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RESEARCH ARTICLE

SPECIES ASSEMBLAGE AND COMMUNITY PATTERNS OF CYCLOPOID COPEPODS IN KAVARATHI ATOLL ALONG THE INDIAN COAST

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ABSTRACT

Despite the importance of cyclopoid copepod community in the global carbon cycle, diversity studies on copepods in Lakshadweep islands have usually been concentrated on calanoid group and little is known about the marine cyclopoid groups. The seasonal abundance, diversity and community structure of cyclopoid copepods in Kavarathi atoll, from April 2013 (premonsoon), September 2013 (monsoon) and January 2014, is presented. A total of 28 cyclopoids belonging to 4 subgenera, 4 genera and 3 families were identified of which 21 are new records to Kavarathi lagoon. They are *Corycaeus clausi, Corycaeus affinis, Corycaeus crassiusculus, Corycaeus speciosus, Corycaeus Agetus limbatus, Urocorycaeus furcifer, Onychocorycaeus catus, Onychocorycaeus agilis, Onychocorycaeus giesbrechti, Onychocorycaeus latus, Ditrichocoryceus andrewsi, Ditrichocoryceus asiaticus, Ditrichocoryceus dahli, Ditrichocoryceus tenius, Farranula concinna, Farranula gracilis, Farranula rostrata, Farranula curta, Oncaea clevei, Oncaea media and Oithona atlandica.* The cyclopoid taxa of Kavarathi lagoon appear to exhibit increase in abundance during the post monsoon; taxa dominance and evenness seemed to be higher during monsoon. The community structure of cyclopoid copepods were also analyzed broadly in accordance with abundance as criterion for different seasons.

INTRODUCTION

Copepods are supposed to be numerically the most abundant metazoans on earth and conservative estimations revealed that they likely outnumber the abundance of insects (Chang *et al*., 2010; Schminke 2007; Hwang *et al*., 2004; Javaid Ahmed *et al*., 2013; Ka *et al*., 2011) Like all wetland ecosystems, coral Islands in Lakshadweep, being unique in diversity and productivity are of great ecological and socio-economic importance **(**Bakus, 1993). The abundance, community structure and diversity of cyclopoid copepods has rarely been investigated in marine areas due to their small size and difficulties in taxonomic identification. Cyclopod copepods have shown to be recorded from previous studies held at Kavarathi as well as Minicoy atoll (Goswami and Usha, 1990; Madhuprathap *et al*., 1977, 1991; Robin *et al*., 2012) and are the main component of the zooplanktonic biomass. The aim of this work is to establish the species abundance, community structure and distribution of the Cyclopoid copepods from Kavarathi, Lakshadweep archipelago. Prior investigations were more concerned with the relative abundance of the total plankton or of major taxa rather than species composition, the same needs to be pointed out in this context as the present study includes an overwhelming data on cyclopoid copepod abundance and diversity as well as a baseline data about mesozooplankton in Kavarathi atoll.

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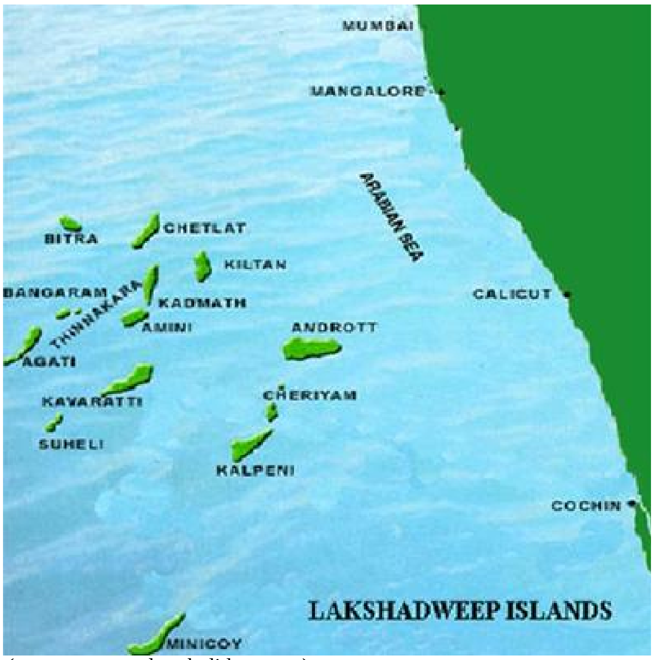
MATERIALS AND METHODS

Study area

Lakshadweep is an archipelago of twelve atolls, three reefs and five submerged banks located in the Arabian sea situated between 8 - 12°N latitude and 71°45 -73°45 E longitude .Kavarathi, located along latitude 10°33' N and longitude 72°36'E has its lagoon oriented in north to south direction which is approximately 4,500 m long and 1200 m wide with a maximum depth of 3.5m. Field sampling for the collection of mesozooplankton and various physico chemical parameters were conducted during April 2013 (premonsoon), September 2013 (monsoon) and January 2014 (postmonsoon).The exact sampling locations were fixed by Global Positioning System (GPS) (Magellan ® Triton 200/300). Samples were collected from three stations, one in the inner lagoon (T2) and the other two stations in the outer lagoon, in which one at the coral area (T1) and the other at boat channel (T3). T1 (coral area) was found to have more interactions with the island than other two stations (T2 and T3) as it was in close proximity to land whereas T2 (inner lagoon) had propinquity to the open ocean and T3 (boat channel) to be highly disturbed area as it was near the boat channel (Fig 1).



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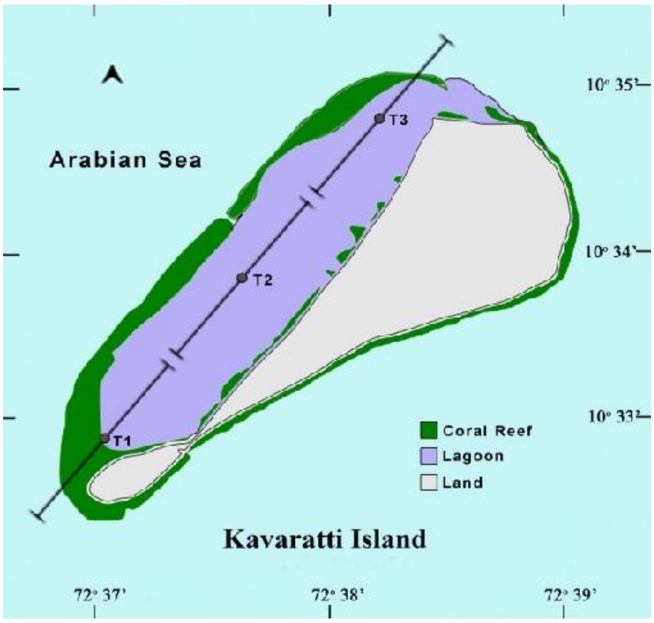

Fig. 1. Map showing the sampling stations at Kavaratti atoll, Union Territory of Lakshadweep

Sampling and analysis

The subsurface water samples were collected using Niskin water sampler (General Oceanics-5L). Temperature, salinity and pH were measured using probes (Eutech Model number PCD 650). Dissolved oxygen concentration was measured by Winkler's method (Strickland and Parsons 1972). For chlorophyll 'a' analysis, water samples were filtered immediately after collection and estimated based on standard procedure (APHA, 2005). For analysis of nutrients such as nitrate-nitrogen, nitrite-nitrogen, phosphate-phosphorous, silicate-silicon and ammonia-nitrogen, samples were acidified with conc. $HNO_3$and analyzed based on standard methods **(**Grasshoff *et al.*, 1999). Mesozooplankton was collected using a plankton net (mesh size 200µm) with a mouth area of 0.28m^2. The net was attached with a calibrated flow meter (General Oceanics model number-2030 R, 2012) and was towed horizontally just below the surface with a fixed speed of ~ 1 knot for the duration of 10 minutes. The samples were then preserved in 4% buffered formalin prepared in seawater. Zooplankton biomass was estimated by displacement volume method and expressed as ml / m^3 (Goswami, 2004; Harris *et al.*, 2000; Johnson and Allen, 2005). Samples were sorted at group level for the major zooplankton taxa (Omori and Ikeda, 1984; Tait 1981; Todd and Laverack1991) and enumerated and density was expressed in No /m^3 (Goswami 2004; Johnson and Allen 2005). Rest of the rare groups are included in "other groups". The cyclopoids were further identified upto species level using standard keys (Boxshall and Halsey 2004; Dahl 1912; Farran 1911, 1929; Kasthurirengan 1963; Karanovic, 2000; Mori, 1964; Tanaka 1957; Wi and Soh 2013a). 3 Multi-Dimensional Scaling (MDS) ordination, following hierarchical cluster using SIMPROF were constructed based on square root transformation on cyclopoid taxa abundance (Clarke and Gorley 2006). The analysis of community structure was performed using statistical software PRIMER version 6.1 (Clarke and Gorley, 2006). A similarity matrix was calculated from the abundance data of cyclopoid copepod taxa. Cluster analysis was used to differentiate the regional copepod communities based on Bray Curtis similarity measure and group linkage classification.

RESULTS

Hydrography and Mesozooplankton abundance

The seasonal variations in hydrographic parameters at Kavaratti atoll are presented in (Table 1).

Table 1. Seasonal average of hydrographical parameters in Kavaratti atoll

Parameter	Premonsoon	Monsoon	Postmonsoon
Water Temperature (ºC)	28.67±0.58	27.33±0.58	29.67±0.58
pH	8.64±0.41	7.75±0.03	8.75±0.01
Turbidity(NTU)	1.45±0.04	3.19±0.02	2.28±0.01
Salinity (‰)	34±0.00	33±0.00	37±0.00
Dissolved Oxygen (ml/L)	6.02±0.09	6.24±0.09	6.89±0.07
Nitrate (µM/L)	2.35±0.30	3.1±0.3	3.03±0.40
Nitrite (µM/L)	0.43±0.01	0.51±0.02	0.49±0.03
Phosphate (µM/L)	0.34±0.03	0.40±0.02	0.39±0.01
Silicate (µM/L)	0.45±0.02	0.30±0.02	0.31±0.01
Ammonia (µM/L)	0.37±0.02	0.35±0.02	0.40±0.02
Chlorophyll a (mg/m^3)	0.51±0.05	0.46±0.05	0.53±0.04

The hydrography showed that the temperature values fluctuated between 27ºC and 30ºC with the highest during post monsoon and lowest during monsoon. Salinity, with no distinct spatial variation, ranged between 33ppt during monsoon and 37pptduring post monsoon. pH ranged between 7.72 and 8.76 with the lowest and highest value observed during monsoon and postmonsoon respectively. Dissolved oxygen recorded a minimum value of 5.94mg/L during pre monsoon in the coral area (T1) and a maximum of 6.11 to 6.95mg/L in boat channel

Table 2. Abundance (No/m^3) and percentage composition of major groups of mesozooplankton in Kavaratti atoll during 2013-14

ZooplanktonGroups	Premonsoon			Monsoon			Postmonsoon		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
Foraminifera	10(1.7)	17(3.6)	3(0.4)	3(1.0)	2(1.3)	2(1.0)	4(0.2)	15(1.7)	7(0.7)
Gastropoda	7(1.0)	22(4.7)	7(1.1)	8(3.3)	11(7.5)	6(3.2)	9(0.6)	5(0.6)	13(1.3)
Bivalvia	1(0.2)	1(0.1)	1(0.1)	0	0	0	0	1(0.1)	0
Chaetognatha	5(0.7)	4((0.8)	7(1.1)	10(4.0)	11(7.5)	5(2.7)	65(4.4)	7(0.8)	6(0.6)
Siphonophora	3(0.5)	2(0.5)	4(0.6)	3(1.2)	2(1.3)	3(1.6)	5(0.3)	3(0.3)	2(0.2)
Appendicularia	5(0.8)	7(1.5)	1(0.2)	0	0	0	0	0	0
Polychaeta	3(0.5)	1(0.3)	2(0.4)	0	1(0.6)	0	1(0.06)	0	0
Ostracoda	5(0.8)	54(11.6)	5(0.7)	1(0.2)	1(0.6)	1(0.5)	4(0.2)	7(0.8)	4(0.4)
Cladocera	26(4.3)	5(1.0)	4(0.7)	1(0.6)	1(0.6)	1(0.5)	27(1.8)	2(0.2)	34(0.4)
Euphausiida	2(0.4)	16((3.4)	6(1.0)	0	1(0.6)	3(1.6)	2(0.1)	3(0.3)	3(0.03)
Decapoda	5(0.8)	15(3.2)	9(1.4)	25(10.2)	17(11.7)	58(31.5)	4(0.2)	2(0.2)	2(0.2)
Zoea	7(1.1)	29(6.1)	18(2.7)	42(17.3)	35(24.1)	44(23.9)	11(0.7)	2(0.2)	3(0.3)
Calanoida	114(18.4)	31(6.6)	165(25.6)	100(41.1)	34(23.4)	32(17.3)	762(51.6)	573(67.8)	626(61.61)
Cyclopioda	298(47.9)	70(14.9)	305(47.3)	39(15.8)	18(12.4)	16(8.6)	494(33.4)	163(19.2)	262(25.8)
Harpacticoida	94(15.2)	36(7.7)	93(14.4)	1(0.6)	2(1.3)	1(0.5)	61(4.1)	12(1.4)	31(3)
Copepodites	13(2.1)	25(5.4)	0	4(1.7)	3(2.0)	3(1.6)	2(0.1)	2(0.2)	0
Fish larvae	13(2.1)	94(20.2)	11(1.7)	0	1(0.6)	4(2.1)	4(0.2)	7(0.8)	4(0.4)
Fish egg	7(1.2)	37(8.0)	3(0.4)	0	0	1(0.5)	15(1.01)	36(4.2)	15(1.5)
Other groups	3(0.4)	2(0.5)	2(0.2)	6(2.4)	5(3.4)	4(2.1)	5(0.3)	5(0.6)	4(0.4)
Total	621	468	646	243	145	184	1475	845	1016

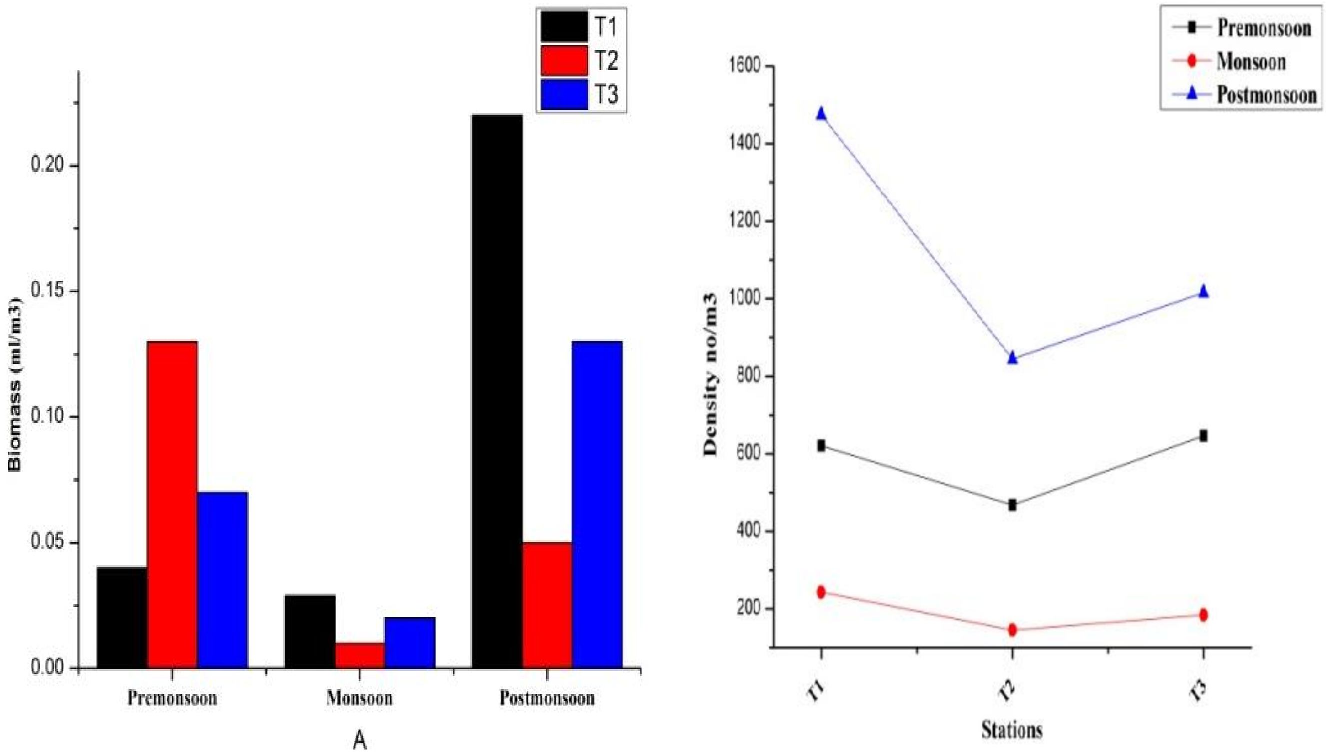

Fig. 2. Mesozooplankton biomass (ml/m^3) and density (no/m^3) of Kavaratti atoll during 2013-2014

(T2) during all the seasons. The highest value of turbidity was during monsoon (3.21) near the boat channel and the lowest in the inner lagoon (2.15) during premonsoon. The maximum values recorded for nitrate (3.2µM/L), nitrite (0.53µM/L) and phosphate (0.39µM/L) were in the coral area (T1) during monsoon and the lowest values were recorded in the inner lagoon during premonsoon except for phosphate, which showed minimum value of (0.29µM/L) in the coral area during postmonsoon. Conversely, the highest value for silicate was recorded in the coral area during premonsoon (0.47µM/L), whereas the lowest value (0.29) was found to be in the inner lagoon during monsoon. Concentration of ammonia in water showed noteworthy spatial and temporal variation. Minimum and maximum values of ammonia ranged from 0.33 in station 3 to 0.42µM/L in station 1 during monsoon and postmonsoon respectively and Chlorophyll a concentration showed major seasonal variation and the values ranged between 0.52 to 0.98mg/m^{3}with the lowest value during postmonsoon and the highest value during premonsoon.

The highest density of zooplankton was recorded during post monsoon season with an average of 1112 no/m^3 and lowest during monsoon with an average of 190no/m^3. The station which showed the highest density was the coral area (243-

1475no/m^3) followed by boat channel (184-1016 no/m^3) and the least exhibited in the inner lagoon (145-845no/m^3) (Table 2). Post monsoon season exhibited the highest biomass in the coral area and the lowest in the inner lagoon during monsoon season. It was noticed that fish larvae contributed for the most part of the total mesozooplankton biomass. Zooplankton biomass was strikingly higher in the inner lagoon during premonsoon season regardless of lower abundance (Fig. 2).

Cyclopoid abundance and taxonomic composition

A total of 28 cyclopoid species belonging to 4 subgenera, 4 genera and 3 families were identified during the present study (Table 3).

Table 3. Cyclopoid copepod species recorded at Kavaratti during 2013-2014

Cyclopoida Burmeister, 1834	Taxa	PreMon	Mon	PoMon
Family Corycaeidae				
Genus *Corycaeus*	*Corycaeusagilis* Dana, 1849	+++	+	++
	Corycaeus subulatus Herrick,1887	++	+	++
	Corycaeus clausi Dahl F,1894	++	+	+++
	Corycaeus vitreus Dana, 1849	+++	+	+++
	Corycaeus affinis McMurich,1916	+++	+	++
	Corycaeus crassiusculus Dana,1849	+++	+	+++
	Corycaeus speciosus Dana,1849	+++	+	+++
Genus *Corycaeus (Agetus)*	*Agetus limbatus* Brady ,1883	–	–	+++
	Agetus sp.	–	–	+++
Genus *Corycaeus (Urocorycaeus)* (Dahl 1912)	*Onychocorycaeus catus* Dahl F,1894	+++	+	++
	Onychocorycaeus agilis Dana, 1849	++	+	++
	Onychocorycaeus giesbrechti Dahl,1894	++	–	++
	Onychocorycaeus latus Dana,1849	+	–	++
Genus *Corycaeus(Ditrichocorycaeus)* (Dahl 1912)	*Ditrichocoryceus andrewsi* Farran,1911	++	+	+++
	Ditrichocoryceus asiaticus Dahl F,1894	++	+	+++
	Ditrichocoryceus dahli Tanaka,1957	+	+	–
	Ditrichocoryceus tenius Giesbrecht, 1891	+	+	+
Genus *Farranula*	*Farranula gibbula* Giesbrecht, 1891	+++	+	+++
	Farranula concinna Dana, 1853	++	+	+++
	Farranula gracilis Dana, 1849	+++	+	+++
	Farranula rostrata Claus, 1863	++	+	++
	Farranula curta Farran,1911	++	+	+++
Family Oncaedae				
Genus Oncaea	*Oncaea clevei* Früchtl, 1923	+++	+	+++
	Oncaea media Giesbrecht, 1891	+++	+	+++
Family Oithonidae				
Genus Oithona	*Oithonasimilis* Claus, 1866	+++	+	+
	Oithona atlandica Farran,1908	++	+	+
	Oithona sp.	+++	+	+++

"+" Denotes presence ,"++" Denotes Less abundant , "+++" Denotes Abundant ,"-" Denotes absence;"Premon", "Mon", "PoMon" denotes Premonsoon, Monsoon and Postmonsoon respectively

Table 4. Variation in abundance (No/m^3) of Cyclopoid copepod species in Kavaratti atoll during 2013-2014

No	Cyclopoids	Premonsoon			Monsoon			Postmonsoon		
		T1	T2	T3	T1	T2	T3	T1	T2	T3
1	*Corycaeus agilis*	32	9	30	1	1	0	30	5	1
2	*Corycaeus subulatus*	9	2	9	1	0	0	8	2	1
3	*Corycaeus clausi*	9	1	9	1	0	0	20	8	1
4	*Corycaeus vitreus*	12	2	14	2	1	2	25	9	22
5	*Corycaeus affinis*	9	2	9	1	0	0	7	3	1
6	*Corycaeus crassiusculus*	20	2	20	5	3	1	32	20	35
7	*Corycaeus speciosus*	15	2	15	3	2	2	26	20	30
8	*Corycaeus Agetus limbatus*	0	0	0	0	0	0	25	8	10
9	*Corycaeus Agetus* sp.	0	0	0	0	0	0	25	10	12
10	*Urocorycaeus furcifer*	0	0	0	0	0	0	12	4	5
11	*Onychocorycaeus catus*	10	2	10	1	0	1	10	1	2
12	*Onychocorycaeus agilis*	6	1	6	1	0	0	5	1	5
13	*Onychocorycaeus giesbrechti*	4	1	4	0	0	0	6	1	2
14	*Onychocorycaeus latus*	2	1	2	0	0	0	3	1	8
15	*Ditrichocoryceus andrewsi*	10	4	10	5	1	1	40	5	27
16	*Ditrichocoryceus asiaticus*	5	1	5	1	1	0	15	8	25
17	*Ditrichocoryceus dahli*	4	1	4	1	1	4	0	0	0
18	*Ditrichocoryceus tenius*	4	1	4	1	1	0	5	2	2
19	*Farranula gibbula*	32	9	32	2	1	2	45	10	21
20	*Farranula concinna*	20	5	20	2	1	1	39	10	17
21	*Farranula gracilis*	18	5	22	3	1	1	15	7	10
22	*Farranula rostrata*	10	2	10	1	1	0	13	9	5
23	*Farranula curta*	12	3	12	1	1	0	20	6	8
24	*Oncaea clevei*	12	2	14	1	1	0	20	2	2
25	*Oncaea media*	10	1	10	2	0	0	20	1	2
26	*Oithona similis*	11	3	11	1	0	0	3	1	2
27	*Oithona atlandica*	9	3	9	1	0	0	5	1	2
28	*Oithona* sp.	13	5	14	1	1	1	20	8	4
	Total	298	70	305	39	18	16	494	163	262

Total abundance of cyclopoid copepods varied among stations and ranged between 16 no/m^3 (T3) and 494 no/m^3 (T1) during monsoon and post monsoon respectively. Corycaeus was the most abundant cyclopoid genus ranging between 46- 591 no/m^3 irrespective of all seasons followed by Farranula (18 - 235 no/m^3) and Oithona (5-78 no/m^3).Oncaea was observed to be the least abundant genus (4 -49 no/m^3). A total of 4 genera and 28species were identified from Kavarathi lagoon during the present study. The most species rich family observed during the present study was the Corycaedae (> 23spp.) followed by Oithonodae (>3spp.) and the least one to be Oncaedae (>2spp.) (Table 4).

The highest number of 151 species per station were found near the coral area and boat channel (T1and T3) and the lowest in the inner lagoon (T2) with 32species during the premonsoon, whereas monsoon season could bring up only 24 spp. as the highest in the coral area and a lowest of 11 spp. in both inner lagoon and boat channel. On the contrary, during post monsoon, 294 spp. was observed in the coral area and a lowest of 108 spp. in the inner lagoon. During pre monsoon, in the coral area (T1), the cyclopoid community was characterized by the dominance of the genus Corycaeus which represented 35.57 % of all cyclopoid specimens at T1 followed by Farranula (30.87%), Oithona (11.07%), Ditrichocorycaeus (7.71%) and the least by Onychocorycaeus and Oncaea (7.75%). But the inner lagoon was characterized by the dominance of Farranula (34.28%) followed by Corycaeus (28.57%), Oithona (15.71%), Ditrichocorycaeus (10%), Onychocorycaeus (7.14%) and the least by Oncaea (4.28%).On the other hand, more or less the same genus dominance pattern as that of T1was observed in the boat channel(T3) which was dominated by Corycaeus (34.75%) followed by Farranula (31.47%), Oithona (11.15%), Oncaea (7.86%), Ditrichocorycaeus (7.54%) and Onychocorycaeus (7.21%).While during the monsoon, cyclopoids in the coral area was characterized by the dominance of genus Corycaeus which came up to35.89% followed by Farranula (23.07%), Ditrichocorycaeus (20.51%),Oncaea and Oithona (7.69%) and Onychocorycaeus (5.12%); the cyclopoids of the inner lagoon also exhibited 38.88% of genus Corycaeus followed by Farranula. (27.77%), Ditrichocorycaeus (22.22%), and the least by Oncaea and Oithona (5.5%); the boat channel showed both Ditrichocorycaeus and Corycaeus to be dominant constituting 31.25% of the cyclopoids followed by Faranula (25%), Oncaea and Oithona (each 6.25%).The pre monsoon cyclopoid community were devoid of the genus Agetus and Urococycaeus and the monsoon cyclopoid community showed the absence of Agetus, Urococycaeus as well as Oncaea genus. During post monsoon T1, T2 and T3 was dominated by Corycaeus [(50.34% -T1), (62.03%-T2), (50.27% -T3)] followed by Farranula (44.89%), (38.88%), (32.27%) in coral area, inner lagoon and boat channel respectively. The genus Urocorycaeaus was represented only during postmonsoon. While premonsoon cyclopoid community was characterized by the high dominance of *Corycaeus agilis* and least dominance by *Onychocorycaeus latus*; the monsoon cyclopoid community was dominated by *Corycaeus crassiusculus* and least dominated by *Onychocorycaeus agilis*, *Corycaeus affinis*, *Corycaeus clausi* and *Corycaeus subulatus* whereas post monsoon was dominated by *Corycaeus crasssiusculus* followed by *Corycaeus speciosus* and *Ditrichocorycaeus andrewsi* and the least by *Onychocorycaeus giebrechti* and *Ditrichocorycaeus tenius.* The highest cyclopoid species diversity (H') (4.45) was recorded during postmonsoon in the coral area while taxa dominance (Lambda) and J' value seemed to be higher during monsoon T2. The lowest J' value recorded was during post monsoon T3 (boat channel) which shows uneven distribution of taxa. Taxa richness (d) value was observed to be higher during monsoon T1 and pre monsoon T2 (Fig .3).

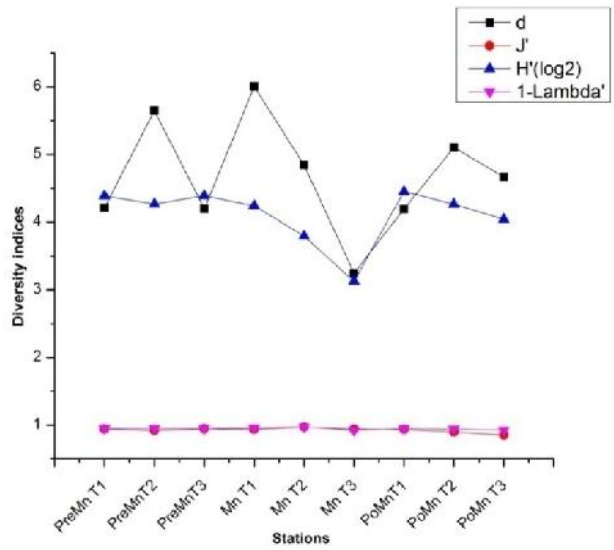

Fig. 3. Diversity indices of cyclopoid copepods during 2013-2014 in Kavaratti atoll (PreMn-Premonsoon, Mn-Monsoon, PoMn-Postmonsoon)

Community structure

Community structure was examined using 28 cyclopoid species selected for their abundance. A cluster analysis was applied to the species matrix, using Bray Curtis similarity and the group linkage method. Results of the Hierarchical cluster analysis and MDS ordination of cyclopoid copepod community is shown in Figs. 4 & 5. From the MDS it is apparent that three main clusters with a similarity of 60% are being formed. During monsoon season (Mn), T2 (inner lagoon) and T3 (boat channel) formed a cluster with 60% similarity whereas during premonsoon (PreMn) T2 and T1 formed another cluster with a similarity of 60%.But, during post monsoon (PoMn), T2 and T3 formed a cluster with 80% similarity. The results of the biota environmental matching (BEST) revealed that the correlation coefficient (Rho) is 0.638 (Fig 6). Dendrogram showing affinities among cyclopoid copepod species and formation of groups in stations is also illustrated in Fig 7.

DISCUSSION

Hydrography and Mesozooplakton abundance

This study provides an ample understanding on the distribution and abundance of cyclopoid copepod inclusive of the existing mesozooplakton, in relation to various hydrographic parameters in Kavarathi atoll where limited information is accessible.

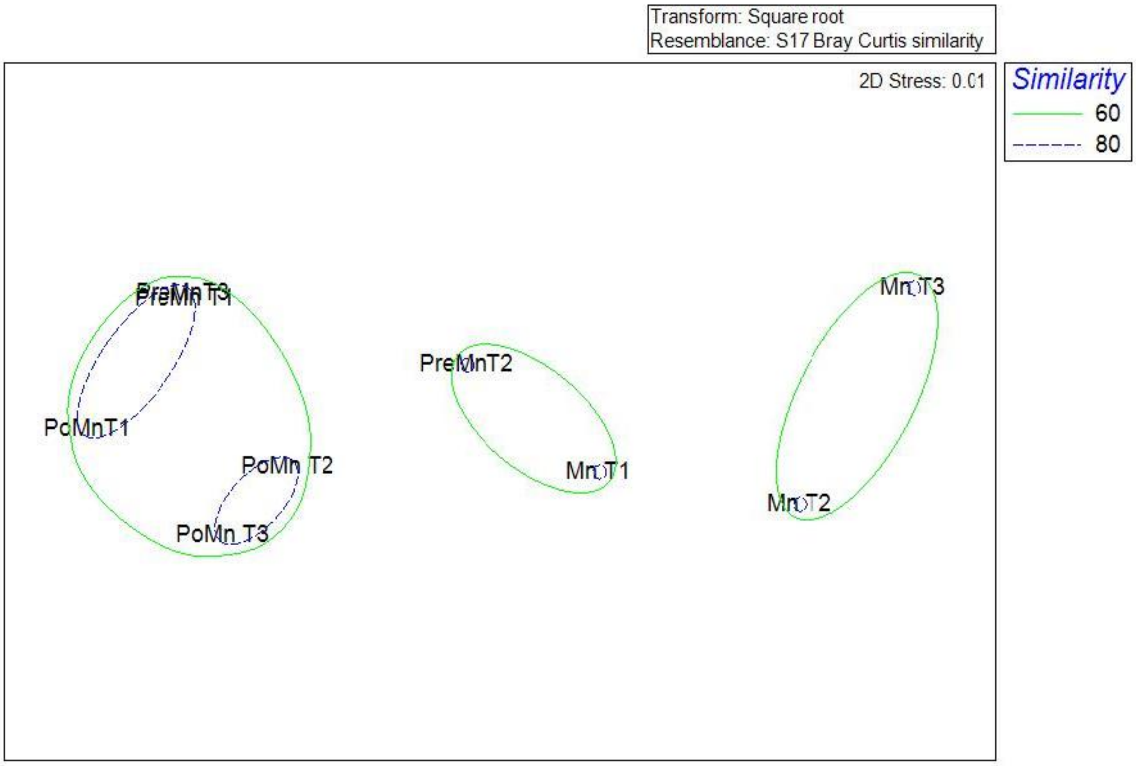

Fig. 4. Hierarchical cluster analysis of the mesozooplankton of Kavaratti atoll during 2013-2014

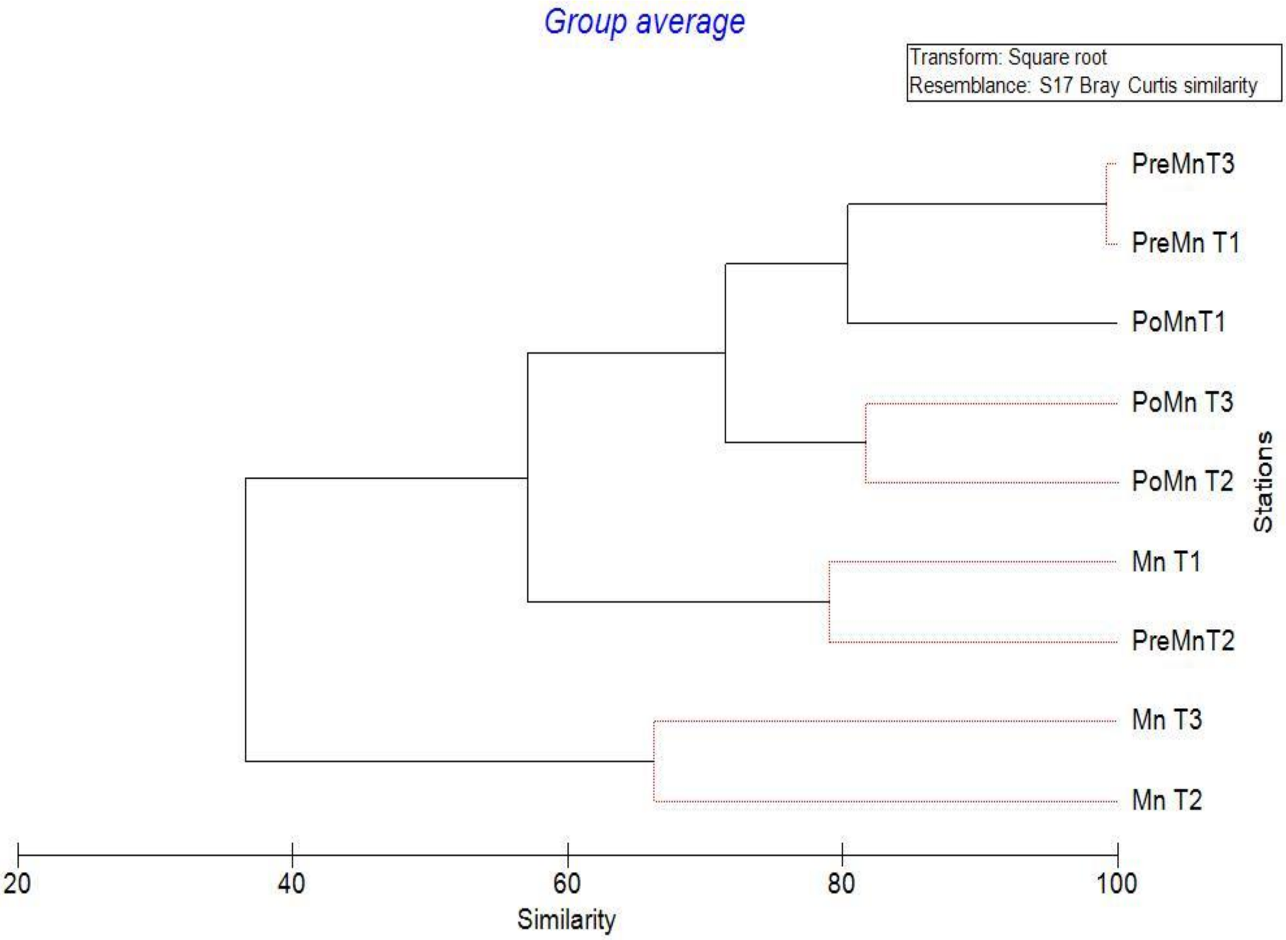

Fig. 5. Non-metric Multi-Dimensional scaling of mesozooplankton of Kavaratti atoll during 2013-2014

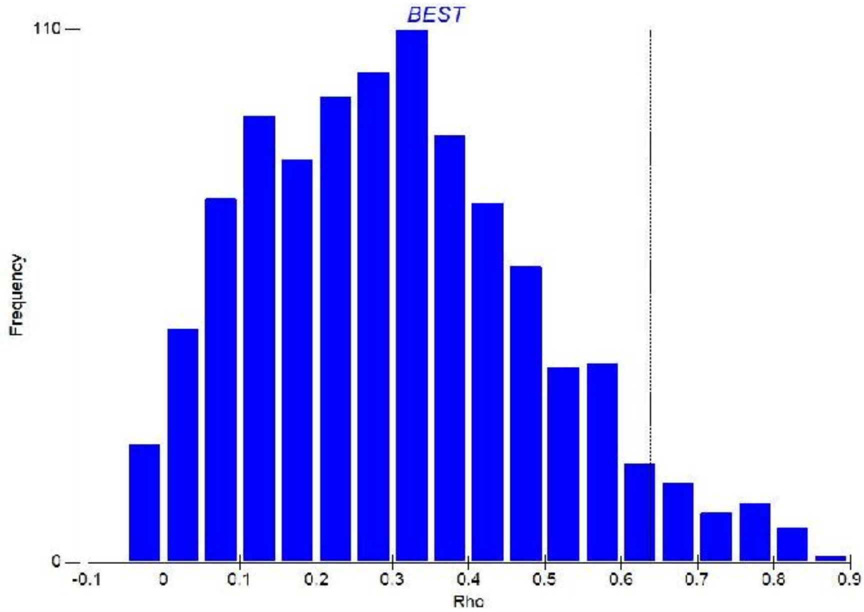

Fig. 6. **Histogram showing the BEST results of seasonal cyclopoid species abundance (Rho=0.638)**

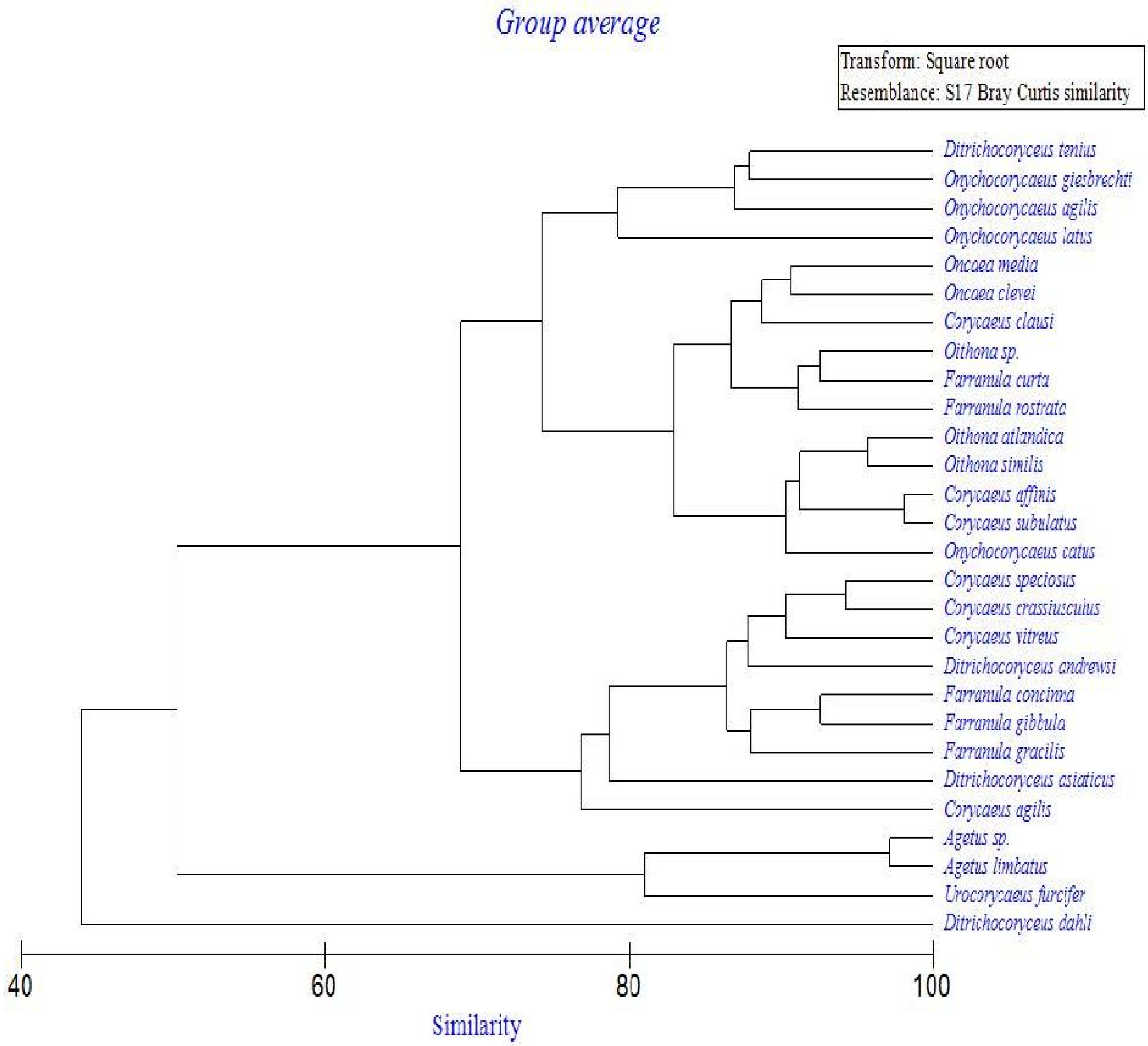

Fig. 7. Dendrogram of cluster analysis showing affinities among cyclopoid species and formation of groups

Goswami, 1979 reported that the water temperature, salinity and pH in the Kavarathi atoll remained higher throughout the study period (temperature, 29.7 to 31.9˚C; salinity, 34.15 to 35.64; pH, 7.9 to 8.3) which were comparable to that of the present study which gave the values as (temperature, 27ºC to 30ºC; Salinity 33 to 37; pH, 7.72 to 8.76). These high values may be accredited to the shallow depth as well as low energy region in the lagoon. Clansen *et.al.*,1975 opined that coral reef growth occurs at an optimum water temperature between 25ºC and 29ºC and flourish at water temperature ranging from 17ºC to 34ºC which very well agrees with that of Kavarathi water temperature. Further, Qasim and Sankaranarayanan, 1970 reported that the high salinity in the lagoon may be ascribed to the unidirectional flow of seawater towards the entrance of the lagoon which in turn is created by the heavy surf breaking across the reef. The same can also be due to the fresh water influx during south west monsoon season (June to September) which consecutively is by precipitation. The role of higher pH in lagoon water in the precipitation of calcium carbonate, the formation of interstitial lime paste and sequentially for the coral development was proposed by Clansen and Roth, 1975; Vacelet, 1984).The higher values of turbidity in the Kavarathi lagoon during monsoon season may be due to the sediment resuspension in the water column associated with heavy rain. Turbidity which limits coral distribution when augmented on the reef flat, light availability for photosynthesis is reduced (Fabricius, 2005; Te, 1997). But, continuous illumination due to less turbid and shallow depth of Kavarathi water sustained the luxuriant growth of sea grass and algae (Suresh and Mathew 1997)

Pervasiveness of saturated condition of dissolved oxygen value could be owed to the active photosynthesis by seaweeds as well as sea grasses (Robin 2012). The oligotrophic nature of Kavarathi waters is very well substantiated by the absorbance even at very low concentrations of inorganic phosphorus by the coral containing zooxanthellae (D'Elia, 1988). The growth and development of corals is greatly affected by the availability of nutrients. The richness of nutrients in the present study particularly in coral area during monsoon might be owing to the incursion of domestic sewage input, leaching from land vegetation and coir spinning industries situated along its coast and increased utilization by macrophytes, and low retention by the sandy substratum contributed to pervasiveness of low nutrients during other seasons (Neudecker, 1987). This was substantiated by (Robin *et al.*, 2012). Silicate concentration showed no marked variation as there was no fresh water influx from the river. Fairly low value of ammonia recorded in the present study owed to its increased uptake by the phytoplankton community which prefers it over nitrate in certain environmental factors.

Suresh *et al.* (1997) reported zooplankton density from Kavarthi ranging from 122.4 to 722.8 no/m^3 which was lower than that observed during present study (145 to 1475 no/m^3). On the contrary, the zooplankton abundance in Kavarathi was higher in sea compared lagoons and deprivation of abundance in Kavarathi lagoon compared with Agatti and Suhelipar lagoons might be because the latter ones are larger and deeper and have more carrying capacity (Madhuprathap *et al.*, 1991) Physicochemical characteristics like temperature, salinity, pH, nutrients, dissolved oxygen, biological (Chl-a) and top-ographical parameters influences the abundance and distribution of zooplankton which substantiates the fact where seasonality in mesozooplakton abundance may be associated with variation in the physicochemical parameters (Chicaro and Chicaro 2000) Factors like low light intensity, high current velocity and high turbidity adversely affects mesozooplankton abundance (Nasser *et al.*, 1998)

Cyclopoid abundance and taxonomic composition

In Kavaratti atoll 28 cyclopoid species belonging to 3 families were recorded. The total number of species reported in the present study were rather higher than other reports from the same area. Goswami, 1973 from National Institute of Oceanography reported 6 cyclopoids from Kavarathi lagoon and sea. Subsequent studies in this same region by (Madhuprathap *et al.*, 1977) recorded only 2 cyclopoids from Kavarathi lagoon. 6 species of cyclopoids were reported from Kavarathi and Minicoy islands (Goswami and Usha, 1977) Recent studies by (Robin *et al*., 2012) reported only 3 cyclopoid species. The present study were represented by 3 families ie Corycaeidae, Oncaedae, Oithonidae. Premonsoon was dominated by the family Corycaeidae followed by Oithonidae and the least by Oncaedae. Rather same pattern was followed during monsoon and post monsoon season also.But the cyclopoid abundance was most prominent during post monsoon season and the least being the monsoon season. Eventhough the cyclopoids recorded by Goswami, 1979 were represented by three families as of recorded in the present study, number was few. The family Oithonodae and Corycaedae contributed greatly to cyclopoid composition in Kavarathi lagoon (Madhuprathap *et al*., 1977). The cyclopoids reported by Goswami, 1990 represented the 3 families recorded in the present study. Recent study by (Robin *et al*., 2012) included only 2 families ie Corycaedae and Oithonidae from those included in the present study.

Community structure

The cyclopoid copepod communities in our study were distinguished broadly in accordance with abundance as criterion for different seasons viz.pre monsoon, monsoon and post monsoon. The assemblages identified by cluster analysis were for the most part determined by species composition and abundance. Dendrogram which was calculated from the abundance data of cyclopoid copepod taxa showed significant similarities between different species. Lack of data on cyclopoid community structure in Kavarathi lagoon leads to an inappropriate basis for comparison. However (Jean Jose *et al*., 2010) have provided the hierarchical analysis of data concerning the zooplankton assemblages over a semidiel pattern in Kavarathi lagoon which described the dominance of gastropod larvae and its interrelationship to other zooplankton groups. He also established a single separate cluster formation for copepods and its presence as an opportunistic invader to the lagoon ecosystem.

Conclusion

Cyclopoid copepod composition, abundance and community structure based on seasonal sampling in Kavarathi lagoon, Lakshadweep are presented in this study. It is concluded from this study that the cyclopoid taxa of Kavarathi lagoon appear to exhibit an increase in abundance during the post monsoon in the coral area, taxa dominance and evenness seemed to be higher during monsoon. In addition 28 cyclopoid species have been identified of which 21 are new records to the lagoon.

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