	-	-	-	-	v	v
19	*Calcarina calcar*	v	v	v	v	-	v
20	*Calcarina spengleri*	v	v	v	v	-	v
21	*Calcarina spengleri*	-	-	-	-	v	v
22	*Caribeanella polystoma*	-	-	-	v	-	-
23	*Challengerella bradyi*	-	-	-	v	v	-
24	*Cibicidella variablis*	v	-	-	-	-	-
25	*Cibicides lobatulus*	v	-	-	-	-	v
26	*Cibicides refulgens*	-	-	-	v	-	v
27	*Coscinospira hemprichii*	-	-	-	-	-	v
28	*Cribromiliolinella milletti*	-	-	-	-	-	v
29	*Cribrononion simplex*	-	-	-	-	v	-
30	*Cycloforina* cf. *C. semireticulosa*	-	-	v	-	-	-

Table 1: Continued

S.No	Name of the Species	VT	KVT	KCT	VCT	PVT	UTT
31	*Cycloforina semiplicata*	-	-	-	-	v	v
32	*Cycloforina semireticulosa*	v	-	-	v	-	-
33	*Cymbaloporella tabelliformis*	v	-	-	-	-	-
34	*Cymbaloporetta bradyi*	-	-	v	v	v	v
35	*Cymbaloporetta plana*	-	-	v	v	v	v
36	*Discorbinella bertheloti*	-	-	-	-	-	v
37	*Edentostomina milleti*	v	-	v	v	v	v
38	*Edentostomina cultrata*	v	-	v	v	v	v
39	*Elphidium advenum*	v	v	v	v	v	v
40	*Elphidium botaniensis*	v	-	-	v	v	v
41	*Elphidium craticulatum*	v	v	v	v	-	v
42	*Elphidium crispum*	v	v	v	v	-	v
43	*Elphidium discoidale*	v	v	v	v	v	-
44	*Elphidium incertum*	v	-	-	v	v	v
45	*Elphidium macellum*	v	v	v	v	v	-
46	*Elphidium maoricensis*	-	-	-	-	v	v
47	*Elphidium maorium*	-	-	-	v	-	-
48	*Elphidium norvangi*	v	v	-	v	v	v
49	*Eponides cribrorepandus*	v	v	v	v	v	v
50	*Eponides repandus*	v	v	v	v	v	v
51	*Flintina bradyana*	v	v	v	v	-	-
52	*Glabratellina tabernacularis*	v	-	v	v	v	v
53	*Glabratellina turriformis*	-	-	v	v	v	v
54	*Glandulina laevigata*	-	-	-	-	-	v
55	*Globulina gibba*	-	-	-	-	-	v
56	*Hanzawaia concentrica*	-	-	-	-	v	v
57	*Hauerina ornatissima*	-	-	v	-	v	v
58	*Helenina anderseni*	v	v	-	-	v	-
59	*Heterostegina depressa*	v	v	-	v	v	v
60	*Lachlanella corrugata*	-	-	v	-	-	-
61	*Lachlanella planciana*	-	v	-	-	-	-
62	*Lachlanella subpolygona*	-	-	v	v	-	-
63	*Laevipeneroplis inornatus*	-	-	v	v	v	-
64	*Massilina gualtieriana*	-	-	-	v	-	v
65	*Massilina secans*	-	-	v	v	v	-
66	*Massilina secans*	-	-	-	-	-	v
67	*Miliolinella circularis*	v	-	v	-	v	v
68	*Miliolinella labiosa*	v	-	v	v	v	-
69	*Miliolinella perplexa*	v	v	v	v	v	v
70	*Millettana milletti*	v	-	-	-	-	-
71	*Neoconorbina terquemi*	-	-	-	-	-	v
72	*Nonionoides boueanum*	v	v	v	v	-	v
73	*Nonionoides elongatum*	v	-	v	v	-	-
74	*Nonionoides grateloupi*	v	-	v	-	-	-
75	*Oolina laevigata*	v	-	v	-	-	-
76	*Oolina piriformis*	-	-	-	-	-	v
77	*Operculina ammonoides*	-	-	-	-	v	-
78	*Orbitina carinata*	v	-	v	-	v	v
79	*Parahauerinoides complanatiformis*	-	-	v	v	v	v
80	*Pararotalia calcar*	v	v	v	v	v	v
81	*Pararotalia nipponica*	v	v	v	v	v	v
82	*Parasorites orbitolitoides*	-	-	-	v	-	-
83	*Parrellina hispidulum*	-	-	-	v	-	v
84	*Parrina bradyi*	-	-	-	-	v	v
85	*Peneroplis pertusus*	v	v	v	v	-	-
86	*Peneroplis planatus*	v	-	v	v	-	-
87	*Planorbulinoides retinaculatus*	-	-	-	-	-	v
88	*Poroeponides lateralis*	-	-	-	-	-	v
89	*Pseudomassilina pacifiensis*	-	-	-	v	-	-
90	*Pseudoschlumbergerina ovata*	v	-	-	-	-	-

Table 1: Continued

S.No	Name of the Species	VT	KVT	KCT	VCT	PVT	UTT
91	*Ptychomiliola separans*	v	-	-	-	v	-
92	*Pyrgo oblonga*	-	-	-	v	-	-
93	*Pyrgo rotalaria*	-	-	-	-	v	-
94	*Quinqueloculina agglutinans*	v	v	v	v	v	v
95	*Quinqueloculina berthelotiana*	-	-	v	-	-	-
96	*Quinqueloculina bicornis*	-	-	v	-	-	-
97	*Quinqueloculina bicostata*	-	v	v	v	v	v
98	*Quinqueloculina costata*	v	v	v	v	v	v
99	*Quinqueloculina echinata*	v	-	v	v	v	v
100	*Quinqueloculina elongata*	v	v	v	v	v	v
101	*Quinqueloculina ferussaci*	v	v	v	v	v	v
102	*Quinqueloculina kerimbaticav*	v	-	v	v	v	v
103	*Quinqueloculina laevigata*	-	-	-	v	-	-
104	*Quinqueloculina lamarckiana*	v	v	v	v	v	v
105	*Quinqueloculina nodulosa*	-	-	-	-	v	v
106	*Quinqueloculina oblonga*	-	v	v	v	-	-
107	*Quinqueloculina parkeri*	-	v	v	v	v	v
108	*Quinqueloculina patagonica*	-	-	-	v	-	-
109	*Quinqueloculina polygona*	v	v	v	v	v	v
110	*Quinqueloculina pseudoreticulata*	v	v	-	v	v	v
111	*Quinqueloculina reticulata*	v	-	-	-	-	-
112	*Quinqueloculina rhodiensis*	v	-	-	-	-	-
113	*Quinqueloculina seminulum*	v	v	v	v	v	v
114	*Quinqueloculina sulcata*	v	v	v	v	v	v
115	*Quinqueloculina tropicalis*	v	v	v	v	v	v
116	*Quinqueloculina undulosecostata*	-	-	v	v	v	-
117	*Rectobolivina raphanus*	-	-	v	v	-	-
118	*Rosalina bradyi*	v	v	v	v	v	v
119	*Rosalina dencitiva*	v	-	-	-	-	-
120	*Rosalina globularis*	v	v	v	v	v	v
121	*Rotorboides granulosus*	v	v	v	v	v	v
122	*Rupertianella rupertiana*	v	v	-	-	v	v
123	*Schlumbergerina alveoliniformis*	-	v	v	v	v	v
124	*Sigmohauerina bradyi*	-	-	-	-	-	v
125	*Sigmoilina costata*	v	v	v	-	v	v
126	*Sigmoilinita tenuis*	-	-	-	-	v	-
127	*Siphonaperta agglutinans*	-	-	v	v	v	v
128	*Siphonaperta horrida*	-	-	-	v	-	v
129	*Sorites marginalis*	-	-	-	v	-	v
130	*Sorites orbicularis*	-	-	-	v	-	v
131	*Sphaeroidina bulloides*	-	-	-	-	-	v
132	*Spirillina denticulogranulata*	v	-	-	-	-	-
133	*Spirolina arietina*	-	-	-	-	v	v
134	*Spirolina cylindracea*	-	-	-	v	v	v
135	*Spirolocilina communis*	v	v	v	v	v	v
136	*Spiroloculina aequa*	-	-	v	v	v	v
137	*Spiroloculina affixa*	-	v	v	v	v	v
138	*Spiroloculina angulata*	v	v	v	v	v	v
139	*Spiroloculina antillarum*	v	v	v	v	v	v
140	*Spiroloculina corrugata*	v	v	v	v	v	v
141	*Spiroloculina costifera*	v	v	v	v	v	v
142	*Spiroloculina depressa*	v	v	v	v	v	v
143	*Spiroloculina henbesti*	v	v	v	v	v	v
144	*Spiroloculina nitida*	v	v	v	v	v	v
145	*Spiroloculina orbis*	v	v	v	v	v	v
146	*Spiroloculina ornata*	-	-	v	-	-	-
147	*Subfischerina galapagosensis*	-	-	-	-	v	-
148	*Textularia agglutinans*	-	-	-	-	v	v
149	*Textularia bocki*	-	-	-	-	-	v
150	*Textularia conica*	-	-	v	v	v	v

Table 1: Continued

S.No	Name of the Species	VT	KVT	KCT	VCT	PVT	UTT
151	*Textularia cushmani*	-	-	v	v	-	v
152	*Textularia foliacea*	-	-	-	v	v	v
153	*Textularia porrecta*	-	v	v	v	v	v
154	*Triloculina affinis*	-	-	v	v	-	-
155	*Triloculina asymmterica*	-	-	-	v	-	-
156	*Triloculina fichteliana*	-	-	-	v	-	-
157	*Triloculina insignis*	-	v	-	v	v	v
158	*Triloculina oblonga*	v	-	-	v	v	-
159	*Triloculina ornata*	-	-	-	v	-	-
160	*Triloculina rotunda*	v	v	v	v	v	v
161	*Triloculina schreiberiana*	v	v	-	v	v	v
162	*Triloculina serrulata*	-	-	-	-	v	v
163	*Triloculina striatotrigonula*	v	v	v	v	v	v
164	*Triloculina terquemiana*	-	-	-	v	-	v
165	*Triloculina terquemiana*	-	-	-	-	v	-
166	*Triloculina tricarinata*	v	-	-	v	v	v
167	*Triloculina trigonula*	v	v	v	v	v	v
168	*Varidentella neostriatula*	-	-	-	-	v	-
169	*Vertebralina striata*	-	v	v	-	v	v

Kasuvar Theevu (KVT): This Island comprised of 11.52% of the total foraminiferan species. *Quinqueloculina ferussaci* is one of the common species around Kasuvar Theevu [10] also had reported this species as *Quinqueloculina* cf. *Q. ferussaci* and observed it to be rare, but associated with the windward and leeward sides of the reef areas and also in areas interpreted by them as reef flats, on the Bikini and nearby atolls, Marshall Islands.

Kariyachalli Theevu (KCT): This Island recorded about 17% of the total foraminiferan species of all the six Islands. The water depth range sampled around Kariyachalli Theevu was between 3.8 and 14.4 m. The substrate around the Island in contention is only sand, which undoubtedly is preferred by *E. crispum*. According to Avşar *et al*. [11], this species was common in the depth range of 22–101 m; This species has also been found to be associated with coral reef areas [12, 13] and therefore, its presence around the coral Island, Kariyachalli Theevu, is not surprising. The higher nutrient-rich influx (after the north-east monsoon) in the form of sewage sludge and domestic waste from the port city of Tuticorin has resulted in higher populations of *A. tepida*, as it is known to be an opportunistic species [14]. *Acervulina mahabeti, Affinetrina planciana, Agglutinella compressa, Alveolinella quoyii, Cycloforina semireticulosa, Lachlanella corrugata, Quinqueloculina berthelotiana* and *Quinqueloculina bicornis,* were the species encountered only in this Island.

Vilaanguchalli Theevu (VCT): About 19.2% of the total foraminiferan species have been identified from this Island. The water depth range from which the surface sediment samples were examined for foraminifera around Vilaanguchalli Theevu was 3.8–16.2 m, i.e., typically shallow water. The foraminifran *Triloculina rotunda* associated with coral reefs was well documented [15], recorded it for the first time from the West Flower Garden Bank, the northernmost coral reef in the Gulf of Mexico [16].. In the surface sediment samples collected around Vilaanguchalli Theevu, this species was found to be randomly distributed at all the stations. From the Indian region, there are many reports of *T. tricarinata* from shallow waters [17,18], however, recorded the occurrence of this species in a depth range of 34.18–63.25 m and associated with clay, silt and fine sand in the Tambelan Islands of Riau Islands. Some of the benthic foraminiferans were recorded only in this Island, namely: *Caribeanella polystoma, Elphidium maorium, Pseudomassilina pacifiensis, Pyrgo oblonga, Triloculina asymmterica, Triloculina fichteliana* and *Triloculina ornata.*

Puluvinichalli Theevu (PVT): This Island composed of about 17.73% of the total foraminiferan species. The substrate around Puluvinichalli Theevu is predominantly sandy in nature. The water depth range from which sediment samples were collected was between 1.2 and 16.2 m. A Brown-colored specimen of the species *Borelis schlumbergeri*, which constitutes one of the major components of the benthic foraminiferal assemblage

around this Island, were observed during both July 2009 and February 2010, which perhaps is the first time observation made in the Indian waters. Around Puluvinichalli Theevu, *Quinqueloculina elongata,* has been recorded from variable depths. However, on the inner shelf of the Bay of Bengal [19] recorded this taxon in a depth range of 7–51 m, with relatively more number of specimens on sand when compared with silty sand and sandt silt. He also found that *Triloculina rupertiana* is found in a water depth range of 7–51 m on sandy, silty sand and sandy silt substrates, which show that *T. rupertiana* can live at depths ranging up to ~50 m on various kinds of substrates; however, around Puluvinichalli Theevu, it was associated with the only available sand substrate. *Cribrononion simplex, Operculina ammonoides, Pyrgo rotalaria, Subfischerina galapagosensis, Triloculina terquemiana* and *Varidentella neostriatula*; were the only species found in this Island.

Upputhanni Theevu (UTT): Of the total foraminiferan species found in all the six Islands, this Island accounted for about 19.56%. The substrate around Upputhanni Theevu is principally sand. According to Cushman *et al*. [20], *Calcarina spengleri* is common in the Indo-Pacific region but less so in the Atlantic. *C. spengleri* has been recorded from variable water depths in the study area [21] recorded it from the near shore areas as well as in deeper water (3–22 m) at Kudingareng Keke, Bone Tambung, Barang Lompo and Langkai on the Spermonde Archipelago. The presence of *C. spengleri* in coral reef areas is well documented. *Ammonia convexa* has, however, been recorded from coral reef regions; in fact, this species was originally described by Collins [22] from the reef flats associated with the Great Barrier Reef, north-east Australia. The following benthic foraminiferal species were observed to be present only in this Island, namely: *Discorbinella bertheloti, Glandulina laevigata, Globulina gibba, Massilina secans, Neoconorbina terquemi, Oolina piriformis, Planorbulinoides retinaculatus, Poroeponides lateralis, Sigmohauerina bradyi* and *Textularia bocki.*

CONCLUSION

Although some research has been carried out on the foraminifers from the Lakshadweep Islands, practically no attempt has been made to undertake a detailed study on the distribution of benthic foraminifers from the coral Islands of the Gulf of Mannar Biosphere Reserve, in spite of their ecological significance. It is for this reason that a part of this biological reserve, comprising six coral Islands (Van Island, Kaasuvar Island, Kaariyachalli Island, Vilaanguchalli Island, Puzhivinichalli Island and Upputhani Island), was chosen for the study. These Islands were selected mainly due to their closer proximity to the port city of Tuticorin; moreover, none of these Islands are inhabited. Among the foraminiferans studied from the six coral Islands, *A. lessonii* and *A. radiata* were witnessed to occur in relatively larger numbers but *H. depressa* had maximum abundance (in terms of total populations) of only 1.4% during July 2009 around Kasuvar Theevu. Although the substrate was predominantly sand, the decreased numbers of this species could be attributed to the restricted nature of sampling due to the constraints imposed by the Forest Department of the Government of Tamil Nadu state. The benthic foraminiferal species around each of the six coral Islands in the Gulf of Mannar Biosphere Reserve are much more evenly distributed than in the Lakshadweep atolls, probably an indicator of better ecological condition in the study area.

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