

First report of *Tropiometra carinata* and its colour morphs from the Gujarat coast, India

(Echinodermata, Crinoidea)

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The present study is the first comprehensive report on the occurrence of the elegant feather star *Tropiometra carinata* with eighteen different morphs from the intertidal area of the Gujarat, India. *Tropiometra carinata* was discovered for the first time on the Gujarat coast. The species shows variation in its colour pattern such as fully brown to reddish brown, yellow with dark stripes to dark brown, some specimens have brown-yellow dotted, brown-white patches, blotches, brown-yellow stripes, brown-white stripes, whole white, whole pale whitish yellow. The present study aims to prevent researchers to be misled by the coloration and misidentify the species.

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Introduction

Feather stars are a member of the phylum Echinodermata and belong to order Comatulida, a most abundant group of living crinoids (Messing 1997). Their habitat ranges from the intertidal zone to the abyssal depth (Belyaev 1966, Oji et al. 2009). *Tropiometra carinata* is the widely occurring species of the elegant feather star family Tropiometridae. A total of four species of Tropiometridae are known worldwide. The detailed taxonomy of the Crinoidea from the Indian subcontinent was described by Clark (1912). In India, *T. carinata* is reported from the Gulf of Munnar and Palk Bay (Venkatraman et al. 2013), Goa, Kerala, Karnataka, Tamil Nadu (Chandrasekar et al. 2019), Andhra Pradesh and Tamil Nadu (Sastry et al. 2012), Andaman and Nicobar (Nigam & Raghunathan 2015). The Echinoderms have been sparsely studied from Gujarat coast. Some

years ago, 37 species of echinoderms were reported, among them four species of Crinoidea (*Comanthus wahlbergii*, *Lamprometra palmata*, *Stephanomentra indica* and *Euantedon sp.*) from Gujarat (Sastry 2004). In addition, there are recent studies at the species level considering diversity and ecological aspects of echinoderms (Baroliya & Kundu 2022, Baroliya et al. 2022, Baroliya et al. 2023). Some abnormal forms of echinoderms species are also noted from Gujarat (Baroliya & Kundu 2021a). There are also interesting findings on feather stars from the intertidal ecosystem of the Saurashtra coast, supported by photographs (Baroliya & Kundu 2021b). In the available literature, there is still little information on the colour variation of *T. carinata*. Thus, the present study describes the occurrence of *Tropiometra carinata* and its colour-pattern morphs from the intertidal zone of Saurashtra coastline, Gujarat, India.

Materials and methods

Fort St. Anthony of Simbor (20°45' N, 71°09' E) is a small islet located at the mouth of the Sahil River in the bay of Simbor, 25 km east to the Diu, India. Simbor has sandy-rocky coast characteristics. The qualitative assessment of the intertidal feather star *T. carinata* and its diversity was done from January 2021 to April 2021, during this period sampling site was surveyed at monthly intervals. A direct handpicking method was used for collection of the specimens. Sometimes hammer (for turning rock) soft brushes, blunt needle, blunt forceps, and scalpel were used. All the variants of *T. carinata* were observed from the diverse habitat range present in 350 m area of sampling site. Field photographs were taken to check the colour and pattern variants (Figs 2 and 3). Alive samples were carried to the laboratory. The samples were examined under a Carl-Zeiss Stemi DV4 stereomicroscope fitted with high resolution CMOS camera and Lawrence & Mayo Image (Model: ISH300) microscopes for identification and morphological study. Species were identified using their taxonomic features with standard references. After identification the collected sample was preserved in 4% formalin. A representative specimen of each morph was submitted to the museum of the Department of Biosciences, Saurashtra University, Rajkot, Gujarat, India. Total count of each morph and relative frequency graphs were created. Relative frequency for each morph was calculated.

Results

Order Comatulida

Family Tropiometridae A. H. Clark, 1908

Genus *Tropiometra* A. H. Clark, 1907

Tropiometra carinata (Lamarck, 1816)

Material examined: More than 50 samples were observed at Fort St. Anthony of Simbor. Representative specimens of each morph were collected and identified. The museum ID of each morph is given in Table 1. Taxonomic details of characters are represented by specimens TC-6 (ZEC21(8)1H4) of *Tropiometra carinata*.

Colour variation. The species shows 18 different morphs varying in colour: yellow with dark stripes to dark brown, some specimens are brown-yellow dotted, have brown-white patches, blotches, brown-yellow stripes, brown-white stripes, are whole white or whole pale whitish yellow (Table 1, Figs 2 and 3).

Description

A total of 10 arms are present. Mouth and anus, both are sub-centric, anal papilla long and upper portion of the papilla is mostly contracted (Fig. 1A). 17–25 pinnules present in pinnules. Pinnules slender form the proximal part. P1 arises from br (3+4). Distal pinnules longer than all other pinnules. First

Table 1. Information about variants of *Tropiometra carinata* denoted as TC, describes their colour-pattern and museum ID.

Name	Museum ID	Colour-pattern
TC-1	ZEC21(8)1H1	bright brown
TC-2	ZEC21(8)1H2	light brown – white dotted pattern on arm
TC-3	ZEC21(8)1H3	brown – white dotted pattern on arm and pinnule
TC-4	ZEC21(8)3H1	yellow, brown dotted pattern on ridge of arm
TC-5	ZEC21(8)3H2	yellow, pinnules half brown – half yellow
TC-6	ZEC21(8)1H4	brown-yellow stripes uniform pattern
TC-7	ZEC21(8)1H5	brown-white stripes on arms and pinnules with dotted pattern
TC-8	ZEC21(8)1H6	yellow arm ridge with brown dot at regular interval of 5–6 pinnules
TC-9	ZEC21(8)1H7	white-brown dotted arm ridge, pinnule dotted brown, yellow, some arms part has stripes pattern
TC-10	ZEC21(8)3H3	white-brown uniform arm pattern, mouth white
TC-11	ZEC21(8)3H4	white-purplish strips pattern and ventral side brown dotted at regular interval uniform pattern
TC-12	ZEC21(8)3H5	white
TC-13	ZEC21(8)3H6	brown-white strips at basal part of arm, middle part of arm fully brown, tip portion brown but have one white strips of 4–5 pinnules before tip
TC-14	ZEC21(8)3H7	light pinkish white
TC-15	ZEC21(8)1H8	reddish-white dotted pattern on arm
TC-16	ZEC21(8)1H9	dark brown-white dotted pattern on arm
TC-17	ZEC21(8)1H10	basal arm white, middle part has brown followed by pale yellow colour
TC-18	ZEC21(8)3H8	dark brown-white stripes on arms and pinnules

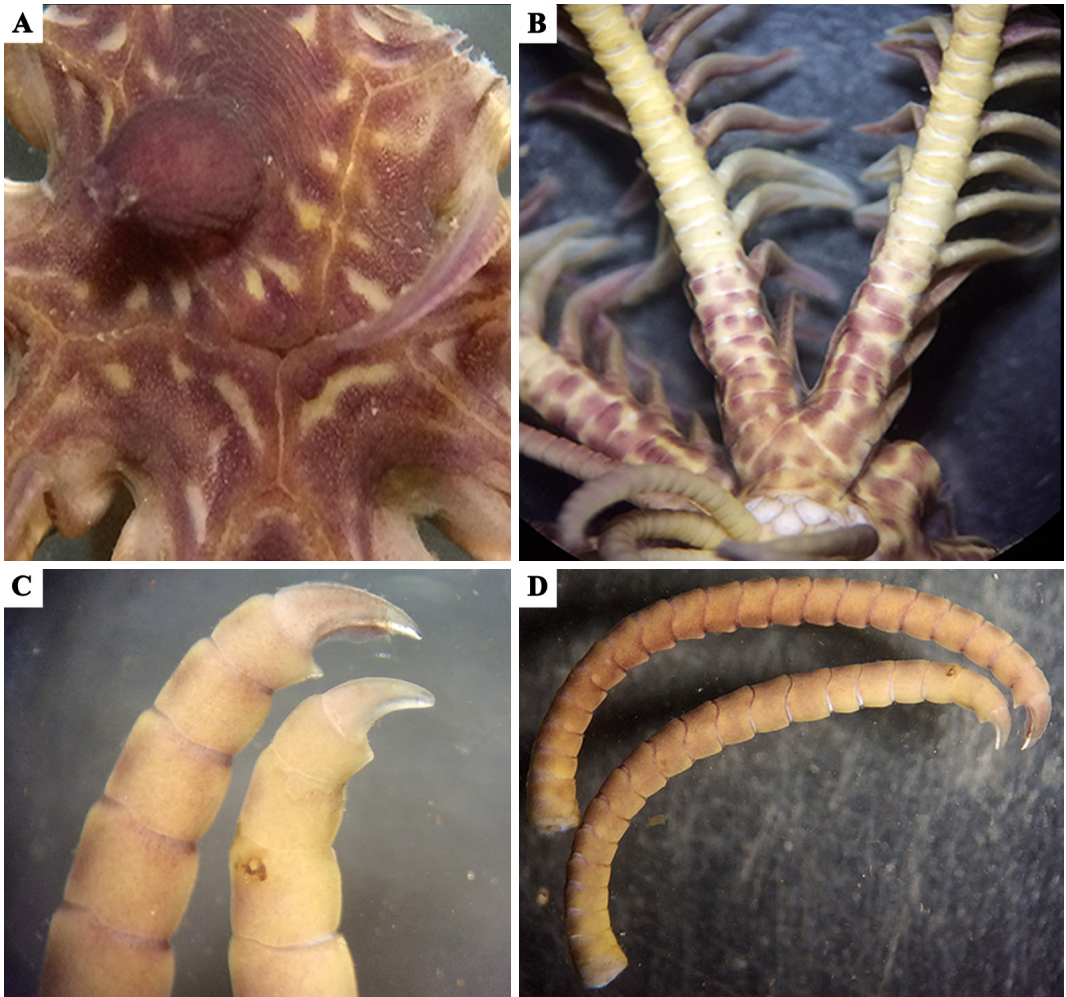


Fig. 1. Taxonomic characters of *Tropiometra carinata*. **A.** Position of mouth and anal papillae; **B.** dorsal surface of arm shows carination, arrangement of syzygy and cirri pockets on basal; **C.** opposing spine and terminal claw of cirri; **D.** entire cirri.

syzygy on br 3+4, second on br 9+10 or br 10+11, third syzygy on around three brachial intervals after second syzygy (Fig. 1B). Cirri arrange in 2-3 rows on basal portion (Fig. 1B), ranges from 22-28 in number, long and slender with 18-24 cirrus in the cirri, terminal claw sharp and long, opposing spine present but exceedingly small and sometimes absent (Fig. 1C and D).

Habitat. In the intertidal belt individuals are found from varied microhabitats such as rock pools, rock caves/crevices, underneath of rock, emergent on rock, attached with rock and shallow sediment pools.

Geographic distribution. From shallow water of Colombia, Barbados, Tobago, St. Vincent, Dominica (Meyer 1973). From the 0-55 m depth of St. Lucia, Trinidad & Tobago and Venezuela to Brazil, St. Helena, False Bay, Cape of Good Hope, South Africa, N to the Red Sea and E to Sri Lanka and SW India, Seychelles, Farquhar Atoll, Mauritius, Madagascar, Réunion, and Cargados Carajos Shoals (Clark 1947). SE Arabia, W India, Pakistan, Ceylon, Bay of Bengal and East Indies (Clark & Rowe 1971).

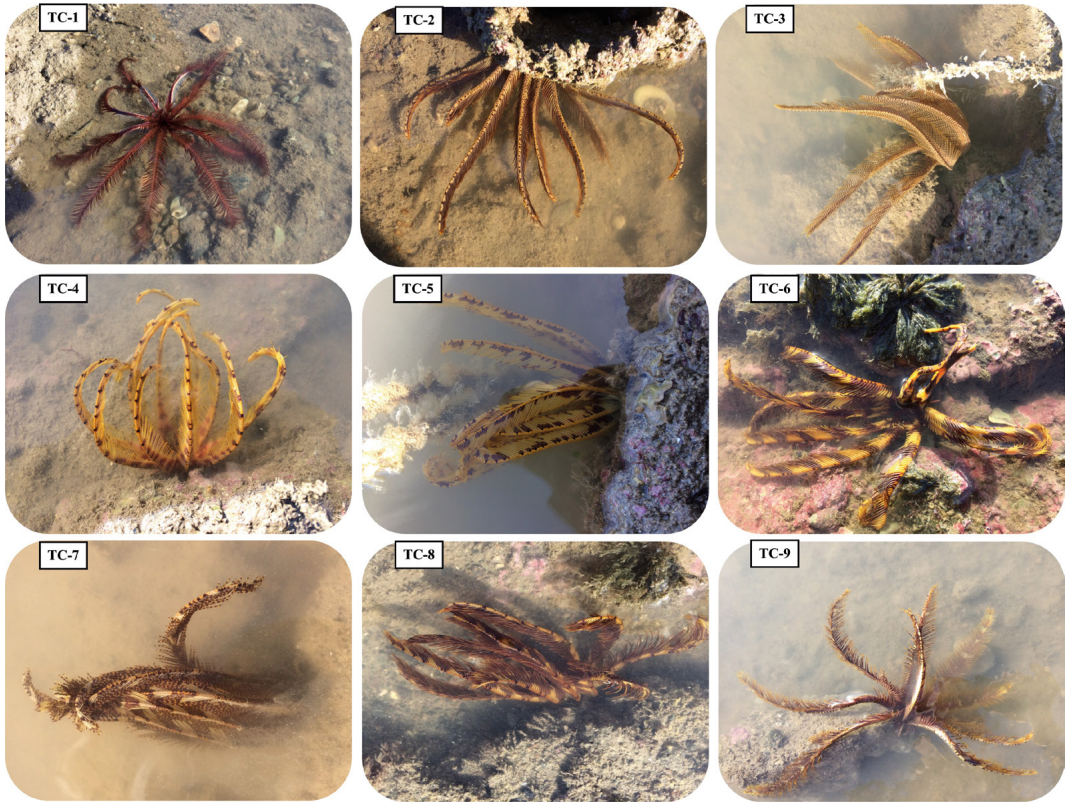


Fig. 2. Colour-pattern morphs of *Tropiometra carinata* (TC-1 to TC-9).

Discussion

Wide colour polymorphism or variations in body coloration is a frequent phenomenon in marine invertebrates. Colour variations in any species lead to misidentification which results in reporting it as a new species or as a different species. Like many echinoderms, *T. carinata* has a variety of colour morphs. *T. carinata* differs from the other three species of genus *Tropiometra* (*T. afra*, *T. macrodiscus*, *T. magnifica*) by having a carination on the dorsal surface of the arms. They all have a smooth dorsal surface of the arms without a median carination. In the present study, all the observed individuals have median carination on the dorsal surface of the arms (see Fig. 1b). Thus, they belong to *T. carinata*. A century ago, Clark (1921) listed colour variations in *Tropiometra* genus (some identified as *T. picta*, which is a junior synonym of *T. carinata*) in the second and fourth part of his monograph. Individuals in the Caribbean were dark purple to reddish-brown with varying degrees of striping, individuals from Brazil were solid black and black with white stripes,

individuals from Indian Ocean were bright orange and yellow with dark stripes (Clark 1917, Lanterbecq et al. 2003, Torrence et al. 2012). Many studies suggest that variations in colour may be related to light or wave exposure, to diet, to age or to behavioural patterns (Cuvier & Valenciennes 1828, Medioni et al. 2001, Stoletzki & Schierwater 2005, Tlustý & Hyland 2005, Calderon et al. 2010). In the present study, *T. carinata* was first time reported from Gujarat. A baseline database of the pattern and colour variants of *T. carinata* from this geographical area was created from this study. It is possible that to survive and reproduce, colour variations are advantageous, like the use of camouflage to avoid predation (Bond 2007). TC-1 was the most occurring form of *T. carinata* at Simbor (Fig. 4). The frequency of occurrence of TC-1 (RF=13.87%, n=106) was relatively highest followed by TC-2 (RF=11.78%, n=90) and TC-3 (RF=11.52%, n=88) compared to all morphs and TC-18 (RF=0.26%, n=2) was relatively lowest compared to all morphs (Fig. 4 and 5). Highest occurrence of the brown coloured morphs and brown-white-yellow striped or dotted pattern appearances due to the



Fig. 3. Colour-pattern morphs of *Tropiometra carinata* (TC-10 to TC-18).

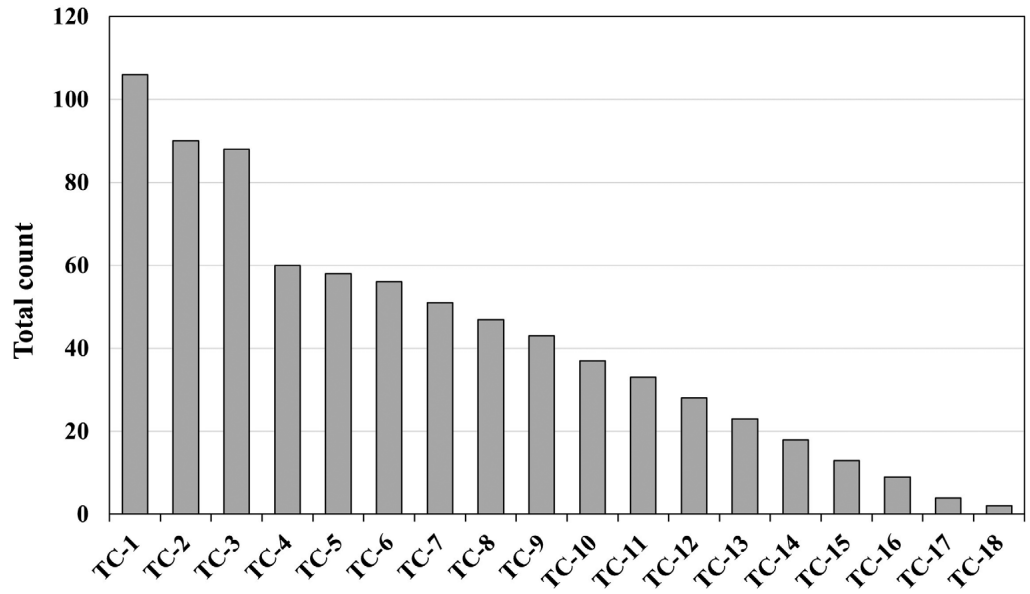


Fig. 4. Total count of each morph of *Tropiometra carinata* recorded during January-March 2021.

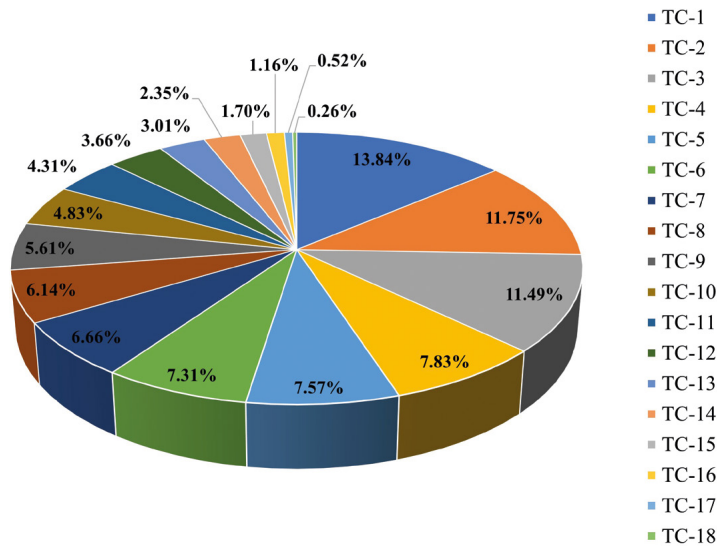


Fig. 5. Relative frequency of the colour-pattern morphs of *Tropiometra carinata*.

coastal qualities, substratum type and their presence in cosmopolitan macro/microhabitats in intertidal areas of Simbor (Baroliya & Kundu 2021b). The study might indicate that the unique variability of the *T. carinata* is favorable for survival in the intertidal area and environment. Although the animals in the present study were considered to be colour morphs of a single species, further studies using molecular biology could be interesting. They could provide insights into (intraspecific) phylogenetic complexity in relation to colour patterns. In addition, we provide help to avoid misidentification of this species.

Declaration of competing interest

The authors acknowledge that they have no known competing interests that influence the work reported in this paper.

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References

- Baroliya, H. & Kundu, R. 2021a. Occurrence of abnormal echinoderms from the intertidal zone of Saurashtra coast, Gujarat, India. *International Journal of Biology and Biomedicine* 6: 66–75.
- & Kundu, R. 2021b. Intertidal aggregation of feather stars (Echinodermata: Crinoidea) on the South Saurashtra coastline of Gujarat State, India. *International Journal of Ecology and Environmental Sciences* 47(4): 339–344.
- & Kundu, R. 2022. Spatiotemporal variations in the population dynamics of a few prominent brittle star species (Echinodermata: Ophiuroidea) from the intertidal flat of the Veraval coast, Gujarat, India. *Indian Journal of Geo-Marine Sciences* 51(6): 543–549.
- , Sabapara, Z., Poriya, P. & Kundu, R. 2023. Habitat preference and role of Ophiuroidea in the intertidal community of Saurashtra coast, Gujarat, India. *Species* 24(74): e12s1012.
- , Solanki, B. & Kundu, R. 2022. Intertidal Ophiuroidea from the Saurashtra coastline, Gujarat, India. *Journal of Threatened Taxa* 14(10): 21968–21975.
- Belyaev, G. M. 1966. Bottom fauna of the ultraabyssal depths of the World Ocean. 247 pp., SSSR (Akademy Nauk, Institute Okeanologii). [in Russian]
- Bond, A. B. 2007. The evolution of color polymorphism: crypticity, searching images, and apostatic selection. *Annual Review of Ecology, Evolution, and Systematics* 38: 489–514.
- Calderón, I., Ventura, C. R. R., Turon, X. & Lessios, H. A. 2010. Genetic divergence and assortative mating between colour morphs of the sea urchin *Paracentrotus gaimardi*. *Molecular ecology*, 19(3): 484–493.

- Chandrasekar, S., Lazarus, S., Chandran, R., Nisha, J. C., Rajan, G. C. & Satyanarayana, C. 2019. In situ observations increase the diversity records of rocky reef inhabiting echinoderms along the Southwest Coast of India. *Indian Journal of Geo-Marine Sciences* 48(10): 1528–1533.
- Clark, A. H. 1912. The crinoids of the Indian Ocean. *Echinoderma of the Indian Museum. Part VII. Crinoidea*. 325 pp., Calcutta (Indian Museum).
- 1921. A monograph of the existing crinoids. Volume 1. The comatulids. Part 2. *Bulletin of the United States National Museum* 82: 1–795, 57 pls.
- 1947. A monograph of the existing crinoids. Volume 1. The comatulids. Part 4b. *Bulletin of the United States National Museum* 82: 1–473, 43 pls.
- Clark, A. M. & Rowe, F. W. E. 1971. Monograph of shallow-water Indo-West Pacific echinoderms. ix+238 pp., 31 pls, London (British Museum (Natural History)).
- Clark, H. L. 1917. The habits and reactions of a comatulid, *Tropiometra carinata*. *Papers from the Department of Marine Biology of the Carnegie Institution of Washington* 11: 113–119.
- Cuvier, G. & Valenciennes, A. 1828. *Histoire naturelle des poissons*. Vol. III. Paris (Levrault).
- Lanterbecq, D., Hempson, T., Griffiths, C. & Eeckhaut, I. 2003. Myzostomida from Madagascar, with descriptions of two new species. *Hydrobiologia* 496: 115–123.
- Medioni, E., Lecomte Finiger, R., Louveiro, N. & Planes, S. 2001. Genetic and demographic variation among colour morphs of cabrilla sea bass. *Journal of Fish Biology* 58: 1113–1124.
- Messing, C. G. 1997. Living comatulids. *Paleontological Society Papers* 3: 3–30.
- Meyer, D. L. 1973. Feeding behavior and ecology of shallow water unstalked crinoids (Echinodermata) in the Caribbean Sea. *Marine Biology* 22(2): 105–129.
- Nigam, N. K. & Raghunathan, C. 2015. First report of feather star *Tropiometra carinata* (Lamarck, 1816) to Andaman and Nicobar islands. *Records of the Zoological Survey of India* 115(4): 357–360.
- Oji, T., Ogawa, Y., Hunter, A. W. & Kitazawa, K. 2009. Discovery of dense aggregations of stalked crinoids in Izu-Ogasawara Trench, Japan. *Zoological Science* 26: 406–408.
- Sastry, D. R. K. 2004. Echinodermata: Crinoidea, Asteroidea, Ophiuroidea and Echinoidea. *Fauna of Gujarat, Part 2. State Fauna Series* 8: 1–427.
- , Rao, Y. K. V., Ganesh, T., Rao, M. S., Sateesh, N., Bharati, A., Annapurna, C. & Raman, A. V. 2012. On some collections of Echinodermata from Andhra Pradesh and Orissa coasts of India. *Records of the Zoological Survey of India* 112(3): 61–87.
- Stoletzki, N. & Schierwater, B. 2005. Genetic and color morph differentiation in the Caribbean Sea anemone *Condylactis gigantean*. *Marine Biology* 147: 747–754.
- Tlusty, M. & Hyland, C. 2005. Astaxanthin deposition in the cuticle of juvenile American lobster (*Homarus americanus*): implications for phenotypic and genotypic coloration. *Marine Biology* 147: 113–119.
- Torrence, K. G., Correia, M. D. & Hoffman, E. A. 2012. Divergent sympatric lineages of the Atlantic and Indian Ocean crinoid *Tropiometra carinata*. *Invertebrate Biology* 131(4): 355–365.
- Venkataraman, C., Venkataraman, K., Rajkumar, R., Shrinivaasu, S., Padmanaban, P., Paramasivam, K. & Sivaperuman, C. 2013. Diversity and distribution of echinoderms in Palk Bay and Gulf of Mannar Biosphere Reserve, southern India. Pp. 197–212 in: Venkataraman, K., Sivaperuman, C. & Raghunathan, C. (eds). *Ecology and conservation of tropical marine faunal communities*. Berlin and Heidelberg (Springer).