

Diversity and First Record of Tunicates (Ascidians) from Gujarat Coast, India

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ABSTRACT

The present study reports 21 species of tunicates belonging to six families from the intertidal zone of Okha coast, Gujarat, India. Tunicates were distributed in small to moderate sized colonies up to 10 cm in various microhabitats and niches like underneath rocks, co-exist with sponges and algal studded rock surfaces of the intertidal zone. Single solitary species *Herdmania momus* were reported underneath boulders and within algal beds. The studied intertidal zone is located at the southern fringe of the Gulf of Kutch which is known for its diverse intertidal coral reefs and possibly this is reason for rich diversity of tunicates in this area than any other coast of Gujarat.

This study is the first to document the occurrence of the ascidian species from this coast and provides a baseline of tunicates fauna of Gujarat coast.

Keywords Tunicates, Ascidians, Diversity, Gujarat, India.

INTRODUCTION

Tunicates, also called sea squirts or ascidian, belong to the subphylum Tunicata (also called Urochordata) are an important ecological group because of their invasive potential and ability to thrive in eutrophic (nutrient-rich) environments. About 2815 ascidian species have been described in marine ecosystems (Shenkar and Swalla 2011). In India, nearly 400 species of tunicates have been recorded by various researchers (Oka 1915, Das 1936, 1938, 1940, 1945; Sebastian 1952-56, 1959; Renganathan 1981-1986, Jaffar Ali *et al.* 2015, Jaffar Ali and Tamilselvi 2016. Mondal and Raghunathan 2016, Meenakshi and Gomathy 2018). Recently, Meenakshi and Gomathy (2018) gave an updated checklist with 263 species of ascidians of the Indian coast but the region wise distribution of tunicates is lacking. Notable works on marine flora and fauna were carried out by various researchers in the coastal areas of Gujarat except for class Ascidiacea. Some photographic records of ascidians are existing in the online portal for the Gulf of Kutch region of Gujarat (<https://www.inaturalist.org>) (Accessed 15 October 2023). Hence, the present study aimed to discover the presence of tunicate diversity from the Gujarat coast, India.

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Coastal zones of Gujarat have varied marine ecosystems including mudflats of the Gulf of Khambhat and South Gujarat coast, rocky-sandy coast of the *Saurashtra peninsula* and coral reefs of the Gulf of Kutch. Habitable ecosystem of ascidians on Gujarat coast includes only fringe and core areas of the Gulf of Kutch. The coast of the *Saurashtra peninsula* was studied by various researchers since three decades but lacked proper records of intertidal tunicates. Okha coast ($22^{\circ}28' \text{ N } 69^{\circ}04' \text{ E}$) is located between the Saurashtra coast and the Gulf of Kutch region of the Gujarat state (India). Geographically, the Okha coast is a unique rocky shore with sandy patches because of the location, wave action and mixed semidiurnal type tide. Another feature of this rocky coast is the noticeable flat long intertidal zone. The intertidal zones of this coast have been extensively studied, mostly for the diversity and other ecological purpose of different fauna and flora like Sponges (Thomas *et al.* 1996; Sabapara and Poriya 2024), Corals (Vala *et al.* 2016), Mollusc (Vakani and Kundu 2020), Polychaetes (Misra and Chakraborty 1983, Shivanagouda and Bhat 2013), Nematodes (Shivanagouda and Bhat 2013), Crustaceans (Gopalakrishnan and Raju 1990, Shivanagouda and Bhat 2021, Trivedi *et al.* 2018), Zoanthids (Pandya *et al.* 2014), Fish (Solanki *et al.*

2020), Marine Mammals (Singh 2003), Seaweeds (Roy *et al.* 2015, Barot *et al.* 2015), Algae (Rao *et al.* 2008, Murthy *et al.* 2009).

MATERIALS AND METHODS

In the present study, regular field surveys for the diversity of tunicates were carried out from the Intertidal coastal area of the Okha coast of Gujarat from June 2021 to March 2023 (Fig. 1). Monthly visual surveys were conducted during the ebb tide. All substrates were observed, especially rocks, small rocks and boulders were overturned and examined. Hand-picking method used for collection of species. The samples were collected after the *in situ* photography and other morphological characters were noted. Tunicate species were identified with the help of key identification literatures (Kott 2001, Jaffar Ali and Tamilselvi 2016), books, and manuals and with the help of websites such as WoRMS (<https://www.marinespecies.org>), SEANET (<https://seanet.stanford.edu>), NIWA (<https://niwa.co.nz>), GBIF (<https://www.gbif.org>). The taxonomic category of identified species is provided with remarks of taxonomic major characters and habitat, taxon identifier and distribution.

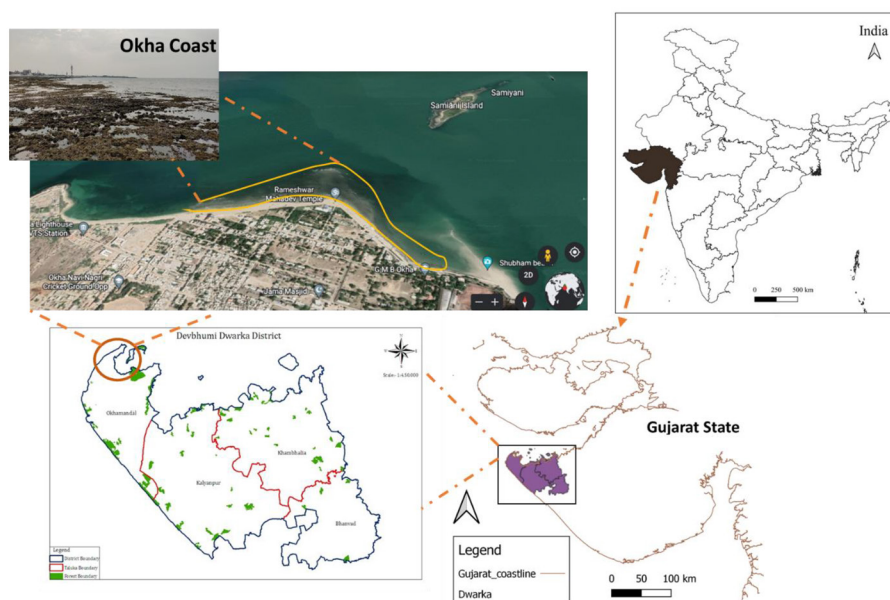


Fig. 1. Map showing the study area.

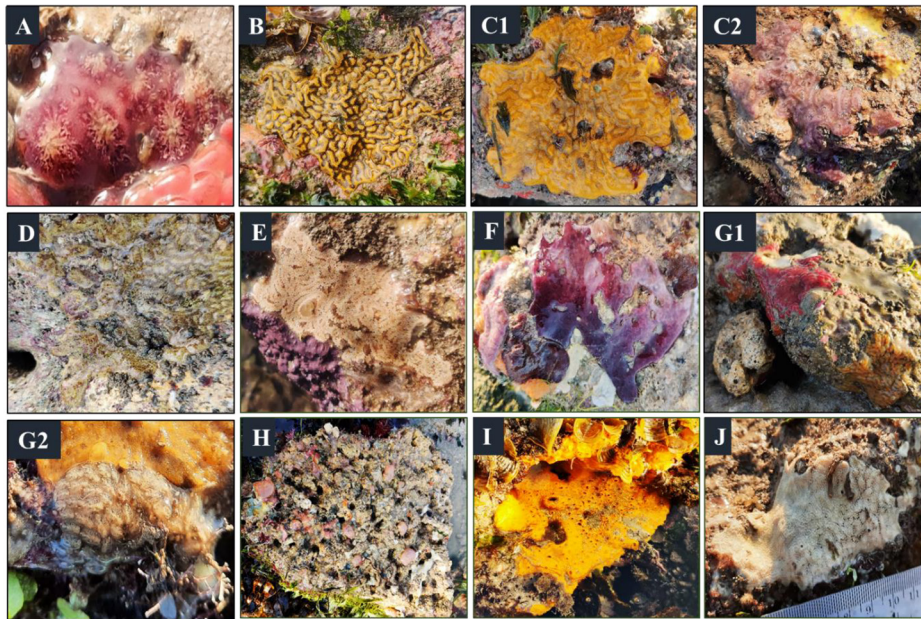


Fig. 2. Observed species of tunicates: A. *Botryllus schlosseri* (Pallas 1766), B. *Botrylloides leachi* (Savigny 1816), C1. *Botrylloides violaceus* Oka 1927, C2. Color morph of *Botrylloides violaceus* Oka 1927, D. *Botrylloides niger* Herdman 1886, E. *Botrylloides* sp., F. *Botrylloides* sp., G1. *Symplegma brakenhielmi* (Michaelsen 1904), G2. Color morph of *Symplegma brakenhielmi* (Michaelsen 1904), H. *Herdmania momus* (Savigny 1816, I. *Didemnum granulatum* Tokioka 1954, J. *Didemnum perlucidum* Monniot F., 1983.

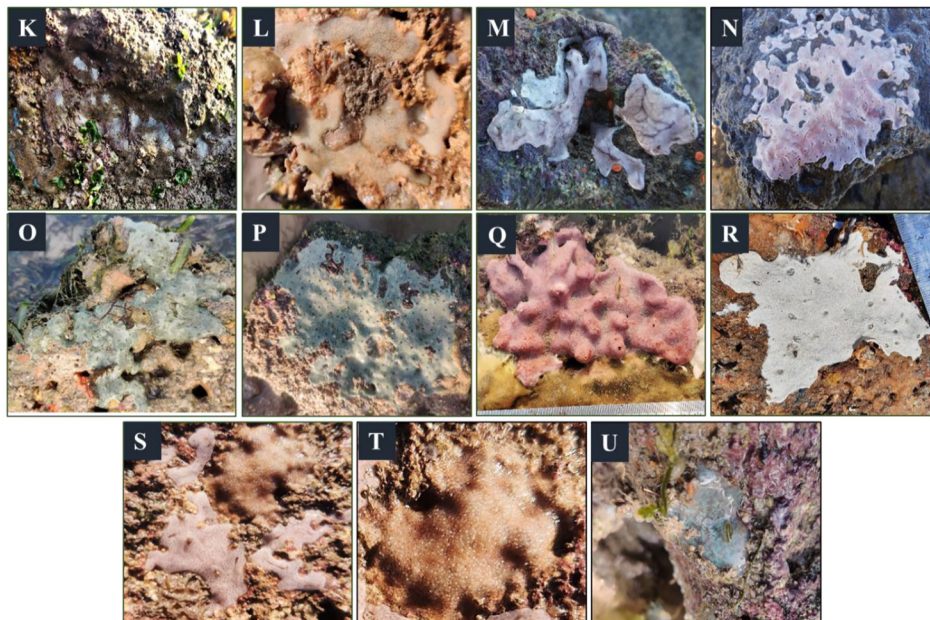


Fig. 3. Observed species of tunicates: K. *Didemnum psammatodes* (Sluiter 1895), L. *Didemnum vexillum* Kott 2002, M. *Didemnum* sp., N. *Trididemnum* sp., O. *Diplosoma listerianum* (Milne Edwards 1841), P. *Polysyncraton* sp., Q. *Polysyncraton* sp., R. *Lissoclinum fragile* (Van Name 1902), S. *Aplidium* sp., T. *Eudistoma constrictum* Kott 1990, U. *Clavelina* sp.

Table 1. List of ascidians encountered during the present study.

Sl. No.	Species name	Genus	Family	Order	Class
1	<i>Botryllus schlosseri</i> (Pallas 1766)	Botryllus			
2	<i>Botrylloides leachii</i> (Savigny 1816)				
3	<i>Botrylloides violaceus</i> (Oka 19270)	Botrylloides			
4	<i>Botrylloides niger</i> (Herdman 1886)		Styelidae		
5	<i>Botrylloides</i> sp.			Stolidobranchia	
6	<i>Botrylloides</i> sp.				
7	<i>Symplegma brakenhielmi</i> (Michaelsen 1904)				
8	<i>Herdmania momus</i> (Savigny 1816)	Herdmania	Pyuridae		Asciacea
9	<i>Didemnum granulatum</i> (Tokioaka 1954)				
10	<i>Didemnum perlucidum</i> (Monniot F. 1983)	Didemnum			
11	<i>Didemnum psammatodes</i> (Sluiter 1895)		Didemnidae	Aplousobranchia	
12	<i>Didemnum vexillum</i> (Kott 2002)				
13	<i>Didemnum</i> sp.				
14	<i>Trididemnum</i> sp.	Trididemnum			
15	<i>Diplosoma listerianum</i> (Milne Edwards 1841)	Diplosoma			
16	<i>Polysyncrator</i> sp.	Polysyncrator			
17	<i>Polysyncrator</i> sp.				
18	<i>Lissoclinum fragile</i> (Van Name 1902)	Lissoclinum			
19	<i>Aplidium</i> sp.		Polyclinidae		
20	<i>Eudistoma constrictum</i> (Kott 1990)	Eudistoma	Polycitoridae		
21	<i>Clavelina</i> sp.	Clavelina	Clavelinidae		

RESULTS

In the present study, a total of 21 species under 12 genera and 6 families (Figs. 2–3) were recorded from Okha coast of Gujarat, India. Single solitary ascidian and 20 colonial species were recorded for the first time from the study area. Maximum representation was from the family Didemnidae (10) followed by Styelidae (7), Pyuridae (1), Polyclinidae (1), Polycitoridae (1), Clavelinidae (1). Taxonomic categories provided in Table 1 based on WoRMS (<https://www.marinespecies.org>).

The taxonomical status, description and distribution of the recorded Tunicate species are as follows:

Order Stolidobranchia

Family Styelidae Herdman 1881

Genus *Botrylloides* Milne Edwards 1841

Botryllus schlosseri (Pallas 1766) (Fig. 2A)

Remarks: Colonial tunicate with two-toned colour. Commonly called as golden star tunicate. Individual

zooids are organized into flower shaped clusters. Colonies are flat, but can develop lobes as they mature into loose rolls and lobes when overgrowing. Found encrusting growing colony form with 1 cm thick and 3–4 cm wide. Species found on the top and underneath of rocks in lower littoral zone of coast.

Distribution: India, Western Australia, Indonesia, New Zealand, West Indian Ocean, Red Sea and South Africa, Adriatic Sea, Italy.

Taxon Identifier: WoRMS-ID: 103862, GBIF taxon ID: 5200757, Dyntaxa ID: 234265, iNaturalist taxon ID: 62408, TAXREF ID: 6910, DORIS ID: 212, IRMNG ID: 10744075, SeaLifeBase ID: 55387, Observation.org ID: 27517, Microsoft Academic ID: 2780204834, BOLD Systems taxon ID: 28455, EUNIS ID: 23862, NBIC taxon ID: 107768.

Genus *Botrylloides* Milne Edwards 1841

Botrylloides leachii (Savigny 1816) (Fig.2B)

Remarks: Species with yellow-brown in color. Colonial in nature. Colonies are encrusting, about 3 cm thick and 15 cm in diameter size. Lobate appearance

noted. The test is transparent, soft and gelatinous. Small granular bodies are visible near the surface of the test between the zooid systems and the border of the colony. Species found in the rock pool- surface of flipped rock in lower littoral zone of coast.

Distribution: India, Western Australia, Indonesia, New Zealand, West Indian Ocean, Red Sea and South Africa.

Taxon Identifier: Encyclopaedia of Life ID: 393415, GBIF taxon ID: 5200739, WoRMS-ID for taxa: 252314, IRMNG ID: 10744587.

Genus *Botrylloides* Milne Edwards 1841

Botrylloides violaceus Oka 1927 (Fig. 2C)

Remarks: Colonial species with yellow color. Pink colour morph is also found. Commonly called chain tunicate. This colonial tunicate is thin and lobe-like with zooids forming long double rows or chains. Zooids are 1-2 mm long, arranged in clusters within a clear and firm matrix. Found encrusting colony with about 7-9 cm in diameter. Species grow on a surfaces of hard substrata in the middle littoral zone of coast. This species was previously observed in the Gulf of Kutch region, Gujarat but no data found in other coastal regions of India.

Distribution: India, Japan, China, France, Brazil, USA, Australia, New Zealand, South Africa.

Taxon Identifier: WoRMS-ID: 148715, NCBI taxonomy ID: 581057, GBIF taxon ID: 435494, iNaturalist taxon ID: 81776, TAXREF ID: 647505, DORIS ID: 4505, IRMNG ID: 10544279, SeaLife-Base ID: 88754.

Genus *Botrylloides* Milne Edwards 1841

Botrylloides niger Herdman 1886 (Fig. 2D)

Remarks: Colonial species with brown-greenish color. The test is soft and translucent. Colony is thin and transparent. Zooids are curved and about 1.5 to 2 mm. This species was observed in the lower intertidal zone of coast. A total size of colony is about 7-8 cm in diameter.

Distribution: India, Australia, USA, Brazil, Belize, Venezuela, Mexico, Bermuda, Morocco, Ecuador.

Taxon Identifier: WoRMS-ID: 252289, IRMNG ID: 10003780, GBIF taxon ID: 2332084, NCBI taxonomy ID: 2719301, TAXREF ID: 552497.

Genus *Botrylloides* Milne Edwards 1841

Botrylloides sp. (Fig. 2E)

Remarks: Colonial species with off white colour. Zooids of colony arranged in a row. Extremely soft tunic. Species attached to substrata of lower intertidal zone of coast. A total size of colony is about 5-7 cm in diameter.

Distribution: India.

Genus *Botrylloides* Milne Edwards 1841

Botrylloides sp. (Fig. 2F)

Remarks: Colonial species with dark purplish with white line color. Species looks like gel cushion with 2-3 mm thickness. Species found on the underneath of rock in lower zone of coast. A total size of colony is 4-6 cm in diameter.

Distribution: India.

Genus *Symplegma* Herdman 1886

Symplegma brakenhielmi (Michaelsen 1904) (Fig. 2G)

Remarks: Colonial species with red and yellow colour. White colour morph found. Tunic is very thin and transparent. Zooids with rows of stigmata and branchial sac with longitudinal vessels per side. Species found with other species of tunicate in the middle and lower zone of coast. A size of colonies were different up to 5 to 10 cm in diameter. Species resembled with *Symplegma rubra* species but differs by the gonads. In *S. brakenhielmi* there is on each side an ovary between 2 testis lobes, both male and female elements maturing at the same time.

Distribution: India, Hong Kong, Indonesia, Thailand, Bahrain, Fiji, Australia, New Caledonia, Palau,

Guam, China, Noumea, Sri Lanka, Hawaii, Caribbean, French Guiana, Brazil, Martinique, Galápagos, Israel (Mediterranean).

Taxon Identifier: WoRMS-ID: 251435, GBIF taxon ID: 2332243, NCBI taxonomy ID: 1656920, TAXREF ID: 528440, IRMNG ID: 11274945, iNaturalist taxon ID: 691932, SeaLifeBase ID: 55723, CAB ID: 275956, BOLD Systems taxon ID: 511380, Australian Faunal Directory ID: *Sympagma_brakenhielmi*.

Family Pyuridae Hartmeyer 1908
Genus *Herdmania* Lahille 1888
Herdmania momus (Savigny 1816) (Fig. 2H)

Remarks: Solitary ascidian. Found in large numbers nearby. The test is tough and leathery in nature. Species are light pink in living condition. Smaller species is about 3 cm, pink with transparent test; large species is about 7 cm, test tough, opaque or even leathery. Both siphons (branchial and atrial) are pointed upward in direction. Cylindrical siphons originate close to one another on upper surface, branchial siphon directed laterally and atrial siphon vertical. Species recorded underneath of rock with other encrusting tunicate species in middle littoral zone of coast. The presence of barbed spines in the test and mantle bodies are the characteristic feature the genus.

Distribution: India, Japan, Taiwan, Philippines, Indonesia, Palau, Hawaii, Fiji, South Africa, Australia, South China Sea, Tahiti, Arafura Sea.

Taxon Identifier: WoRMS-ID: 103830, NCBI taxonomy ID: 7733, GBIF taxon ID: 5200658, TAXREF ID: 372774, DORIS ID: 3274, IRMNG ID: 11440771, iNaturalist taxon ID: 471730, SeaLifeBase ID: 55232, BOLD Systems taxon ID: 493700, EUNIS ID for species: 23830.

Order Aplousobranchia

Family Didemnidae Giard 1872

Genus *Didemnum* Savigny 1816

Didemnum granulatum Tokioka 1954 (Fig. 2I)

Remarks: Colonial ascidian. Zooids are yellow in

color. Surface of the colony is granules like and test is hard. Numerous common cloacal openings are arranged at a distance of 0.3 to 0.5 mm between them. Zooids are arranged in circular manner. Recorded encrusting colony with 8-10 cm in diameter. Species grow on the surface of underneath rocks in lower littoral zone.

Distribution: India, Australia, Tokara Islands, Fiji, Palau Islands, French Polynesia, Hawaii.

Taxon Identifier: WoRMS-ID: 212503, NCBI taxonomy ID: 1132391, GBIF taxon ID: 2329715, TAXREF ID: 459135, IRMNG ID: 10967793, iNaturalist taxon ID: 662222, SeaLifeBase ID: 53643, BOLD Systems taxon ID: 505887, Australian Faunal Directory ID: *Didemnum granulatum*, Catalogue of Life ID: 6CT94.

Didemnum perlucidum Monniot F., 1983 (Fig. 2J)

Remarks: Colonial species with off white colour. Colony grow in small lobes. The test is hard and rough surface. Zooids of colony clearly visible with about 2 mm size and linearly pattern of arrangements. Species observed attached to the substrata of the middle zone of the coast.

Distribution: India, Brazil, Australia, Puerto Rico, Guadeloupe, USA, Panama, Colombia, Philippines, Venezuela, Palau, French Polynesia, Guam, Belize, Indonesia, Tanzania.

Taxon Identifiers: WoRMS-ID: 212506, NCBI taxonomy ID: 1157906, GBIF taxon ID: 2329727, iNaturalist taxon ID: 195379, TAXREF ID: 459143, IRMNG ID: 11012844, SeaLifeBase ID: 53957, CAB ID: 312941, BOLD Systems taxon ID: 505889.

Didemnum psammatodes (Sluiter 1895) (Fig. 3K)

Remarks: Colonial species with brown color. This species abundantly found in intertidal zone of the coast. The colony looks like thin encrusting sheet. Zooids of species are very small, less than 1 mm. A total size of colony is about 10-13 cm in diameter. Accumulation of faecal pellets throughout in the colony is the characteristic feature. Species are mostly

observed on hard substrata of the middle and lower littoral zone.

Distribution: India, China, Indonesia, Philippines, New Caledonia, Papua New Guinea, Fiji, Palau, Tonga, Guam, Red Sea, Persian Gulf, East and South Africa, Australia, Ifaluk, Japan, Hawaii, Guadeloupe, SE Brazil, Panama (Caribbean), French Guiana, Gulf of Mexico, Florida.

Taxon Identifier: WoRMS-ID: 252853, NCBI taxonomy ID: 516030, GBIF taxon ID: 4356253, TAXREF ID: 552183, IRMNG ID: 11680385, iNaturalist taxon ID: 662229, BOLD Systems taxon ID: 717063.

Didemnum vexillum Kott 2002 (Fig. 3L)

Remarks: Species with creamy white color. This species is a compound, colonial, with small, individual zooids. Zooids are randomly distributed and embedded in a common tunic. Some open as open hole; other zooids as close opening and looks like white dots. Found on hard substrate of rock in lower littoral zone of coast. Species also called as sea vomit.

Distribution: India, Alaska, Australia, New Zealand, Netherland, Mexico.

Taxon Identifier: GBIF Taxon Id: 7707408.

Didemnum sp. (Fig. 3M)

Remarks: Colonial species with purple white colour. Test is very transparent and smooth surface. Zooids are not clearly visible. Species observed in small patches of diameter about 3 cm on the substrata in the middle and lower zone of coast.

Genus *Trididemnum* Della Valle, 1881

Trididemnum sp. (Fig 3N)

Remarks: Colonial species with pinkish-white color. Test is leathery and hard. Surface of the colony is very smooth. Zooids are evenly distributed in the test. Common cloacal opening is observed. Species observed in sheet like patch of diameter about 15 cm on the substrata in the middle and lower zone of coast.

Distribution: India.

Genus *Diplosoma* Macdonald 1859

Diplosoma listerianum (Milne Edwards 1841) (Fig 3O)

Remarks: Colonial species with greenish color. It has a translucent appearance with granules like whitish pigment. Zooids are colorless and adhere very hard to the tunic. The colony looks like extensive thin sheets up to 8-10 cm in diameter size. Species observed underneath of rock in lower zone of the coast.

Distribution: India, Japan, Indonesia, New Zealand, Australia, USA, Brazil, Greece, South Africa, Argentina, Belgium.

Taxon Identifier: WoRMS-ID: 103579, NCBI taxonomy ID: 168635, GBIF taxon ID: 5200414, Dyntaxa ID: 234228, iNaturalist taxon ID: 81778, TAXREF ID: 379202, DORIS ID: 213, IRMNG ID: 10375255, SeaLifeBase ID: 54011, BOLD Systems taxon ID: 406736, EUNIS ID for species: 23579, NBIC taxon ID: 107663.

Genus *Polysyncraton* Nott 1892

Polysyncraton sp. (Fig. 3P)

Remarks: Colonial species with light green colour. Zooids of species clearly visible with 2-3 mm size. There are usually many cloaca with a smooth rim. Species found on the flipped big rock of tide pool in middle littoral zone of coast. A total size of colony is about 12-15 cm in diameter.

Distribution: India.

Polysyncraton sp. (Fig. 3Q)

Remarks: Colonial species with pink-purple color. Colony is thin, encrusting and easily torn test. Zooids are not noticeable but there are large and common exhalent apertures evenly distributed throughout the colony. Species observed in the shallow pools substrata of middle and lower intertidal zone of coast. A total size of colony is about 8 cm in diameter.

Distribution: India.

Genus *Lissoclinum* Verrill 1871

Lissoclinum fragile (Van Name 1902) (Fig. 3R)

Remarks: Colonial species with white colour, even in preserved specimens. Colony is thin, soft and encrusting. Zooids has no pigmentation and clearly visible 1-1.5 mm size. Species found in the big flipped rock of the middle and lower intertidal zone of the coast. The total size of the colony is about 10 cm in diameter.

Distribution: India, Argentina, Brazil, Mexico, Palau, Belize, Philippines, Bermuda, Virgin Islands (US), Jamaica, Marshall Islands, French Polynesia, New Caledonia, Guadeloupe, Philippines, Mayotte, Madagascar, West Indies.

Taxon Identifier: WoRMS-ID: 250786, NCBI taxonomy ID: 1079457, GBIF taxon ID: 2329852, iNaturalist taxon ID: 209012, TAXREF ID: 459155, IRMNG ID: 10004402, SeaLifeBase ID: 54112, BOLD Systems taxon ID: 667483, Google Knowledge Graph ID: /g/12322wxb4, Catalogue of Life ID: 3VF53.

Genus *Aplidium* Savigny 1816

Aplidium sp. (Fig. 3S)

Remarks: Colonial encrusting and whitish color. The tunic is jellylike. The common cavity of colony species is wide, with zooids in linear manner arrangement. The species observed on the flipped big rock in the middle zone of the coast. The total size of colony is about 7 cm in diameter. Growth of colony observed in nearby patches.

Distribution: India.

Family Polycitoridae Michaelsen 1904

Genus *Eudistoma* Caullery 1909

Eudistoma constrictum Kott 1990 (Fig. 3T)

Remarks: Colonial gelatinous species with transparent- brown color. The colony has very smooth surface.

The basal half is a thick, cylindrical stalk without zooid openings. Zooids are large with row of stigmata and open independently on the upper half of the lobe. The colony is grow on an algae species and covered substrate. Total size of the colony is about 20 cm in diameter and is observed in lower zone of the coast.

Distribution: India, Australia

Taxon Identifier: WoRMS-ID: 250206, GBIF taxon ID: 2330350, IRMNG ID: 11123761, SeaLifeBase ID: 54479.

Family Clavelinidae Forbes & Hanley 1848

Genus *Clavelina* Savigny 1816

Clavelina sp. (Fig. 3U)

Remarks: Colonial species with transparent sky-blue color. Zooids are freely embedded in matrix. This species observed in the lower intertidal zone of the coast. The test is transparent and very soft-smooth. Total size of the colony is 3-4 cm in diameter.

Distribution: India.

DISCUSSION

Studied intertidal zones get exposed to sunlight during low tide due to flat substratum that make species more vulnerable against desiccation. Encountered colonial tunicates mostly found under the boulders which provides shelter against desiccation that creates boulder dependent patchy distribution of ascidians in Okha coast. Out of 21 species, 20 species are colonial and a single species *Herdmania momus* is solitary and distributed abundantly throughout coast. It was also marked that majority of tunicates found only during winter season. The present study insight new aspect of ecological study in this coastline since ascidians are also considered as emerging model system for studying ecological dominance in rocky intertidal habitats and can fundamentally transform entire ecosystems in invasive forms (Teske *et al.* 2017). Invasive status of reported species is also not cleared due to limited information on the diversity, existence, distribution and ecology of tunicates on this coastline. Other intertidal species on studied coast observed amongst variety of substratum such as submerged blocks, pebbles, zoanthids bed, underneath of rocks with its

characteristic faunal and floral associations. However, colonies found herein were dominating underneath rocks, only members of Didemnidae family coexist with sponges. That indicates ability of these species to structure their own communities in terms of species composition, diversity, biomass, spatial arrangement and occupancy (Teske *et al.* 2017). Interactions of dominating and space occupier communities studied on this coastline (Poriya and Kundu 2016) that indicates, these interactions or strategies can also regulate the distribution and abundance of other species.

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