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First report on the distribution of *Aegiceras corniculatum* (L.) Blanco (Primulaceae) from the Nicobar archipelago, India

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ABSTRACT

The 2004 Sumatra-Andaman earthquake (9.3 Mw) and subsequent tsunami caused upliftment and subsidence throughout the Andaman and Nicobar archipelago. This incident has significantly impacted the mangroves (97% vegetation loss) and coastal ecosystems of the Nicobar archipelago. Interestingly, the coastal subsidence has also created new intertidal habitats in the erstwhile agricultural lands and terrestrial forests, which provided an opportunity for the colonization of mangrove species. During our long-term monitoring of mangrove colonization in the Nicobar archipelago, we collected *Aegiceras corniculatum* (L.) Blanco (Primulaceae) from Alreak, in Nicobar Islands. The occurrence of this species forms a new distributional record for the Nicobar archipelago. The present article provides detailed information on its taxonomy, ecology, and discusses the potential future spread of this species in the Nicobar Islands.

Keywords: 2004 Tsunami, Coastal Subsidence, Mangrove colonization, New intertidal habitats, Southeast Asia

Natural disturbances and geological processes play a critical role in shaping species distribution patterns and composition of ecological communities (White, 1979; Alongi, 2008; Krauss and Osland, 2020). Especially, the high-intensity large-scale disturbances can result in the colonization of species that are distinct from the species that previously occupied the landscape (Platt and Connell, 2003; Nehru and Balasubramanian, 2018). The 2004 Indian Ocean tsunami and the geo-morphological changes due to tectonic subsidence have created two opposite ecological scenario in the Nicobar Islands. Firstly, the catastrophe has degraded 97% of Nicobar's mangrove cover, and secondly, the coastal subsidence has formed new intertidal habitat for mangrove colonization (Nehru and Balasubramanian, 2018). While the mangroves are reconciling post disturbance, the disturbance event has drastically altered the mangroves' species assemblage (Nehru and Balasubramanian, 2018), and provided an opportunity for the colonization of mangrove species that were earlier unreported in this archipelago (Thirumurugan et al., 2022).

The post tsunami studies have documented a slightly higher mangrove species richness (n=24 species) (Nehru and Balasubramanian, 2011, 2018; Goutham-Bharathi et al., 2014; Ragavan et al., 2015; Thirumurugan et al., 2022), compared to the pre-tsunami studies (n=23 species) in the Nicobar archipelago (Thothathri et al., 1973; Gopinathan and

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Rajagopalan, 1983; Chakrabarthy, 1985; Dagar et al., 1991, 1993; Jagtap, 1992; Sinha, 1999) (Table 1). Meanwhile, five species that were reported to be common in the archipelago were expectedly become locally extinct after the 2004 tsunami due to habitat loss (Prabakaran, 2020; Thirumurugan et al., 2022). Moreover, most of the post tsunami studies have reported species without proper authentication, such as the collection of herbarium specimens and description of distribution and ecology. Meanwhile, *Sonneratia ovata* Backer (Nehru and Balasubramanian, 2012), *Sonneratia lanceolata* Blume*, Schypiphora* (Ragavan et al., 2015; Nehru and Balasubramanian, 2018), and *Avicennia marina* (Forssk.) Vierh (Thirumurugan et al., 2022), previously unknown to the Nicobar Islands, were reported only after the 2004 tsunami, found colonizing the newly created intertidal habitats (Nehru and Balasubramanian, 2012; Thirumurugan et al., 2022). These new distributional reports are critical to understand the natural recovery and colonization pattern of this high ecological value coastal vegetation system.

Table 1. Details of mangrove species reported in the Nicobar archipelago before and after the 2004 tsunami (# – Reported by this study)

S.no	Species reported before the 2004 tsunami	Species reported after the 2004 tsunami	Local extinction after the 2004 tsunami	New distribution after the 2004 tsunami
1	*Acanthus ilicifolius*	*Acanthus ilicifolius*	*Acanthus volublis*	*Avicennia marina*
2	*Acanthus volublis*	*Acrostichum aureum*	*Bruguiera sexangula*	*Aegiceras corniculatum #*
3	*Acrostichum aureum*	*Avicennia marina*	*Bruguiera parviflora*	*Lumnizera racemosa*
4	*Acrostichum speciosum*	*Bruguiera gymnorhiza*	*Cynometra ramiflora*	*Scyphiphora hydrophyllacea*
5	*Bruguiera gymnorhiza*	*Ceriops tagal*	*Xylocarpus moluccensis*	*Sonneratia lanceolata*
6	*Bruguiera sexangula*	*Dolichandrone spathacea*	*Acrostichum speciosum*	*Sonneratia ovata*
7	*Bruguiera parviflora*	*Excoecaria agallocha*	-	-
8	*Ceriops tagal*	*Excoecaria indica*	-	-
9	*Cynometra ramiflora*	*Heriteria littoralis*	-	-
10	*Dolichandrone spathacea*	*Lumnitzera littoralis*	-	-
11	*Excoecaria agallocha*	*Lumnizera racemosa*	-	--
12	*Excoecaria indica*	*Nypa fruitcans*	-	-
13	*Heriteria littoralis*	*Rhizophora mucronata*	-	-
14	*Lumnitzera littoralis*	*Rhizophora apiculata*	-	-
15	*Nypa fruitcans*	*Rhizophora stylosa*	-	-
16	*Rhizophora apiculata*	*Rhizophora x lamarkii*	-	-
17	*Rhizophora mucronata*	*Scyphiphora hydrophyllacea*	-	-
18	*Rhizophora stylosa*	*Sonneratia lanceolata*	-	-
19	*Rhizophora x lamarkii*	*Sonneratia ovata*	-	-
20	*Sonneratia alba*	*Sonneratia alba*	-	-
21	*Sonneratia caseolaris*	*Sonneratia caseolaris*	-	--
22	*Xylocarpus granatum*	*Sonneratia x gulngai*	-	-
23	*Xylocarpus moluccensis*	*Sonneratia x urama*	-	-
24	-	*Xylocarpus granatum*	-	-
References	Thothathri et al. 1973; Gopinathan and Rajagopalan 1983; Chakrabarty 1985; Dagar et al. 1991; Jagtap, 1992; Dagar et al. 1993; Sinha 1999	Nehru and Balasubramanian, 2012; Ragavan et al., 2014; Goutham-Bharathi et al., 2014; Nehru and Balasubramanian, 2018; Thirumurugan et al. 2022	Nehru and Balasubramanian 2012; Ragavan et al., 2014; Nehru and Balasubramanian, 2018	Nehru and Balasubramanian, 2012; Ragavan et al., 2014; Nehru and Balasubramanian, 2018; Thirumurugan et al. 2022

As a part of the long-term monitoring of the mangrove colonization in the Nicobar archipelago, we have collected a species belonging to the genus *Aegiceras* (Primulaceae) in Alreak, Noncowrie Island (7.99388° N, 93.52285° E). After a thorough scrutiny of relevant literature (Parkinson, 1923; Tomlinson, 1986; Dagar et al., 1991; Ragavan et al., 2015), the species was identified as *A. corniculatum* (L.) Blanco. The occurrence of this species forms a new distributional record for the Nicobar group of Islands. This article provides detailed information on the species ecology, taxonomy with photographs, and distribution to facilitate the precise identification of the species.

The Nicobar archipelago is a part of the Sundaland biodiversity hotspot and denoted as one of the 25 micro-centers of endemism in India (Nayar, 1996). The Nicobar archipelago comprises 21 islands with 1841 Km^2 and constitutes three major island groups, i.e., the Northern, Central, and Southern groups. Intensive field surveys were carried out across the archipelago to investigate the post-tsunami colonization of mangrove species from 2009 to 2011, and 2019 to 2022. These surveys have focused on documenting the species richness, community composition, and the rate of vegetation change in the newly created intertidal zones where mangrove species are found colonizing (Nehru and Balasubramanian, 2012, 2014, 2018; Prabakaran et al., 2021; Thirumurugan et al., 2022). During our recent survey in April 2022, *A. corniculatum* was documented from a single site: Alreak, Noncowrie Islands, Central Nicobar group. A line transect consisting of six plots (10 m × 10 m), equally distanced at 50 m intervals from landward to seaward zone, was established for species enumeration (individuals ≥1 cm girth at breast height – GBH) and future monitoring of the site (Figure 1). Additionally, all the individuals of *A. corniculatum* from the site were also counted. The GPS location, species abundance, and detailed site-specific information along with fresh flowering and fruiting specimens of *Aegiceras* were collected for the preparation of herbarium.

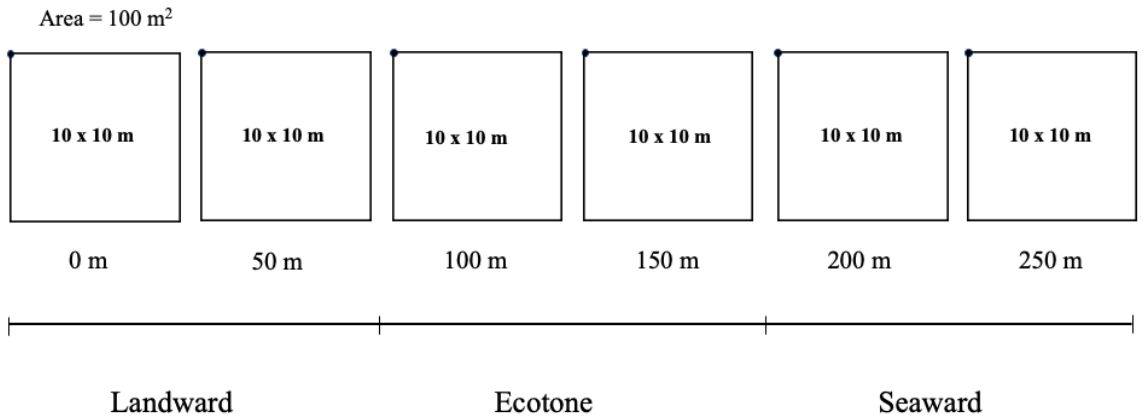

Figure 1. Schematic representation of sampling plots along a transect line used for vegetation monitoring in the mangrove sites across the Nicobar archipelago.

Site description: The site Alreak (Nicobarese: *Al* = in front; *reak* = fresh water) is situated on the north-western part of Noncowrie Island in the Central Nicobar (Figure 2). The mangrove vegetation of Alreak was completely lost, except for a few individuals of *Nypa fruticans,* after the tsunami and coastal subsidence. Currently, mangroves are seen sparsely colonizing in the newly formed intertidal areas. The remnants of pre-tsunami mangrove vegetation can be seen today in the form of dead trees in the shallow waters (Figure 3). The topography is flat with mud clays (up to 50 cm belowground) near the seaward side. The seaward soil is humus-rich, dark in color, mostly muddy-clay, and more compact, while the soil in the landward side is firm and sandy. The site was fed by perennial freshwater streams, and dead corals were seen close to the freshwater stream. The water salinity ranges from 09 to 24 ppt, pH ranges from 6.5–7.8, and the total dissolved solvents (TDS) ranges from 300–400 ppm.

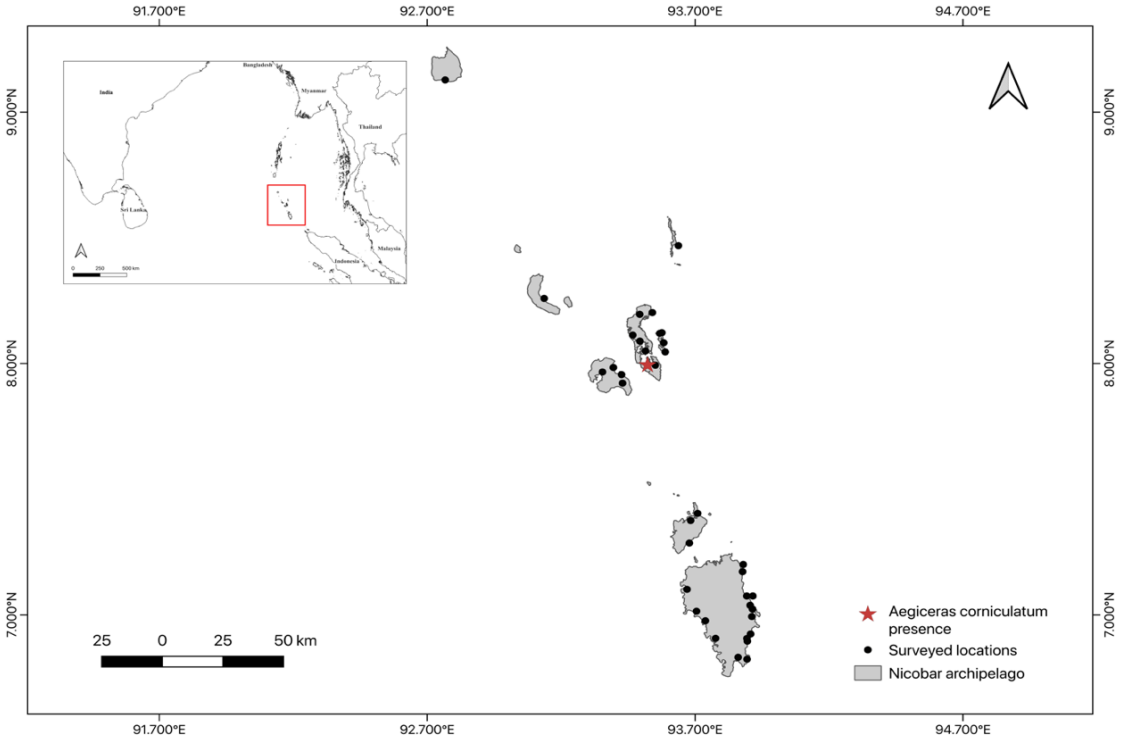

Figure 2. Locations of sites surveyed for mangrove colonization in Nicobar archipelago indicating the *Aegiceras corniculatum* presence in Alreak, Central Nicobar.

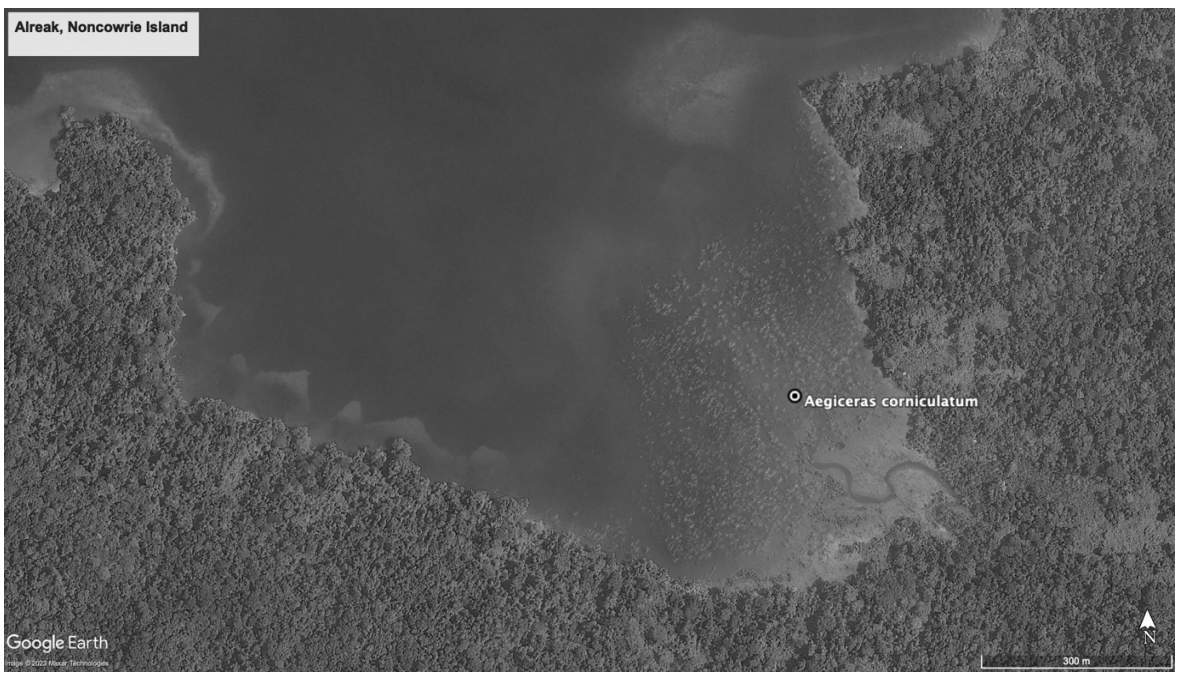

Figure 3. Aerial image showing the extent of dead mangrove vegetation and new colonizing mangroves at Alreak site in Nancowrie Island, Central Nicobar.

Taxonomy

Aegiceras corniculatum (L.) Blanco, Fl. Filip.: 79. 1837. *Rhizophora corniculata* L., Herb. Amb.: 13. 1754.

This species is characterized as a shrub or small tree with stilt roots, up to 3 m high; stems *c.* 15 cm in diameter at base; young branches 4-angled, brown with reddish tinge, glabrous. Leaves are alternate, obovate, 3.5–9 × 1.5–4 cm, attenuate base, entire to minutely revolute margins, retuse apex, coriaceous, shiny, glabrous, green above, glaucous beneath; lateral veins 6–12 pairs, conspicuous above; petioles sub-sessile, up to 5 mm long. Inflorescence is umbel, terminal, with 12–35-flowers; flowers are 12–20 mm long, pentamerous, bisexual, white, fragrant; pedicels 6–10 mm long, glabrous. Sepals 5, aposepalous, oblong, 4–7 × 2–3 mm, green, glabrous. Corolla tubular, sympetalous, 5-lobed; lobes lance-ovate, 7–15 mm long, reflexed, glabrous. Stamens 5, 4–6 mm long; anthers linear-oblong, 3–4 mm long, dorsifixed. Ovary inferior; style *c.*9 mm long; stigma simple. Capsules terete to cylindrical, falcate, 4–9 cm long, pointed at apex, pale green when young, pink at maturity; seed 1, crypto viviparous; hypocotyl curved, pointed.

Flowering and fruiting: February–May (Figure 4)

Specimen Examined: India, Nicobar Islands, Central Nicobar Islands, Alreak in Nancowrie Island, 7.99388° N, 93.52285° E, 14th April 2022, Thirumurugan Vedagiri, 12751, (Madras Christian College Herbarium, Chennai).

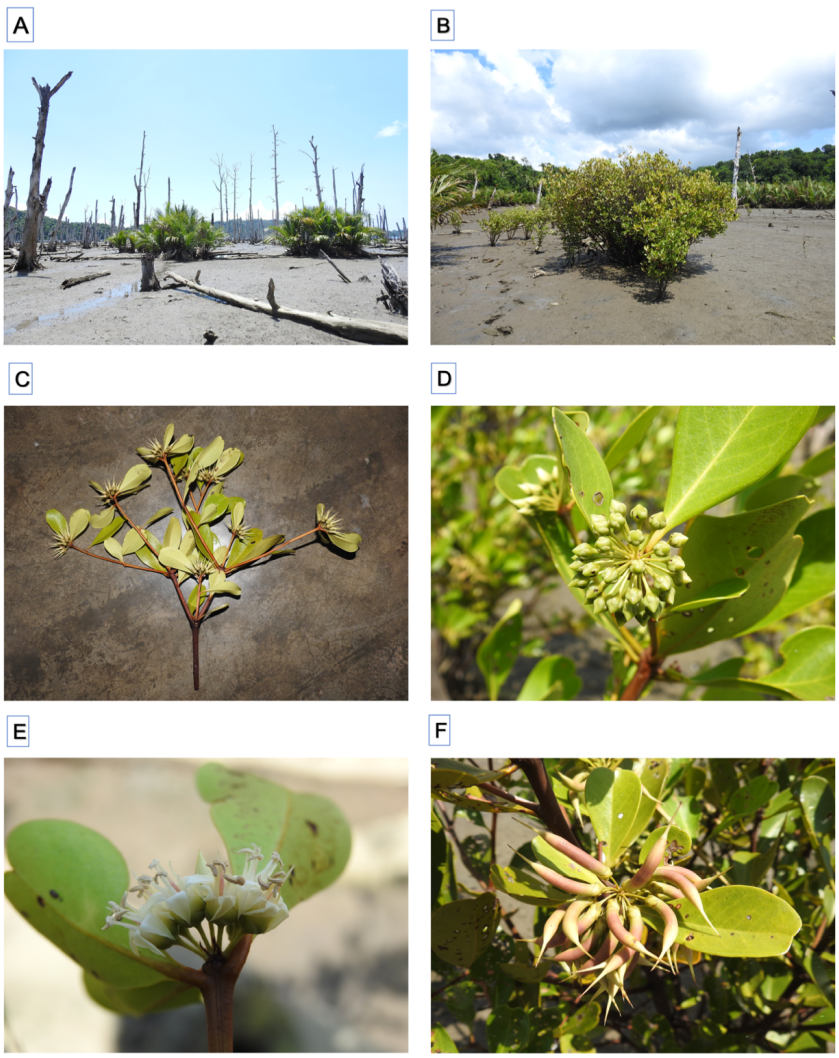

Figure 4. A. View of Alreak, Nancowrie – A new intertidal mangrove habitat; B. *Aegiceras corniculatum* habit with new recruitments; C. Flowering twig with inflorescence; D. Bud; E. Flower; F. Fruits.

A total of 35 sites (Figure 2) were surveyed across the Nicobar Island during 2009–2011 (Nehru and Balasubramanian, 2018). During our recent field survey, conducted from February to May 2022, across 19 mangrove sites in the Nicobar archipelago, we collected *Aegiceras corniculatum* (L.) Blanco, a new distribution record from the single site of Alreak, Nancowrie Island (Central Nicobar). The other mangrove species collected from Alreak were: *Nypa fruticans* Wurmb*, Bruguiera gymnorhiza* (L.) Lam.*, Rhizophora mucronata* Lam.*, Dolichandrone spathacea* (L.f.) Seem.*,* and *Heritiera littoralis* Aiton. *Aegiceras corniculatum* dominated the seaward zone at Alreak, while *Nypa fruticans* dominated the landward zone where the soil was muddy with continuous freshwater input.

We counted 40 small trees (ranged between 1.5–3m height), and ~260 seedlings of *Aegiceras corniculatum* from the entire site. Additionally, one tree (~45 cm Girth at Breast Height (GBH)) and few seedlings of *Rhizophora mucronata* were occasionally present across the site. The site also withheld small *Rhizophora mucronata* plantation block recently planted by the forest department (approx. two years old).

At Alreak, *A. corniculatum* (Relative abundance (RA) = 54.02%) was the most abundant species followed by *N. fruticans* (RA = 44.83%), and *R. mucronata* (RA = 1.15%). 19 small trees (around 2 m in height), and 30 seedlings were encountered in the survey plots. *A. corniculatum* was found growing in scattered patches (clump of 10–15 small trees) mostly along the creek channel.

A. corniculatum is widespread (7,400 km coastal area) across the Indo-West Pacific region, ranging from Pakistan to South China, to Tropical Asia through Malaysia to Polynesia and North-Eastern Australia (Tomlinson, 1986; Clarke et al., 2001). In India, the species is distributed in all along the west and east coast (Ragavan et al., 2016). This species is reported from various sites in the Andaman Islands (Parkinson, 1923; Dagar et al., 1991; Debnath, 1994; Goutham-Bharathi et al., 2014; Ragavan et al., 2015) In the Andaman Islands, *A. corniculatum* in generally found along the creek margin, and it dominates the areas of the medium to high salinity conditions. Although, a checklist of plants in Andaman and Nicobar Islands by Pandey and Diwakar (2008) reported the distribution of this *Aegiceras* from the Nicobar Islands, this report was not substantiated with any evidence (i.e. herbarium specimen, information of distribution localities, ecology, etc.). Our observation confirms the distribution of *A. corniculatum* in the Nicobar Islands with the specimen deposited at the Madras Christian College Herbarium (Thirumurugan 12751) along with documentation of its distribution and habitat specific information.

Aegiceras corniculatum is a pioneer mangrove species that usually grows along the margins of estuary banks (Tomlinson, 1986; Clarke et al., 2001). It has diffuse-porous wood, which is adapted for different soil salinities (Sun and Lin, 1997). *A. corniculatum* is a crypto viviparous species with adaptability towards high salinity conditions (has eight salt tolerance-related genes) via the salt secretion glands present in the leaves to survive and adapt against saline and hypoxic conditions of intertidal forest (Feng et al., 2021; Khan et al., 2021). It excludes 97% salt through gland/surface opening rather than metabolic mechanism (Hogarth, 2013) and can also resist other environmental stresses, such as shade, moisture, and chilling stress (Peng et al., 2015). The propagules of *A. corniculatum* are buoyant and float in the sea for up to three months until it reaches the conducive environment (Clarke, 1995; Tomlinson, 2016). Therefore, propagules of *A. corniculatum* have a long-distance dispersal ability (Clarke, 1995; Clarke et al., 2001). Their ability to disperse over long distances and their adaptability to establish and survive in high saline areas are typical attributes of seaward mangrove zones in the new intertidal areas of Nicobar Islands. These attributes have likely facilitated the establishment of *A. corniculatum* in Nicobar Islands. However, further studies focusing on genetics aspects is required to assume the source of propagule dispersal that potentially enabled a new population establishment in the Nicobar Islands.

The post-tsunami studies indicated an increase in the dominance of saline-tolerant species in the Nicobar Islands (Goutham-Bharathi et al., 2014; Ragavan et al., 2015; Nehru and Balasubramanian, 2018; Thirumurugan et al., 2022). This is also supported by the recent discovery of *Avicennia marina*, which has a rapid

colonizing strategy in Nicobar's new intertidal habitats (Thirumurugan et al., 2022). Similarly, despite being recorded from just one site in Nicobar Islands, and given its ability to establish in challenging conditions and to disperse long-distances, *A. corniculatum* has a greater chance to spread across the Central Nicobar Islands and neighboring intertidal habitats. However, long-term monitoring of new intertidal habitats in the Nicobar archipelago would be essential to understand not only the future spread of *A. corniculatum*, but also the mangrove forest successional dynamics, and species competitions that can provide significant knowledge for mangrove management.

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AUTHOR CONTRIBUTIONS

V.T.A.: Data curation, Validation, Formal analysis, visualization, Conceptualization, Writing- original manuscript, Writing- review & editing.

A.R.S B.: Data collection, Writing- review & editing.

G.G.C: Writing- review & editing.

N.P.D.: Funding, Data collection, Supervision, Writing- original manuscript, Writing- review & editing.

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