Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Original article doi: 10.12980/jclm.4.2016j5-156 

# Diversity assessment of echinoderms from Mudasalodai and Pazhayar in the southeast coast of India

Maheswaran Murugan, Narendran Rajendran, Sundaravarman Kasirajan, Pravinkumar Moorthy, Gunalan Balakrishnan*

*Centre for Advance Study in Marine Biology, Faculty of Marine Sciences, Parangipettai, Tamil Nadu, India*

ARTICLE INFO

*Article history:*
Received 20 Aug 2015
Received in revised form 2 Sep 2015
Accepted 25 Dec 2015
Available online 16 Jan 2016

*Keywords:*
Echinoderms
Diversity
Percentage composition
Seasonal variation

ABSTRACT

**Objective:** To study the echinoderms diversity in Mudasalodai and Pazhayar landing centers during November 2012 to December 2014.
**Methods:** All the collected echinoderm samples were stored at 4 ˚C until further use.
**Results:** As many as 19 species of echinoderms were recorded in both stations and it belongs to 10 families, three classes such as Asteroidea, Echinoidea and Ophiuroidea. The percentage composition varied from 0.15% to 73%. The species diversity ranged from 1.031 to 2.6; species richness was from 1.02 to 4.06 and species evenness ranged from 0.93 to 0.99. K-dominance curve drawn paralleled the trend of diversity indices. Cluster and multidimensional scaling showed the similarity in echinoderms composition within the stations.
**Conclusions:** The present investigation is evident that the echinoderm occurrence was predominant during the summer season and proved statistically by using SPSS Primer 6.0.

## 1. Introduction

Echinodermata are the most familiar invertebrates and are a group of exclusively marine, triploblastic, coelomate animals. They are spiny skinned and possess penta-radially symmetrical body having endoskeleton formed by calcareous ossicles and spines with water vascular system. They are the highly advanced group among invertebrates. Since, they don't have heart, brain and eyes, produced by sexual or asexual reproduction. The soft tissue and skeletal characters are the key to identification and study of echinoderm. Therefore, maintaining the integrity of the skeleton and connective tissue is the key to successfully preserving and archiving echinoderm specimens. Most of the echinoderm has five radii or multiples thereof. They range in size from 1 cm to 1 m in diameter and often have brilliant colouring. They have numerous small, moveable protrusions called tube feet that aid in movement, feeding, respiration and excretion.

The echinoderms consist of six named classes, including Asteroids, Crinoids, and Concentric cycloids, Echinoids, Ophiuroids and Holothuroids. Moreover, echinoderms are the only animals that have mutable connective tissue. The phylum contains nearly 6 500 known species and constitutes the only major group of deuterostome invertebrates[1]. Echinoderms are globally distributed in almost all depths, latitudes and environments in the ocean, rich in reef environments but also wide spread in shallow shores.

Echinoderms bear an important evolutionary relationship with vertebrates. Evidences indicate that the echinoderm may share a common ancestor with the lower chordates and hence the vertebrates. The sample collection was followed for twenty months starting from December 2012 to August 2014. The predominant species found in this landing belongs to phylum Asteroidea and Echinoidea. However, knowledge on the diversity of Ophiuroidea remains scarce in Brazil, with 134 recorded species[2,3]. Although ophiurans are common and conspicuous animals, the scientific effort to describe their diversity has varied over the centuries, resulting in patchy knowledge[4]. The objective of the present work is to present an updated list of the echinoderms of the above mentioned landing centres with information coming from scientific collections, literature review and discuss the taxonomic distinctness and composition similarity for each class.

## 2. Materials and methods

### 2.1. Study area and sampling methods

This study was conducted during the month of December 2012 to November 2014. A total of 2 stations, namely, Mudasalodai

*Corresponding author: Dr. Balakrishnan Gunalan, Assistant Professor, Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai, Tamil Nadu 608 502, India.
Tel: +91-9600622965
Fax: 04144-243555
E-mail: aquagunal@gmail.com
The journal implements double-blind peer review practiced by specially invited international editorial board members.
Foundation Project: Supported by the Ministry of Human Resources and Development Govt. of India for the financial assistance, Grant No: G4 (1)/1630/2013.

(latitude 11°21' N; longitude 79°50' E) and Pazhayar (latitude 11°21' N; longitude 79°50' E), southeast coast of India were selected for the investigation of echinoderm diversity (Figure 1). All the echinoderm samples were collected by using trawl net from 100 to 200 m depth. The echinoderm samples were washed thoroughly with seawater to remove silt, debris and then moisture was removed using the blotting papers. The echinoderms were stored out, transferred to 10% formalin and preserved in 70% ethanol. All the echinoderm species were identified using the standard systematic key reference[5,6], and they were arranged systematically[7,8].

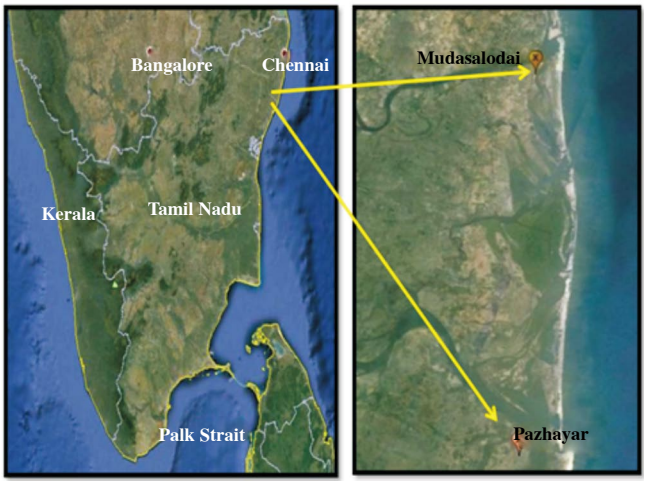


**Figure 1.** Map showing the study area.

### 2.2. Data analysis

All the data were analysed by various statistical methods, namely, univariate measures such as Margalef's species richness (*d*), Shannon-Wiener diversity (*H'*) and Pielou's evenness (*J'*) and graphical tools like k-dominance curve and multivariate tools such as Bray-Curtis similarity after suitable transformation of sample abundance data. Classification (hierarchical agglomerative clustering using group-average linking) and ordination [multidimensional scaling (MDS)] were used for data treatment with the help of Primer (version 6.0)[9].

## 3. Results

Echinoderms in India have 651 species (Crinoidea 65, Asteroidea 158, Ophiuroidea 152, Echinoidea 113 and Holothuroidea 163), Andaman and Nicobar Islands and Tamil Nadu having 424 and 193 species[10]. In the present study, echinoderms from the Mudasalodai and Pazhayar coast had recorded 19 species (Figure 2) and it belongs to 10 families under three classes Asteroidea, Echinoidea and Ophiuroidea. Among the 19 species, the *S. virgulata* was dominant in Mudasalodai and Pazhayar coast (Table 1). Data showed the number of species (*N*), eveness, Shannon-Wiener index, Margalef's richness and the results were shown in Table 2. In the present study, the diversity of echinoderms from Mudasalodai and Pazhayar coast was higher when compared to that of diversity of the echinoderms from two landing canters (Mudasalodai and Nagapattinam) reporting 8 families, 11 genera and 14 species[11]. More than 30 species of asteroids from Gulf of Mannar and Palk Bay regions have been reported[5,12,13]. The percentage composition of the echinoderms showed the maximum of 73.00% in *C. rarispinus* from the month of January and minimum of 0.15% in *P. affinis* recorded in the month of December (Tables 3 and 4, Figure 3).

**Table 1**

Dominant species recorded during the study period (Dec 2012–Dec 2014).

| Species | Family | Mudasalodai | Pazhayar |
|---|---|---|---|
| *A. indicus* | Astropectinidae | ++++ | +++ |
| *O. marmorata* | Ophiagonidae | +++ | + |
| *S. bicolor* | Temnopleuridae | +++ | +++ |
| *S. virgulata* | Temnopleuridae | ++++ | ++++ |
| *S. dussumieri* | Temnopleuridae | + | ++++ |
| *T. toreumaticus* | Temnopleuridae | ++++ | + |
| *C. rarispinus* | Clipasteriodae | ++ | ++ |
| *C. humilis* | Clipasteriodae | +++ | +++ |
| *E. bisperforatus* | Astriclybeidae | +++ | ++ |

++++: Indicates more profusion (> 400); +++: Indicates abundance (> 300); ++: Indicates less than 200; +: Indicates below 100.

**Table 2**

Data analysis by using SPSS Primer 6.0

| Samples | *N* | *d* | *J'* | *H'* |
|---|---|---|---|---|
| Station1-Dec | 23 | 2.85 | 0.96 | 2.21 |
| Station2-Dec | 30 | 3.81 | 0.97 | 2.56 |
| Station1-Jan | 18 | 2.77 | 0.97 | 2.15 |
| Station2-Jan | 23 | 3.19 | 0.98 | 2.36 |
| Station1-Feb | 17 | 3.18 | 0.97 | 2.25 |
| Station2-Feb | 18 | 2.77 | 0.98 | 2.16 |
| Station1-Mar | 9 | 1.79 | 0.99 | 1.60 |
| Station2-Mar | 13 | 2.70 | 0.98 | 2.04 |
| Station1-Apr | 9 | 1.82 | 0.98 | 1.58 |
| Station2-Apr | 11 | 2.10 | 0.96 | 1.73 |
| Station1-May | 13 | 2.37 | 0.98 | 1.91 |
| Station2-May | 13 | 2.36 | 0.98 | 1.91 |
| Station1-Jun | 25 | 3.73 | 0.98 | 2.53 |
| Station2-Jun | 25 | 4.06 | 0.98 | 2.60 |
| Station1-Jul | 21 | 3.26 | 0.97 | 2.34 |
| Station2-Jul | 18 | 3.13 | 0.96 | 2.21 |
| Station1-Aug | 7 | 1.02 | 0.93 | 1.03 |
| Station2-Aug | 7 | 1.52 | 0.99 | 1.38 |
| Station1-Sep | 14 | 1.91 | 0.98 | 1.76 |
| Station2-Sep | 12 | 1.61 | 0.96 | 1.55 |
| Station1-Oct | 14 | 2.25 | 0.97 | 1.90 |
| Station2-Oct | 16 | 2.53 | 0.98 | 2.04 |
| Station1-Nov | 21 | 2.64 | 0.96 | 2.11 |
| Station2-Nov | 24 | 3.46 | 0.98 | 2.44 |

In the case of H', the maximum value was 2.6 at Pazhayar in summer and the minimum was recorded in Mudasalodai of 1.031 in the Premonsoon. The evenness (*J'*) showed the maximum range of 0.997 in Mudasalodai during post monsoon and the minimum was recorded in Mudasalodai at 0.938 in pre-monsoon. The maximum value of Margalef's *d* was observed in Pazhayar at 4.06 in summer, while minimum in Mudasalodai (1.02) at pre-monsoon.

The k-dominance curve showed the maximum diversity of echinoderms was recorded in Pazhayar in summer. The lowest diversity was recorded in the month of August at Mudasalodai (Figure 4). However, as cluster analysis has inherent disadvantages of linking ultimately with the dissimilar groups, ordination of the samples was also done using MDS. The aim of this method is to represent the samples collected as points in a map (usually low-dimensional space). Samples lying closer have more similarity in species composition and abundance while samples lying far apart have more dissimilarity in species composition and abundance. The MDS plot also revealed the variation in species composition and abundance in two stations grouped in month. The stress value, overlying on the right top corner of this map, was also very minimum indicating the good ordination of the samples (Figure 5) and also similar reports were found on clustering and MDS pattern[14]. The k-dominance curve showed the maximum diversity of echinoderms was recorded in Pazhayar (summer). The lowest diversity was


**Figure 2.** Diversity of echinoderm species from Mudasalodai and Pazhayar.
A: *E. bisperforatus* (*Echinodiscus bisperforatus*); B: *A. pentagonula* (*Anthenea pentagonula*); C: *E. tenuissimus* (*Echinodiscus teniussimus*); D: *S. virgulata* (*Salmaciella virgulata*); E: *E. auritus* (*Echinodiscus auritus*); F: *A. indicus* (*Astropecten indicus*); G: *C. rarispinus* (*Clypeaster rarispinus*); H: *L. maculate* (*Linckia multifora*); I: *T. toreumaticus* (*Temnopleurus toreumaticus*); J: *S. dussumieri* (*Salmaciella dussumieri*); K: *L. multifora* (*Linckia multifora*); L: *M. angustus* (*Metalia angust*); M: *S. equestris* (*Stellaster equestris*); N: *P. mammillatus* (*Pentaceraster mammillatus*); O: *A. bengalensis* (*Astropecten bengalensis*); P: *O. marmorata* (*Ophiocnemis marmorata*); Q: *C. humilis* (*Clypeaster humilis*); R: *P. affinis* (*Parapinnixa affinis*); S: *S. bicolor* (*Salmaciella bicolor*).

**Table 3**
Percentage composition of echinoderm in Mudasalodai during 2012–2014.

| Species | Average percentage composition | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
| *L. maculate* | 6.50 | 2.00 | 0.90 | 2.00 | 1.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 |
| *A. indicus* | 2.48 | 57.00 | 26.00 | 4.00 | 2.72 | 12.00 | 19.40 | 0.00 | 0.00 | 43.00 | 42.60 | 19.00 |
| *A. bengalensis* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 |
| *S. equestris* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 14.00 | 22.60 | 10.00 | 15.00 | 13.00 | 12.90 | 48.00 |
| *P. mammillatus* | 0.00 | 0.00 | 0.00 | 3.00 | 2.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 |
| *P. affinis* | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.00 |
| *A. pentagonula* | 0.00 | 0.00 | 0.00 | 1.00 | 0.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 |
| *O. marmorata* | 13.30 | 18.00 | 8.10 | 40.00 | 27.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *S. bicolor* | 24.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 2.97 | 0.00 |
| *S. virgulata* | 40.70 | 38.00 | 17.00 | 4.00 | 2.72 | 20.00 | 32.30 | 34.00 | 52.00 | 0.00 | 0.00 | 32.00 |
| *S. dussumieri* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 | 9.68 | 0.00 | 0.00 | 11.00 | 10.90 | 13.00 |
| *T. toreumaticus* | 9.91 | 16.00 | 7.20 | 12.00 | 8.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *C. rarispinus* | 1.08 | 73.00 | 33.00 | 7.00 | 4.76 | 10.00 | 16.10 | 16.00 | 24.00 | 0.00 | 0.00 | 43.00 |
| *C. humilis* | 0.46 | 3.00 | 1.40 | 64.00 | 43.50 | 0.00 | 0.00 | 3.00 | 4.50 | 7.00 | 6.93 | 46.00 |
| *E. auritus* | 0.62 | 12.00 | 5.40 | 10.00 | 6.80 | 0.00 | 0.00 | 4.00 | 6.10 | 22.00 | 21.8 | 6.00 |
| *E. bisperforatus* | 0.00 | 3.00 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *E. teniussimus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 1.98 | 10.00 |
| *M. angustus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *L. multifora* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

**Table 4**
Percentage composition of echinoderms in Pazhayar during 2012–2014.

| Species | Average percentage composition | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
| *L. maculate* | 1.92 | 4.00 | 1.30 | 2.00 | 0.97 | 0.00 | 0.00 | 3.00 | 2.50 | 0.00 | 0.00 | 6.00 |
| *A. indicus* | 6.72 | 43.00 | 14.00 | 7.00 | 3.38 | 4.00 | 4.55 | 0.00 | 0.00 | 32.00 | 32.30 | 16.00 |
| *A. bengalensis* | 0.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 1.70 | 0.00 | 0.00 | 16.00 |
| *S. equestris* | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 19.00 | 21.60 | 4.00 | 3.40 | 17.00 | 17.20 | 12.00 |
| *P. mammillatus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.00 | 7.95 | 0.00 | 0.00 | 1.00 | 1.01 | 3.00 |
| *P. affinis* | 0.64 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.27 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 |
| *A. pentagonula* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *O. marmorata* | 5.44 | 9.00 | 2.90 | 32.00 | 15.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 |
| *S. bicolor* | 15.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 16.00 | 16.20 | 0.00 |
| *S. virgulata* | 27.70 | 38.00 | 12.00 | 8.00 | 3.86 | 32.00 | 36.40 | 36.00 | 31.00 | 0.00 | 0.00 | 42.00 |
| *S. dussumieri* | 11.70 | 22.00 | 7.10 | 17.00 | 8.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *T. toreumaticus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 14.00 | 15.90 | 0.00 | 0.00 | 9.00 | 9.09 | 16.00 |
| *C. rarispinus* | 2.88 | 94.00 | 30.00 | 16.00 | 7.73 | 9.00 | 10.20 | 67.00 | 57.00 | 0.00 | 0.00 | 42.00 |
| *C. humilis* | 24.50 | 60.00 | 19.00 | 94.00 | 45.40 | 0.00 | 0.00 | 6.00 | 5.10 | 3.00 | 3.03 | 2.00 |
| *E. auritus* | 0.48 | 19.00 | 6.10 | 24.00 | 11.60 | 0.00 | 0.00 | 0.00 | 0.00 | 21.00 | 21.20 | 6.00 |
| *E. bisperforatus* | 0.00 | 6.00 | 1.90 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 |
| *E. teniussimus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| *M. angustus* | 0.96 | 13.00 | 4.20 | 7.00 | 3.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *L. multifora* | 0.32 | 2.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

recorded in the month of August at Mudasalodai (Figure 6).

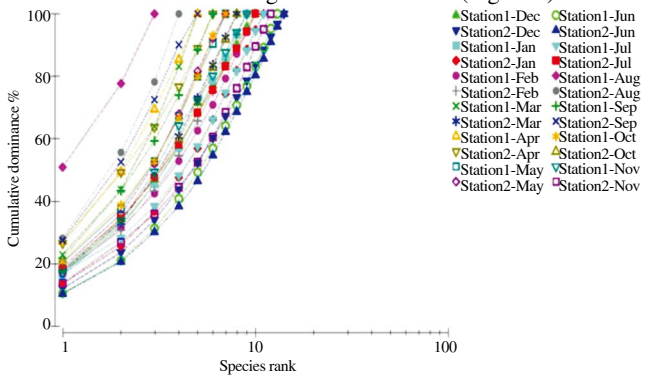


**Figure 3.** K-dominance curves for two stations.

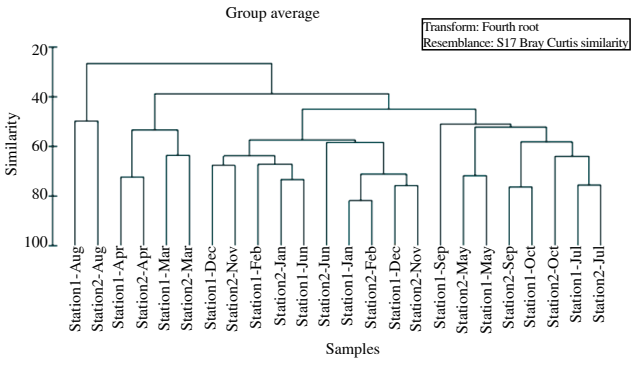


**Figure 4.** Dendrogram showing grouping of two stations sampled during different seasons for echinoderms.

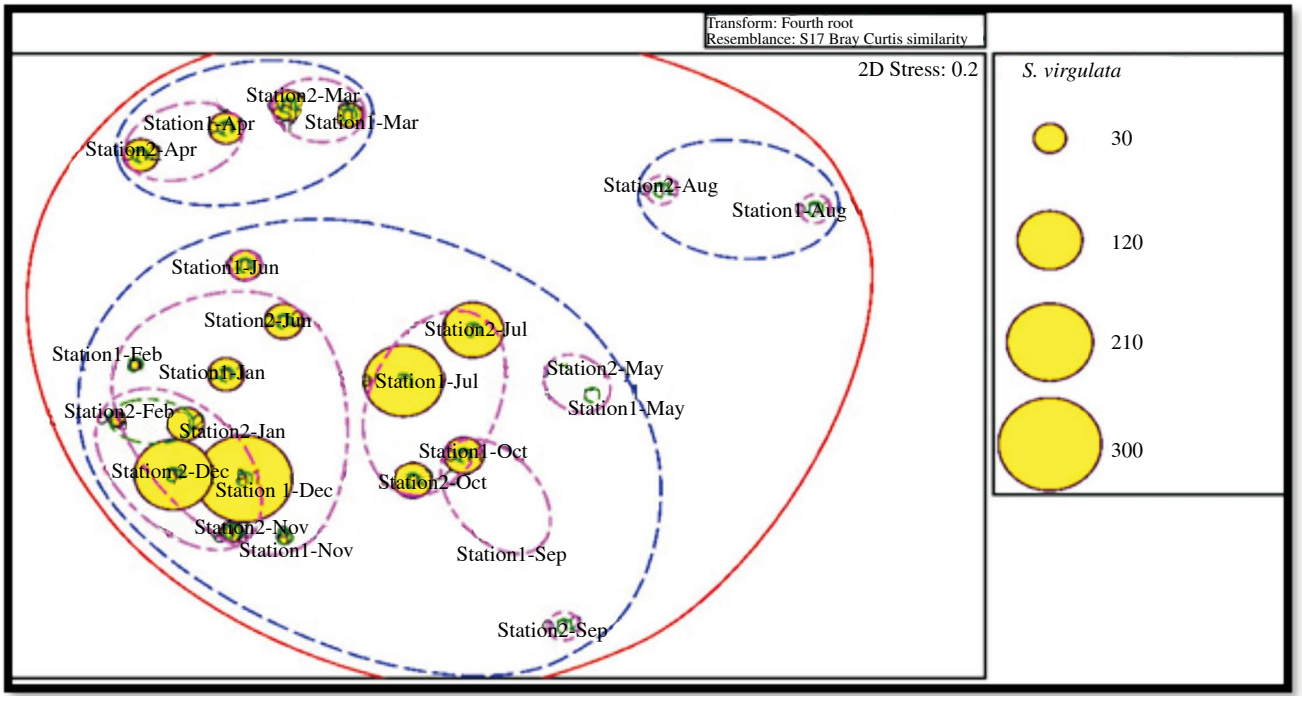


**Figure 5.** MDS or bubble plot.

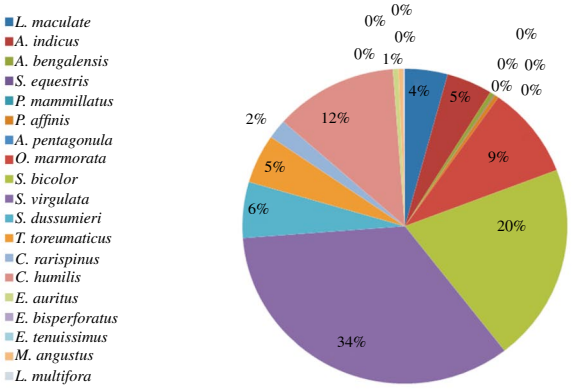


**Figure 6.** Percentage composition of echinoderms throughout the study period.

## 4. Discussion

Eight species of asteroids have been recorded during the present study. Echinoids are one of the more diverse and successful echinoderm groups today; 14 species and 11 families were recorded in Taiwan water[15]. Echinoids species are dominating in Caribbean regions, and asteroids and holothurians in Northeast Pacific region. A total of 86 echinoderm species were found in different parts of the world (Census of M arine Life, Natural Geography in Shore Areas) during 2003–2009; among these, there were 32 asteroids, 18 echinoids, 21 ophiuroids and 15 holothuroids[16]. A total of 53 species of echinoderms belonging to 30 genera and 19 families were observed through scuba diving (up to 15 m depth) in 6 different areas (Aves Island, Sound Island, Rail Island, Karlo Island, Interview Island, and North Reef Island) of North Andaman, India. Reef associated echinoderms, new report on crinoids and asteroid, and community structure of echinoderms in North Andaman were also studied[17-20]. Previously, it was observed and confirmed that asteroids are inhabitant of both hard and soft substrata[21,22]. Almost 88 species of echinoderms were observed along the southeast cost of India. Among them, 33 species of asteroids were recorded from Mudasalodai landing centre[23]. The wide distribution of echinoderms was reported and 18 genera and 117 species of the Asteroidea were listed[24]. Eight genera and 37 species of asteroids from the Australian region, including 10 *Astrina* sp and 10 *Patiriella* sp were recorded[25]. In the present investigation, it is evident that echinoderm occurrence was predominant during the summer season. This is may be due to some physiological factors (pH, salinity and temperature). Interestingly, more research is needed in this particular aspect and the exact explanation was not reported by any researchers still now. The echinoderm diversity differs according to various depth (15–40 m) and *M. angustus*, *L. multifora* are not found in Mudasalodai, but in Pazhayar very few are observed[19,26].

Species diversity is a simple and useful measure of a biological system. A high level of agreement between species diversity and the mature environment was found. Hence, the measure of species diversity is regarded as an ecologically powerful tool. The species diversity is mainly controlled by the fluctuations in the environment that leads to fewer diversity[27,28]. Moreover, it is proposed that the use of diversity indices is advantageous for the description of faunas at different stages in the succession[29].

The pattern of lower species diversity, evenness and richness during monsoon and higher diversity values in summer recorded in the study area is in conformity with the earlier observations made in Cochin waters[30].

The k-dominance plot drawn clearly demonstrated the diversity pattern in three stations. When the data of all the stations were plotted together, the curves for stations Mudasalodai and Pazhayar were found to lie below the curve of station 2 (June) and rose slowly due to the presence of more number of species giving '∫' shape, indicating maximum diversity, whereas the curve for station 1 (August) was lying above, showing minimum diversity. This plot also ably proved the rich diversity nature of station 1 (Mudasalodai) compared to Station 2 (Pazhayar) (Figure 3).

In the present study, cluster analysis and MDS were used to find

out the degree of similarity among the stations of Mudasalodai and Pazhayar. Cluster analysis (or classification) is helpful to find out natural groupings of samples; such samples within a group are more similar to each other than the samples in different groups. In the present study, monthly data of two stations were allowed as input for cluster and MDS analysis. The dendrogram revealed that samples of various zones got grouped individually indicating variation on species composition in a particular station.

Totally, 19 species were recorded from the present study and the diversity of echinoderms was found higher in Mudasalodai landing centers during summer season recorded during 2012–2014. It may be due to that asteroids are inhabitant of both hard and soft substrata. So the present investigation is evident that the echinoderm occurrence was predominant during the summer season. The migration patterns of echinoderms are not reported and the reason behind them is a mystery. Hence from the present study, the diversity of echinoderms was proved statistically that they are more abundant in summer season.

## Conflict of interest statement

We declare that we have no conflict of interest.

## Acknowledgments

Authors are thankful to Prof. K. Kathiresan, Dean and Director, CAS in Marine Biology, Faculty of Marine Sciences, and Parangipettai for providing facilities. We are also grateful to the Ministry of Human Resources and Development Govt. of India for the financial assistance, Grant No: G4 (1)/1630/2013.

## References

[1] Raghunathan C, Venkataraman K. Diversity of echinoderms in Rani Jhansi Marine National Park, Andaman and Nicobar Islands. International Day for Biological Diversity. 2012, p. 36-48. [Online] Available from: http://www.upsbdb.org/pdf/Souvenir2012/ch-4.pdf [Accessed on 10th August, 2015]

[2] De Moura Barboza CA, Borges M. A checklist of the extant species of ophiuroids (Echinodermata: Ophiuroidea) from Brazilian waters. *Zootaxa* 2012; **3447**: 1-21.

[3] Gondim AI, Dias TLP, Manso CLC. Updated morphological description of *Asteroporpa* (*Asteroporpa*) *annulata* (Euryalida: Gorgonocephalidae) from the Brazilian coast, with notes on the geographic distribution of the subgenus. *Rev Biol Mar Oceanogr* 2012; **47**: 141-6.

[4] Stöhr S, O'Hara TD, Thuy B. Global diversity of brittle stars (Echinodermata: Ophiuroidea). *PLoS One* 2012; **7**(3): e31940.

[5] Clark AM, Rowe FWE. *Monograph of shallow-water Indo-West Pacific echinoderms*. London: Trustees of the British Museum (Natural History); 1971.

[6] Hyman LH. *The invertebrates: echinodermata, the coelomate bilateria*. 4th ed. New York: McGraw Hill; 1955.

[7] Stöhr S, O'Hara T, Thuy B. World Ophiuroidea Database. [Online] Available from: http://www.marinespecies.org/ophiuroidea [Accessed on 10th August, 2015]

[8] Smith AB, Paterson GLJ, Lafay B. Ophiuroid phylogeny and higher taxonomy: morphological, molecular and palaeontological perspectives. *Zool J Linn Soc* 1995; **114**: 213-43.

[9] Clark KR, Gorley RN. PRIMER v6: user manual/tutorial. Plymouth: PRIMER- E; 2006.

[10] Sastry DRK. *Echinodermata of India: an annotated list*. Kolkata: Zoological Survey of India; 2007, p. 1-387.

[11] Sakthivel K, Antony Fernando S. Echinoderm diversity in Mudasal Odai and Nagapattinam coast of South east India. *Int J Biodivers Conserv* 2013; **6**(1): 1-7.

[12] James DB. Research on Indian echinoderms - a review. *J Mar Biol Assoc India* 1983; **25**: 91-108.

[13] James DB. Zoogeography of shallow-water echinoderms of Indian seas. In: *Recent advances in marine biology*. New Delhi: Today and Tomorrow Printers and Publishers; 1986, p. 569-91.

[14] Kundu, Mondal N, Lyla PS, Khan SA. Biodiversity and seasonal variation of macro-benthic infaunal community in the inshore waters of Parangipettai Coast. *Environ Monit Assess* 2010; **163**: 67-79.

[15] Chao SM. The irregular sea urchins (Echinodermata: Echinoidea) from Taiwan, with descriptions of six new records. *Zool Stud* 2000; **39**: 250-65.

[16] Iken K, Konar B, Benedetti-Cecchi L, Cruz-Motta JJ, Knowlton A, Pohle G, et al. Large-scale spatial distribution patterns of echinoderms in near shore rocky habitats. *PLoS One* 2010; **5**: 1-14.

[17] Sadhukhan K, Raghunathan C. A study on diversity and distribution of reef associated echinoderm fauna in South Andaman, India. *Asian J Exp Biol Sci* 2012; **3**(1): 187-96.

[18] Sadhukhan K, Raghunathan C. New record of feather stars (Class: Crinoidea) from Andaman and Nicobar Islands. *Int J Plant Anim Environ Sci* 2012; **2**(1): 183-9.

[19] Sadhukhan K, Raghunathan C. A general account on community structure of echinoderms in North Andaman. *Int J Biol Pharm Allied Sci* 2012c; **1**(1): 44-55.

[20] Sadhukhan K, Raghunathan C. New record of sea star *Nardoa tuberculata* Gray (Echinodermata: Ophidiasteridae) from Andaman and Nicobar Islands. *Int J Sci Nat* 2012; **3**(1): 167.

[21] James DB. Studies on Indian echinoderms-11. On *Protankyra tuticorenensis* sp.nov. and other apodus holothurians from Indian seas. *J Mar Biol Assoc India* 1982; **24**: 92-105.

[22] Sastry DRK. Some echinoderms new to Mahatma Gandhi Marine National Park with two new records form India. In: Proceedings of the symposium on island ecosystem and sustainable development. 1998, p. 133-8.

[23] Karuppaiyan M. Diversity of echinoderms along the South east coast of India [dissertation]. Tamil Nadu: Annamalai University; 2007.

[24] Clark AM. An index of names of recent Asteroidea: Part 2. Valvatida. In: Jangoux M, Lawrence JM, editor. *Echinoderm studies*. Vol. 4. Rotterdam: A. A. Balkema; 1993, p. 187-366.

[25] Rowe FWE, Gates J. Echinodermata. In: Wells A, editor. *Zoological catalogue of Australia*. Vol. 33. Melbourne: CSIRO Australia; 1995, p. 1-510.

[26] Jeng MS. Shallow-water echinoderms of Taiping Island in the South China Sea. *Zool Stud* 1998; **37**: 137-53.

[27] Sanders HL. Marine benthic diversity: A comparative study. *Am Nat* 1968; **102**: 243-82.

[28] Redding JM, Cory RL. *Macroscopic benthic fauna of three tidal creeks adjoining the Rodhe river, Maryland (water resources investigations)*. Reston: U.S. Geological Survey; 1975.

[29] Pearson TH, Rosenberg R. Macrobenthic succession in relation to organic enrichment and pollution in the marine environment. *Oceanogr Mar Biol Ann Rev* 1978; **16**: 229-311.

[30] Deepa RP, Biju Kumar A. Echinoderm biodiversity of Kerala: Inventory, distribution and ecology. Peechi: Proceedings of 22nd Kerala Science Congress, KFRI; 2010, p. 869-70.