Non-indigenous sea slug *Tenellia adspersa* in the southeast coast of the Arabian Sea, India

Nudibranchs are gastropod molluscs belonging to suborder Opisthobranchia. They are easily identified based on their shell-less bodies and a pair of rhinophores (tentacles) on the dorsal side of the head. These organisms are stunningly colourful, hence are often called 'butterflies of the ocean'. About 3000 species of Nudibranchs are known globally[1], and 311 species have been reported from India[2]. *Tenellia adspersa* is a tiny nudibranch, commonly known as lagoon sea slug or miniature aeolis. It is a euryhaline aeolid sea slug inhabiting shallow areas from 1 to 34 m depth, and with salinity ranging from 3‰ to 50‰ (ref. 3). Its preferred habitats are estuaries, brackish water bodies, lagoons and harbours of temperate and tropical regions[3]. This species was first described by Nordmann[4] in 1844, based on specimens collected from the Black Sea, Ukraine.

ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi has been monitoring the benthos in Cochin harbour and the adjacent coastal region from 2010. In the present study, the benthos samples were collected using a sampler (Van Veen Grab) with an area of 0.28 m^2. The samples (surface layer sediments) were sieved using 2 mm and 500 µm sieves. The benthos retained in the sieves was preserved in 4% buffered formalin stained with Rose Bengal solution and subsequently identified. During one such investigation, *T. adspersa* was identified on the basis of 17 specimens collected from the bar mouth of Cochin harbour (9°58′N, 76°15′E) at 5 m depth (Figure 1) on 13 September 2013. This is the first record from Indian waters. The collection consisted of juveniles (2.96 mm) and adults (up to 7.80 mm) (Figure 2). Table 1 provides the morphometric details. The benthos sample also contained amphipods, decapod crustaceans, polychaetes (*Nereis* spp., *Malmgrenia* spp.) and Oligochaetes. Table 2 provides the environmental parameters recorded during the sampling period. The specimens have been deposited in the Marine Biodiversity Museum of CMFRI (accession no. DB.1.3.1). It has been reported that *T. adspersa* grows up to 8 mm length and attains maturity at 3.6 mm (ref. 3). Its known longevity is less than one year and it reaches sexually maturity in 20 days (ref. 5). It spawns 3–5 times, with each spawning period lasting for 3–5 days, and lays 25–50 eggs per spawn[5].

Taxonomical studies on the *T. adspersa* specimens were carried out following Alder and Hancock[6], and Roginskaya[3]. This species is known to be pale brown-coloured with tiny black spots.

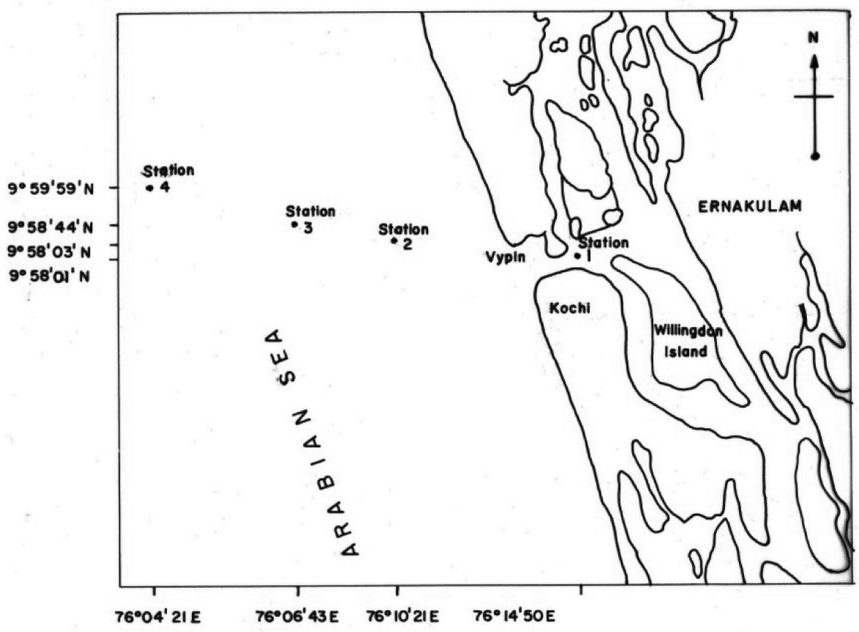

Figure 1. Map showing the sampling point (station-1) at Cochin estuary, Kerala, India.

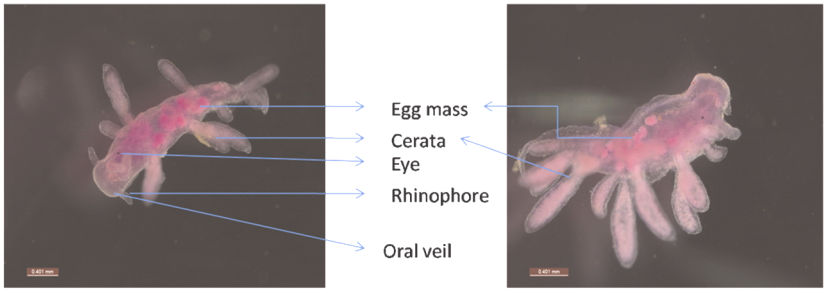

Figure 2. Morphometric characteristics of miniature sea-slug *T. adspersa*.

Table 1. Total length and body width of *Tenellia adspersa* specimens

Total length (mm)	Body width (mm)
2.96	1.16
3.41	1.99
3.55	1.35
4.13	1.85
4.30	2.34
4.37	1.55
4.44	2.18
5.13	2.07
5.37	1.32
5.46	1.96
5.63	2.19
5.90	2.57
6.37	2.74
6.76	2.02
6.90	2.05
7.07	2.39
7.80	2.01

However, in the present study the colour of the fresh specimens could not be observed, and identification was based on preserved specimens. It is easily distinguished by its minute slender body tapering behind and two short, cylindrical rhinopores/tentacles or veils on the sides of the head, which serve as chemosensory organs. The tentacle-like dorsal outgrowths called papillae/cerata form 2–6 groups of 1–3 simple cerata each.

T. adspersa is closely associated with hydroids and mainly feeds on them. It mostly prefers to feed on hydroids, *Garveia franciscana*, *Cordylophora caspia*, *Gonothyraea loveni* and *Ectopleura crocea*[3,7]. Among these, *Garveia franciscana* commonly called rope grass hydroid, has been reported from the Cochin backwaters. Leloup[8] described *Bimeria franciscana* (a junior synonym of *Garveia franciscana*) for the first time from the west coast of India. Subsequently, Mammen[9] reported it in large numbers from Cochin, wherein its colonies generally grew up to 15 cm (maximum of 30 cm) and the distance between the branches was 3–10 mm. The rope grass hydroid had been surviving in fresh, brackish and marine water habitats and tolerated salinities varying from 1‰ to 35‰ (ref. 10). It is one of the important prey items for *T. adspersa*[11]; one *T. adspersa* can devour 100 individuals of *Garveia* species per day[3]. *Garveia franciscana* provides shelter and habitats to many crustaceans like amphipods, shrimps, crabs and juvenile fishes[12], and is probably helpful in sustaining good fishery. The major impacts of invasive species are the alteration of nutrient cycling, food webs, community structure and shifting of native species[13,14]. Invasive alien species are the major threats to biodiversity.

To the best of our knowledge, there are no earlier records of this species from the Indian Ocean rim countries. The natural geographical range of the species is from northeastern Atlantic Ocean to the Caspian Sea[3,7]. More recently, it has been introduced into New Zealand (Table 3). It has also been introduced to the several Pacific Ocean countries through ballast water of ships[3]. Ballast water is stored in ballast tanks located at the bottom chamber of empty cargo ships to maintain buoyancy. When these ships enter the next port of call to load cargo, the ballast water is discharged. Microscopic marine animals (zooplankton, nekton) and plants (phytoplankton) are transported along with the ballast water to new biogeographical areas, where they become marine pests. Similarly, benthos may unintentionally enter the ballast tank. Cochin backwater is a tropical estuary along the southwest coast of India, in which the Cochin harbour is situated. The bar mouth of the Cochin estuary is the main entrance of the Cochin harbour and is permanently connected to the Arabian Sea. Cochin port is a major international transhipment terminal and latest statistics has revealed that it handled 1430 vessels during the year 2013–14 and 1476 vessels in 2014–15 (ref. 15). The intensive international shipping activity could have triggered the invasion of *T. adspersa*. Ship hulls contain several fouling organisms, including hydroids. The adult *T. adspersa* might have got attached to the hydroids on the surface of the ship hull and then transported to Cochin. Another possibility is

Table 2. Hydrological characteristics observed at the sampling site

Observed parameters	Surface	Bottom
Water temperature (°C)	29	26.2
pH	6.78	7.47
Salinity (PSU)	4.62	31.9
Chlorophyll *a* (mg m^{-3})	1.364	0.929
Chlorophyll *b* (mg m^{-3})	0.031	0.000
Chlorophyll *c* (mg m^{-3})	0.213	0.000
Dissolved oxygen (mg l^{-1})	5.82	3.28
SiO_3-Si (mg l^{-1})	2.74	0.05
PO_4 -P (mg l^{-1})	0.040	0.045
NO_3-N (mg l^{-1})	0.002	0.000
NO_2-N (mg l^{-1})	0.003	0.007
Total NH_3-N (mg l^{-1})	0.013	0.252
GPP (mg C L^{-1} h^{-1})	0.038	–
NPP (mg C L^{-1} h^{-1})	0.059	–

GPP, Gross Primary Productivity; NPP, Net Primary Productivity.

Table 3. First records of *Tenellia adspersa* reported in different countries

Tenellia adspersa/synonym	Year	Country name	Reference
Tergipes edwardsii	1846	Ukraine	4
Tergipes lacinulatus	1849	Germany	18
Embletonia pallida	1881	Finland	19
Embletonia pallida	1907	Russia	20
Embletonia pallida	1907	Sweden	20
Embletonia pallida	1910	England	21
Embletonia pallida	1926	France	22
Tenellia pallida	1944	Denmark	23
Embletonia mediterranea	1953	Brazil	24
Tenellia ventilabrum	1953	Atlantic Ocean	25
Embletonia pallida	1955	Mediterranean	26
Embletonia pallida	1960	Brazil	27
Tenellia pallida	1963	Japan	28
Tenellia adpsersa	1970	Russia	3
Tenellia adspersa	1972	East coast of USA	29
Tenellia adspersa	1979	West coast of USA	30
Tenellia pallida	1979	South Carolina, USA	31
Tenellia adspersa	1990	Russia	32
Tenellia adspersa	1996	Australia	33
Tenellia adspersa	2001	New Zealand	34
Tenellia adspersa	2005	The Netherlands	35
Tenellia adspersa	2006	Hong Kong	36
Tenellia adspersa	2013	Norway	37

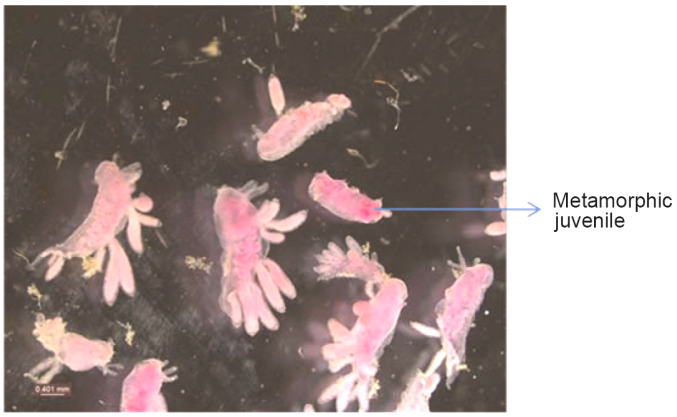

Figure 3. Juvenile and adult specimens of *T. adspersa*.

the transport of egg masses of *T. adspersa* discharged through ballast water, which might have developed into adults. This is corroborated by the occurrence of juveniles as well as adult stages (Figure 3). During the monsoon months (June–September), the Cochin estuary salinity gradients are very low[16], which might have favoured *T. adspersa* development and survival. India is one of the signatories to the Convention on Biological Diversity (CBD)[17]. Article 8(h) of the CBD states that, 'Each contracting Party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'. Therefore, continuous monitoring of harbours/ports is essential to prevent the invasion of non-indigenous species.

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