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Halophytic Community of Foredunes in South-Central Coast of Vietnam

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Abstract: The halophytic communities on foredunes are increasingly threatened by global climate change and human activities, particularly in the South-Central Coast of Vietnam. The botanical surveys were conducted across 41 study sites in eight provinces along foredunes in this region. The results show that halophytic community comprises 195 native taxa, 64 families, and 165 genera. Fabaceae is the most diverse family, with the highest number of genera (20) and species (25), followed by Asteraceae (13 genera, 13 species), Malvaceae (10 genera, 12 species), and Poaceae (10 genera, 11 species), collectively representing 32.12% of total genera and 31.28% of total species. The ten most species-rich families contribute 55.38% of the total floristic diversity in the coastal foredunes while 37 families, comprising 57.8%, are represented by single genus and single species. The habit spectrum shows that the herbs predominate and constitute 23.59% (46 species) of the recorded taxa. These findings suggest that the halophytic composition of foredunes in the South-Central Coast of Vietnam exhibits similarities to tropical desert regions in Southwest Asia, China, Pakistan. The composition of habits indicates the distinguished vegetation between incipient dune (creepers, prostrate, herbs, rhizomatous, stoloniferous) and established foredune (shrubs, woody, climbers).

Keywords: Botanical survey, Flora, Halophytes, Vietnam

Halophytes are plant species adapted to survive in saline environments such as seawater, salt marshes, coastal shores, saline flats, and salt deserts. These plants are found across a wide range of climatic zones from cold temperate to subtropical to tropical ecosystems (Flowers and Colmer 2008, Cunningham and Jankowitz 2010, Grigore 2020). The eHALOPH database currently documented 1.457 records of salt-tolerant plants belonging to 123 families of flowering plants, with 75% concentrated in 24 families; Amaranthaceae accounting for nearly a quarter of all recorded halophytes (Santos et al.,., 2016). Grigore provided a definition and classification of halophytes as an ecological group of plants with specific salt tolerance mechanisms (Grigore 2020).

The floristic studies on coastal dune ecosystems in India, Kenia, South Australia, Southwest Assia, China, and Cape St Francis identified Poaceae, Fabaceae, Asteraceae, Euphorbiaceae, Rubiaceae, and Malvaceae as the dominant families (Abuodha et al., 2003, Khan and Qaiser 2006, Zhao et al., 2011, Ghazanfar et al., 2014). In these regions, psammophytes (sand-adapted plants), herbaceous form (grasses), and shrubs exhibit the highest species richness on the life-form spectra (Rodrigues et al., 2011, Cowling et al., 2019, Jr 2019, Valcheva et al., 2020, Grobler and Cowling 2021, Romeroso et al., 2021, Anbarashan et al., 2022).

In Vietnam, the concept of halophyte in relation to coastal sandy plant remains relatively new although the floristic studies have been conducted. Surveys on Truong Sa Archipelago flora documented its biodiversity (265 species) and analyzing lifeform proportions (Tran et al., 2022). Before that, research on species composition and biodiversity in Quang Tri province's sand dune region (311 species) and Doi Hong, Phan Thiet province (96 species) provided insights into coastal composition (Ho et al., 2018, Hoang et al., 2020). These authors indicate the dominant plant families are Fabaceae, Poaceae, Cyperaceae, Asteraceae, Euphorbiaceae, Apocynaceae, Verbenaceae, Rubiaceae, Myrtaceae, Malvaceae, Lauraceae, Convolvulaceae, Capparaceae, Connaraceae, Convolvulaceae and Sterculiaceae on coastal sand dune ecosystem. The findings are presentative for islands ecosystem as well as the north and the south coastal region of Central Vietnam (Ho et al., 2018, Hoang et al., 2020, Tran et al., 2022). However, these studies were conducted in relatively small scale and unmentioned to address the ecological aspects of salt resilience in the context of halophytes, as outlined in Grigore's (2020). The present research integrates ecological perspectives on foredune plant composition in the South-Central Coast of Vietnam.

The South-Central Coast is characterized by low rainfall and high temperature. So, plants growing in this environment are affected by multiple stressors including drought, saltwater intrusion into the soil, evaporation, and nutrient-poor sandy soil. Coastal salt-tolerant plant communities play a crucial role in stabilizing sandy ecosystems, serving as the first vegetation cover negatively impacted by climate change and human activities in the South-Central Coast of Vietnam, particularly sea level rise and tourism activities. Increasing risks of species loss, habitat degradation, and biodiversity decline highlight the need for comprehensive survey and assessment of halophytic plant communities in this region. Therefore, establishing databases of the halophytic community of the foredunes in the South of Central Coast of Vietnam is critical for evaluating the future impacts of climate change on foredune ecosystems and implementing effective conservation strategies.

MATERIAL AND METHODS

Study area: The South-Central Coast of Vietnam comprises eight provinces: Da Nang, Quang Nam, Quang Ngai, Binh Dinh, Phu Yen, Khanh Hoa, Ninh Thuan, and Binh Thuan (Fig. 1a, b). This study was conducted on foredune ecosystems (coastal dunes near seashores). The total of 41 study sites were established along the shoreline to assess plant taxa distribution (Fig. 1c). Global Positioning System (GPS) coordinates were recorded for each site at a local scale (Table 1). Sampling locations were selected to represent the foredunes, with monitoring sites randomly distributed at a minimum distance of 30 km from each other.

Source: Google Map 2024

Fig. 1. Surveyed zone a. Vietnam position, b. The South-Central Coast zone, c. Surveyed sites

Sampling and data analysis: Samples containing reproductive organs (flowers, fruits) and vegetative parts were collected on foredunes through five field trips. Diane Bridson and Leonard Forma's Herbarium Handbook (1999) employed drying samples and voucher preparation (Bridson and Forma 1999). The dried specimens made a checklist after identifying taxa using illustrated guides and literature (Pham 1999, Nguyen et al., 2003, 2005, Le et al., 2015, Ho et al., 2018, Hoang et al., 2020, Tran et al., 2022), and online available herbariums (VMN, DLU, K). The terms of habits are based on Henk Beentje (2010). The plant classification follows APG IV (https://www.mobot.org/mobot /research/apweb/). The figures were analyzed using Excel software, and survey map was created using Google Maps (2025).

RESULTS AND DISCUSSION

Diversity of flora: Halophytic plant identification was reported on incipient foredunes from the South-Central Coast of Vietnam after sampling had occurred comprises 195 native taxa, 64 families, and 165 genera (Fig. 2). All species were documented as belonging to Angiospermae (Table 4). The surveys of Ho et al.,.(2018) listed 96 plant species of 92 genus, 54 families of Magnoliophyta in Hong hill, a sand dune in Phan Thiet province while the other survey of Hoang et al. (2020). Quang Tri province's sand dunes, recorded a significantly higher diversity, with 311 species belonging to 226 genera, 94 families. The higher species richness observed in Quang Tri is likely due to its inland and landward sand dune ecosystems, which support greater biodiversity. In contrast, surveys conducted along the South-Central Coast focused on foredunes and sandy beaches near the shoreline, where halophytic species must adapt to extreme environmental conditions such as high salinity from seawater, salty winds, drought, loose sandy substrates, and nutrient-poor soils. These harsh conditions result in a lower number of recorded species compared to inland sand dune ecosystems.

Among the 64 plant families identified, 8 belong to Monocots (12.5%) and 56 to Eudicots (87.5%). Of the 165 genera recorded, 21 (12.73%) are Monocots, while 144 (87.27%) are Eudicots. In terms of species diversity, Monocots comprise 26 species (13.33%), whereas Eudicots account for 169 species (86.67%) (Fig. 2).

Fabaceae is the most diverse family, with the highest number of genera (20) and species (25), followed by Asteraceae (13 genera, 13 species), Malvaceae (10 genera, 12 species), and Poaceae (10 genera, 11 species), collectively representing 32.12% of total genera and 31.28% of total species (Table 2). Other families with notable richness

Table 1. Ethnobotanical and botany sites

Code	Latitude	Longitude	Localities
Vin1	11°59'20"N	109°12'45"E	Nguyen Chi Thanh Street, Cam Ranh City, Khanh Hoa Province
Vin2	12°00'27"N	109°12'30"E	Nguyen Tat Thanh Street, Cam Ranh City, Khanh Hoa Province
Vin3	12°44'16.7"N	109°22'27.2"E	Dam Mon port, Van Ninh district, Khanh Hoa province
Vin4	12°39'49"N	109°24'51"E	Dam Mon port, Van Ninh district, Khanh Hoa province
Vin5	12°05'22.1"N	109°11'41.8"E	Gac Ma Memorial Area, Cam Lam District, Khanh Hoa Province
Vin6	13°07'53.8"N	109°17'53.6"E	Nghinh Phong Tower, Tuy Hoa district, Phu Yen province
Vin7	13°34'56.7"N	109°15'54.9"E	Song Cau Town, Phu Yen Province
Vin8	13°30'28.6"N	109°17'23.7"E	Vinh Hoa, Song Cau Town, Phu Yen Province
Vin9	13°27'57.3"N	109°18'19.1"E	Tu Nham Beach, Song Cau Town, Phu Yen Province
Vin10	13°28'44.8"N	109°17'39"E	Tu Nham Beach, Song Cau Town, Phu Yen Province
Vin11	13°35'59"N	109°14'15"E	Song Cau Town, Phu Yen Province
Vin12	13°52'58"N	109°17'00"E	Quy Nhon City, Binh Dinh Province
Vin13	13°42'51"N	109°12'53"E	Science Avenue, Quy Nhon City, Binh Dinh Province
Vin14	12°33'44.5"N	109°13'54"E	Ninh Hoa Town, Khanh Hoa Province
Vin15	11°48'36"N	109°11'12"E	Binh Tien Beach, Cam Ranh City, Khanh Hoa Province
Vin16	11°45'35"N	109°12'38"E	Ninh Hai district, Ninh Thuan province
Vin17	11°48'36"N	109°11'32"E	Binh Tien Beach, Ninh Thuan Province
Vin18	10°54'57.7"N	108°17'19.2"E	Mui Ne beach, Phan Thiet city, Binh Thuan Province
Vin19	10°70'93"N	107°99'61"E	Ke Ga Beach, Tan Thanh Commune, Binh Thuan Province
Vin20	10°40'57.0"N	107°47'52.8"E	La Gi District, Binh Thuan Province
Vin21	10°56'46.4"N	108°16'02.9"E	Tien Thanh Commune, Phan Thiet City, Binh Thuan Province
Vin22	10°56'56.5"N	108°18'03.5"E	Mui Ne beach, Phan Thiet city, Binh Thuan Province
Vin23	90°61'25"N	107°66'60"E	Tan Thang Commune, Ham Tan District, Binh Thuan, Binh Thuan Province
Vin24	11°02'10.3"N	108°24'21.4"E	Tan Binh Commune, La Gi District, Binh Thuan Province
Vin25	11°03'47.8"N	108°27'26.6"E	Bac Binh district, Binh Thuan Province
Vin26	11°10'40.8"N	108°43'05.9"E	Bac Binh district, Binh Thuan Province
Vin27	11°00'32.4"N	108°21'03.7"E	Hon Rom, Phan Thiet City, Binh Thuan Province
Vin28	11°15'32.4"N	108°44'55.7"E	Phuoc The, Tuy Phong District, Binh Thuan Province
Vin29	11°22'56.6"N	108°59'43.6"E	Phuoc Dinh, Thuan Nam District, Ninh Thuan Province
Vin30	11°19'56.3"N	108°50'39.5"E	Vinh Tan, Tuy Phong District, Binh Thuan Province
Vin31	14°38'53.4"N	109°03'55.8"E	Sa Huynh, Pho Chau Commune, Duc Pho District, Quang Ngai Province
Vin32	15°14'25.0"N	108°56'23.9"E	Ba Lang An Beach, Tinh Ky Commune, Binh Son District, Quang Ngai Province
Vin33	15°11'19.3"N	108°53'41.7"E	My Khe Beach, Tinh Khe Commune, Son Tinh District, Quang Ngai Province
Vin34	15°15'47.4"N	108°53'36.1"E	Chau Tan Beach, Binh Chau Commune, Binh Son District, Quang Ngai Province
Vin35	15°37'19.6"N	108°31'40.6"E	Tinh Thuy village, Tam Thanh District, Quang Nam Province
Vin36	16°06'02.2"N	108°15'23.2"E	Hoang Sa Street, Tho Quang Ward, Son Tra District, Da Nang City
Vin37	16°08'17.2"N	108°07'23.9"E	Son Tra Peninsula, Tho Quang Ward, Son Tra District, Da Nang City
Vin38	16°06'16.4"N	108°17'58.1"E	South Beach, Son Tra Peninsula, Tho Quang Ward, Son Tra District, Da Nang City
Vin39	13°43'32.7"N	109°13'04.0"E	Science Avenue, Quy Nhon City, Binh Dinh Province
Vin40	13°01'24.2"N	109°21'53.2"E	Hiep Hoa Bac commune, Dong Hoa District, Phu Yen Province
Vin41	16°09'44.7"N	108°08'19.1"E	Van Village, Hai Van Pass, Hiep Hoa Bac District, Da Nang City

Table 2. Number of genera by family

Families	Number of genus	Percentage of genus	Number of species	Percentage of species
Fabaceae	20	12.12	25	12.82
Asteraceae	13	7.88	13	6.67
Malvaceae	10	6.06	12	6.15
Poaceae	10	6.06	11	5.64
Apocynaceae	9	5.45	9	4.62
Lamiaceae	8	4.85	8	4.10
Amaranthaceae	6	3.64	6	3.08
Euphorbiaceae	5	3.03	9	4.62
Rubiaceae	5	3.03	8	4.10
Cyperaceae	3	1.82	7	3.59
Phyllanthaceae	3	1.82	4	2.05
Annonaceae	3	1.82	3	1.54
Commelinaceae	3	1.82	3	1.54
Dipterocarpaceae	3	1.82	3	1.54
Rutaceae	3	1.82	3	1.54
Sapindaceae	3	1.82	3	1.54
Convolvulaceae	2	1.21	5	2.56
Combretaceae	2	1.21	3	1.54
Sapotaceae	2	1.21	3	1.54
Solanaceae	2	1.21	3	1.54
Aizoaceae	2	1.21	2	1.03
Capparaceae	2	1.21	2	1.03
Cucurbitaceae	2	1.21	2	1.03
Myrtaceae	2	1.21	2	1.03
Verbenaceae	2	1.21	2	1.03
Zygophyllaceae	2	1.21	2	1.03
Caryophyllaceae	1	0.61	3	1.54
Nyctaginaceae	1	0.61	2	1.03
Thymelaeaceae	1	0.61	2	1.03
Acanthaceae	1	0.61	1	0.51
Annacardiaceae	1	0.61	1	0.51
Arecaceae	1	0.61	1	0.51
Bignoliaceae	1	0.61	1	0.51
Boraginaceae	1	0.61	1	0.51
Cactaceae	1	0.61	1	0.51
Calophyllaceae	1	0.61	1	0.51
Celastraceae	1	0.61	1	0.51
Colchicaceae	1	0.61	1	0.51
Connaraceae	1	0.61	1	0.51
Ebenaceae	1	0.61	1	0.51
Ericaulaceae	1	0.61	1	0.51
Gisekiaceae	1	0.61	1	0.51
Goodeniaceae	1	0.61	1	0.51
Lecythidaceae	1	0.61	1	0.51
Linderniaceae	1	0.61	1	0.51
Melastomataceae	1	0.61	1	0.51
Molluginaceae	1	0.61	1	0.51
Moraceae	1	0.61	1	0.51
Moringaceae	1	0.61	1	0.51
Nepenthaceae	1	0.61	1	0.51
Oleaceae	1	0.61	1	0.51
Oxalidaceae	1	0.61	1	0.51
Pandanaceae	1	0.61	1	0.51
Passifloraceae	1	0.61	1	0.51
Plantaginaceae	1	0.61	1	0.51
Portulacaceae	1	0.61	1	0.51
Primulaceae	1	0.61	1	0.51
Restionaceae	1	0.61	1	0.51
Rhamnaceae	1	0.61	1	0.51
Salicaceae	1	0.61	1	0.51
Salvadoraceae	1	0.61	1	0.51
Simaroubaceae	1	0.61	1	0.51
Urticaceae	1	0.61	1	0.51
Xyridaceae	1	0.61	1	0.51
Total	165	100	195	100

include Apocynaceae, Lamiaceae, Amaranthaceae, Euphorbiaceae, Rubiaceae, Cyperaceae, and Phyllanthaceae. The ten most species-rich families contribute 55.38% of the total floristic diversity in the coastal foredunes. In contrast, 37 families within the halophytic community are represented by single genus and single species, comprising 57.8% of the total recorded families). This highlights the ecological specificity and limited distribution of many halophytic taxa in the region.

The first four families, Fabaceae, Asteraceae, Malvaceae, and Poaceae, are one of the most diversity genera and species of halophytes worldwide (Santos et al., 2016). This result also aligns with the halophytic families and genera reported in Southwest Asia, China, and Pakistan as well as global (Kefu et al., 2002, Khan and Qaiser 2006, Zhao et al., 2011, Ghazanfar et al., 2014, Santos et al., 2016). Furthermore, the dominant families are identified in this study are consistent with previous researches on coastal sand dune flora in Vietnam (Ho et al., 2018, Hoang et al., 2020, Tran et al., 2022), although some differences are noted, particularly in the presence of Capparaceae, Lauraceae, Sterculiaceae.

Amaranthaceae (including Amaranthaceae *s. str.* and Chenopodiaceae *s. str.*) is the most significant contributor to species richness worldwide and regionally of halophytes (Santos et al., 2016). It also is one of the most diverse families regarding the richness of genera and species on foredunes from the South-Central Vietnam. These results suggest that halophytic composition of the South-Central Coast's foredunes is resemble to tropical desert ecosystem (Southwest Asia, China, Pakistan and Vietnam).

Diversity of habit forms: The habit spectrum of foredune plants shows that herbs predominate and constitute 23.59% (46 species) of the recorded taxa, followed by tree (16.92%, 33 species), decumbent shrub (9.74%, 19 species), virgate shrub (8.21%, 16 species), ascending shrub (7.18%, 14

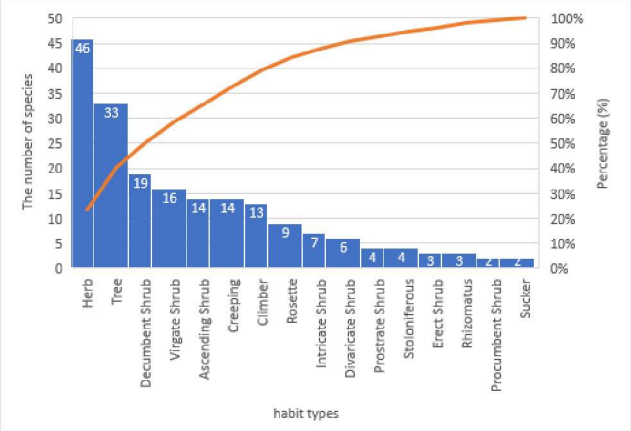

Fig. 3. The habit formed by numbers and accumulated percentage

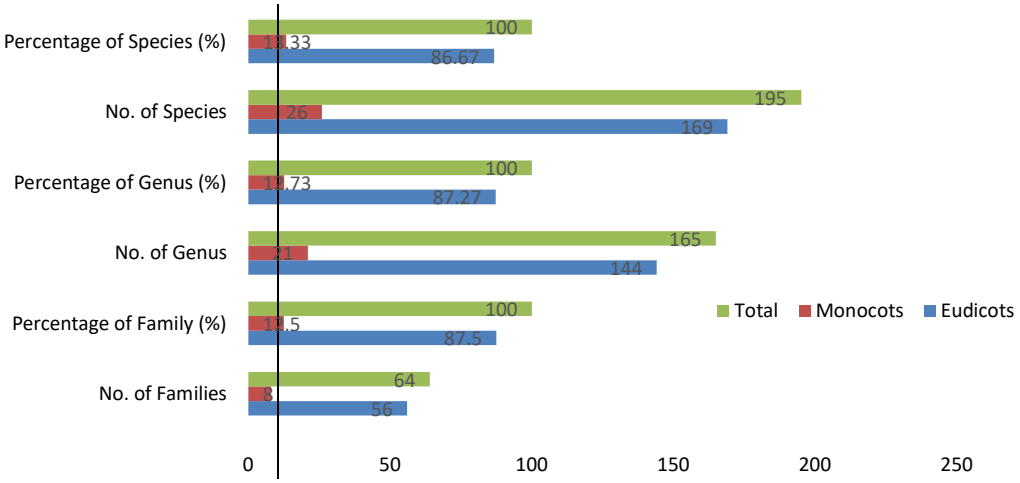

Fig. 2. Number and percentage by taxa

Fig. 4. Forms of foredunes

Table 3. Common plant and habit form on foredune type

Fore dunes	Habit forms	Common species
Incipient foredunes	Creepers, prostrate, herbs, rhizomatous, stoloniferous	*Ipomoea pes-caprae, Launaea sarmentosa, Spinifex littoreus, Vitex rotundifolia, Cyperus stoloniferus, Canavalia cathartica, Zoysia matrella*
Established foredunes	Shrubs, woody, climbers	*Canavalia cathartica, Zoysia matrella, Clerodendrum inerme, Scaevola taccada, Heliotropium foertherianum, Premna serratifolia, Severinia monophylla, Buchanania reticulata, Calophyllum inophyllum*

Table 4. Checklist of Halophytes in the south-central coast of Vietnam

Scientific names	Genus	Family	Group	Habits
Abrus precatorius L.	*Abrus*	Fabaceae	Eudicots	Climber
Abutilon indicum (L). Sweet.	*Abutilon*	Malvaceae	Eudicots	Virgate Shrub
Acalypha indica L.	*Acalypha*	Euphorbiaceae	Eudicots	Herb
Achyranthes aspera L.	*Achyranthes*	Amaranthaceae	Eudicots	Ascending Shrub
Adenanthera pavonina L.	*Adenanthera*	Fabaceae	Eudicots	Tree
Ageratum conyzoides L.	*Ageratum*	Asteraceae	Eudicots	Herb
Albizia corniculata (Lour.) Druce	*Albizia*	Fabaceae	Eudicots	Tree
Alternanthera sessilis (L.) A. DC.	*Alternanthera*	Amaranthaceae	Eudicots	Decumbent Shrub
Alysicarpus vaginalis (L.) DC.	*Alysicarpus*	Fabaceae	Eudicots	Procumbent Shrub
Amaranthus lividus L.	*Amaranthus*	Amaranthaceae	Eudicots	Herb
Antidesma cochinchinensis Gagnep.	*Antidesma*	Phyllanthaceae	Eudicots	Tree
Artabotrys sp.	*Artabotrys*	Annonaceae	Eudicots	Ascending Shrub
Arthraxon hispidus (Thunb.) Makino	*Athraxon*	Poaceae	Monocots	Rhizomatous
Atalantia buxifolia (Poir.) Oliv. ex Benth.	*Atalantia*	Rutaceae	Eudicots	Divaricate Shrub
Axonopus compressus (Sw.) Beauv.	*Axonopus*	Fabaceae	Eudicots	Rhizomatous
Azima sarmentosa (Blume) Benth. & Hook. f.	*Azima*	Salvadoraceae	Eudicots	Divaricate Shrub
Balanites roxburghii Planch.	*Balanites*	Zygophyllaceae	Eudicots	Tree
Barringtonia asiatica (L.) Kurz.	*Barringtonia*	Lecythidaceae	Eudicots	Tree
Bauhinia viridescens Desv.	*Bauhinia*	Fabaceae	Eudicots	Tree
Bidens pilosa L.	*Bidens*	Asteraceae	Eudicots	Herb
Blumea laevis (Lour.) Merr.	*Blumea*	Asteraceae	Eudicots	Decumbent Shrub
Boerhavia chinensis (L.) Rottb.	*Boerhavia*	Nyctaginaceae	Eudicots	Herb
Boerhavia diffusa L.	*Boerhavia*	Nyctaginaceae	Eudicots	Decumbent Shrub
Breynia fruticosa (L.) Hook. f.	*Breynia*	Euphorbiaceae	Eudicots	Virgate Shrub
Brucea javanica (L.) Merr.	*Brucea*	Simaroubaceae	Eudicots	Virgate Shrub
Buchanania reticulata Hance	*Buchanania*	Annacardiaceae	Eudicots	Decumbent Shrub
Cajanus scarabaeoides (L.) Thouars	*Cajanus*	Fabaceae	Eudicots	Climber
Callicarpa candicans (Burm.f.) Hchr	*Callicarpa*	Lamiaceae	Eudicots	Virgate Shrub
Calophyllum inophyllum L.	*Calophyllum*	Calophyllaceae	Eudicots	Tree
Calotis anamitica Merr.	*Calotis*	Asteraceae	Eudicots	Herb
Calotropis gigantea (L.) W.T.Aiton	*Calotropis*	Apocynaceae	Eudicots	Virgate Shrub
Canavalia cathartica Thouars	*Canavalia*	Fabaceae	Eudicots	Creeping
Canavalia rosea (Sw.) DC.	*Canavalia*	Fabaceae	Eudicots	Creeping
Capparis annamensis (Baker f.) M. Jacobs	*Capparis*	Capparaceae	Eudicots	Ascending Shrub
Catharanthus roseus (L.) G. Don	*Catharanthus*	Apocynaceae	Eudicots	Herb
Cenchrus brownii Roem. & Schult.	*Cenchrus*	Poaceae	Monocots	Herb
Centrosema pubescens Benth.	*Centrosema*	Fabaceae	Eudicots	Climber
Cerbera manghas L.	*Cerbera*	Apocynaceae	Eudicots	Tree
Christia pierrei (Schindl.) Ohashi	*Christia*	Fabaceae	Eudicots	Decumbent Shrub
Chromolaena odorata (L.) R.M.King & H.Rob.	*Chromolaena*	Asteraceae	Eudicots	Intricate Shrub
Cleome viscosa L.	*Cleome*	Capparaceae	Eudicots	Herb
Coccinia grandis (L.) Voigt	*Coccinia*	Cucurbitaceae	Eudicots	Climber
Colubrina asiatica (L.) Brongn.	*Colubrina*	Rhamnaceae	Eudicots	Ascending Shrub

Cont...

Table 4. Checklist of Halophytes in the south-central coast of Vietnam

Scientific names	Genus	Family	Group	Habits
Combretum deciduum Coll. & Hemsley	*Combretum*	Combretaceae	Eudicots	Tree
Combretum quadrangulare Kurz.	*Combretum*	Combretaceae	Eudicots	Tree
Commelina benghalensis L.	*Commelina*	Commelinaceae	Monocots	Decumbent Shrub
Connarus semidecandrus Jack	*Connarus*	Connaraceae	Eudicots	Tree
Conyza sp.	*Conyza*	Asteraceae	Eudicots	Herb
Corchorus aestuans L.	*Corchorus*	Malvaceae	Eudicots	Herb
Crotalaria anagyroides Kunth	*Crotalaria*	Fabaceae	Eudicots	Erect Shrub
Crotalaria retusa L.	*Crotalaria*	Fabaceae	Eudicots	Virgate Shrub
Croton dongnaiensis Pierre ex Gagnep.	*Croton*	Euphorbiaceae	Eudicots	Virgate Shrub
Croton hirtus L'Hér	*Croton*	Euphorbiaceae	Eudicots	Herb
Cucumis melo L.	*Cucumis*	Cucurbitaceae	Eudicots	Creeping
Cyanotis cristata (L.) D. Don	*Cyanotis*	Commelinaceae	Monocots	Rosette
Cynanchum hooperianum (Blume) Liede & Khanum	*Cynanchum*	Apocynaceae	Eudicots	Climber
Cyperus bulbosus Vahl	*Cyperus*	Cyperaceae	Monocots	Rosette
Cyperus radians Nees & Meyen ex Kunth	*Cyperus*	Cyperaceae	Monocots	Rosette
Cyperus sp2.	*Cyperus*	Cyperaceae	Monocots	Herb
Cyperus stoloniferus Retz.	*Cyperus*	Cyperaceae	Monocots	Stoloniferous
Dactyloctenium aegyptium (L.) Willd	*Dactyloctenium*	Poaceae	Monocots	Rhizomatous
Dapsilanthus disjunctus (Mast.) B.G.Briggs & L.A.S.Johnson	*Dapsilanthus*	Restionaceae	Monocots	Sucker
Decaspermum parviflorum (Lam.) A.J.Scott (Lam.) A.J.Scott	*Decaspermum*	Myrtaceae	Eudicots	Erect Shrub
Deeringia amaranthoides (Lam.) Merr.	*Deeringia*	Amaranthaceae	Eudicots	Ascending Shrub
Desmodium harmsii Schindl.	*Desmodium*	Fabaceae	Eudicots	Erect Shrub
Desmodium sp.	*Desmodium*	Fabaceae	Eudicots	Herb
Dimocarpus longan Lour.	*Dimocarpus*	Sapindaceae	Eudicots	Tree
Diospyros nhatrangensis Lecomte	*Diospyros*	Ebenaceae	Eudicots	Tree
Dodonaea viscosa Jacq.	*Dodonaea*	Sapindaceae	Eudicots	Virgate Shrub
Eclipta prostrata L.	*Eclipta*	Asteraceae	Eudicots	Herb
Epaltes australis Less.	*Epaltes*	Asteraceae	Eudicots	Creeping
Eragrostis zeylanica Nees & Meyen	*Eragrostis*	Poaceae	Monocots	Herb
Eriocaulon aff. *cinereum*	*Eriocaulon*	Ericaulaceae	Monocots	Herb
Euphorbia atoto Forst. & Forst. f.	*Euphorbia*	Euphorbiaceae	Eudicots	Decumbent Shrub
Euphorbia heterophylla L.	*Euphorbia*	Euphorbiaceae	Eudicots	Herb
Euphorbia hirta L.	*Euphorbia*	Euphorbiaceae	Eudicots	Decumbent Shrub
Euphorbia thymifolia L.	*Euphorbia*	Euphorbiaceae	Eudicots	Prostrate Shrub
Evolvulus alsinoides (L.) L.	*Evolvulus*	Convolvulaceae	Eudicots	Herb
Fimbristylis lasiophylla J. Kern	*Fimbristylis*	Cyperaceae	Monocots	Rosette
Fimbristylis sericea R. Br.	*Fimbristylis*	Cyperaceae	Monocots	Rosette
Gisekia pharnaceoides L.	*Gisekia*	Gisekiaceae	Eudicots	Creeping
Glinus oppositifolius (L.) Aug.DC.	*Glinus*	Molluginaceae	Eudicots	Decumbent Shrub
Gloriosa superba L.	*Gloriosa*	Colchicaceae	Monocots	Herb
Gmelina asiatica L.	*Gmelina*	Lamiaceae	Eudicots	Ascending Shrub
Gomphrena celosioides Mart.	*Gomphrena*	Amaranthaceae	Eudicots	Prostrate Shrub

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Table 4. Checklist of Halophytes in the south-central coast of Vietnam

Scientific names	Genus	Family	Group	Habits
Gynura lycopersicifolia DC.	*Gynura*	Asteraceae	Eudicots	Herb
Hedyotis auriculata L.	*Hedyotis*	Rubiaceae	Eudicots	Herb
Hedyotis crassifolia A. DC.	*Hedyotis*	Rubiaceae	Eudicots	Herb
Hedyotis sp.	*Hedyotis*	Rubiaceae	Eudicots	Herb
Heliotropium indicum L.	*Heliotropium*	Boraginaceae	Eudicots	Herb
Hexasepalum sarmentosum (Sw.) Delprete & J.H.Kirkbr.	*Hexasepalum*	Rubiaceae	Eudicots	Procumbent Shrub
Hibiscus tiliaceus L.	*Hibicus*	Malvaceae	Eudicots	Tree
Hopea cordata Vidal	*Hopea*	Dipterocarpaceae	Eudicots	Tree
Ichnocarpus frutescens (L.) W.T.Aiton	*Ichnocarpus*	Apocynaceae	Eudicots	Climber
Indigofera tinctoria L.	*Indigofera*	Fabaceae	Eudicots	Virgate Shrub
Ipomoea imperati (Vahl) Griseb.	*Ipomoea*	Convolvulaceae	Eudicots	Creeping
Ipomoea obscura (L.) Ker Gawl.	*Ipomoea*	Convolvulaceae	Eudicots	Climber
Ipomoea pes-caprae (L.) R. Br.	*Ipomoea*	Convolvulaceae	Eudicots	Creeping
Ipomoea pes-tigridis L.	*Ipomoea*	Convolvulaceae	Eudicots	Climber
Jasminum nervosum Lour.	*Jasminum*	Oleaceae	Eudicots	Ascending Shrub
Launaea sarmentosa (Willd.) Kuntze.	*Launaea*	Asteraceae	Eudicots	Stoloniferous
Leonotis nepetifolia (L.) R. Br.	*Leonotis*	Lamiaceae	Eudicots	Herb
Lepisanthes rubiginosa (Roxb.) Leenh	*Lepisanthes*	Sapindaceae	Eudicots	Tree
Leucaena leucocephala (Lam.) De Wit	*Leucaena*	Fabaceae	Eudicots	Tree
Leucas aspera (Willd.) Link	*Leucas*	Lamiaceae	Eudicots	Herb
Lycianthes biflora (Lour.) Bitter	*Lycianthes*	Solanaceae	Eudicots	Herb
Macroptilium atropurpureum (DC.) Urb.	*Macroptilium*	Fabaceae	Eudicots	Climber
Malvastrum coromandelianum (L.) Garcke	*Malvastrum*	Malvaceae	Eudicots	Ascending Shrub
Markhamia stipulata (Wall.) Seem. var. *pierrei* (Dop) Santisuk.	*Markhamia*	Bignoliaceae	Eudicots	Tree
Memecylon umbellatum Burm. f.	*Memecylon*	Melastomataceae	Eudicots	Ascending Shrub
Micromelum minutum (Forst.f.) Wight & Arn.	*Micromelum*	Rutaceae	Eudicots	Virgate Shrub
Microstachys chamaelea (L.) Müll. Arg.	*Microstachys*	Euphorbiaceae	Eudicots	Decumbent Shrub
Miliusa bangoiensis Ast.	*Miliusa*	Annonaceae	Eudicots	Tree
Moringa oleifera Lam.	*Moringa*	Moringaceae	Eudicots	Tree
Murdannia spectabilis (Kurz) Fade	*Murdannia*	Commelinaceae	Monocots	Rosette
Myrsine linearis (Lour.) S.	*Myrsine*	Primulaceae	Eudicots	Tree
Nepenthes mirabilis (Lour.) Druce	*Nepenthes*	Nepenthaceae	Eudicots	Herb
Ocimum basilicum L. var. *pilosum* (Willd.) Benth.	*Ocimum*	Lamiaceae	Eudicots	Herb
Oldenlandia corymbosa L.	*Oldenlandia*	Rubiaceae	Eudicots	Herb
Opuntia stricta (Haw.) Haw.	*Opuntia*	Cactaceae	Eudicots	Virgate Shrub
Oxalis barrelieri L.	*Oxalis*	Oxalidaceae	Eudicots	Herb
Pandanus odorifer (Forssk.) Kuntze	*Pandanus*	Pandanaceae	Monocots	Tree
Panicum repens L.	*Panicum*	Poaceae	Monocots	Stoloniferous
Passiflora foetida L.	*Passiflora*	Passifloraceae	Eudicots	Climber
Pennisetum alopecuroides (L.) Spreng.	*Pennisetum*	Poaceae	Monocots	Herb
Pentatropis pierrei Costantin	*Pentatropis*	Apocynaceae	Eudicots	Creeping
Phoenix humilis Royle	*Phoenix*	Arecaceae	Monocots	Rosette

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Table 4. Checklist of Halophytes in the south-central coast of Vietnam

Scientific names	Genus	Family	Group	Habits
Phragmites sp.	*Phragmites*	Poaceae	Monocots	Virgate Shrub
Phyla nodiflora (L.) Greene	*Phyla*	Verbenaceae	Eudicots	Creeping
Phyllanthus amarus Schumach. & Thonn.	*Phyllanthus*	Phyllanthaceae	Eudicots	Herb
Phyllanthus arenarius Beille in Lecomte	*Phyllanthus*	Phyllanthaceae	Eudicots	Decumbent Shrub
Pithecellobium dulce (Roxb.) Benth.	*Pithecellobium*	Fabaceae	Eudicots	Tree
Planchonella obovata (R. Br.) Pierre	*Planchonella*	Sapotaceae	Eudicots	Tree
Pleiospermium littorale (Miq.) Tanaka	*Pleiospermium*	Rutaceae	Eudicots	Intricate Shrub
Pluchea indica (L.) Less	*Pluchea*	Asteraceae	Eudicots	Intricate Shrub
Polycarpaea chungana V.T. Tran, H.T. Truong, N.V. Binh	*Polycarpaea*	Caryophyllaceae	Eudicots	Decumbent Shrub
Polycarpaea gaudichaudii Gagnep.	*Polycarpaea*	Caryophyllaceae	Eudicots	Herb
Polycarpaea vanana V.T. Tran, H.T. Truong, N.V. Binh	*Polycarpaea*	Caryophyllaceae	Eudicots	Herb
Pongamia pinnata (L.) Pierre	*Pongamia*	Fabaceae	Eudicots	Tree
Portulaca pilosa L.	*Portulaca*	Portulacaceae	Eudicots	Creeping
Pouzolzia zeylanica (L.) Benn	*Pouzolzia*	Urticaceae	Eudicots	Decumbent Shrub
Premna serratifolia L.	*Premna*	Lamiaceae	Eudicots	Intricate Shrub
Raphistemma pulchellum (Roxb.) Wall.	*Raphistemma*	Apocynaceae	Eudicots	Climber
Rhynchospora aff. *triflora*	*Rhynchospora*	Cyperaceae	Monocots	Rosette
Ruellia tuberosa L.	*Ruellia*	Acanthaceae	Eudicots	Herb
Sauropus bacciformis (L.) Airy Shaw	*Sauropus*	Phyllanthaceae	Eudicots	Decumbent Shrub
Scaevola taccada (Gaertn.) Roxb	*Scaevola*	Goodeniaceae	Eudicots	Intricate Shrub
Scleromitrion pinifolium (Wall. ex G.Don) R. J. Wang	*Scleromitrion*	Rubiaceae	Eudicots	Herb
Scolopia buxifolia Gagnep.	*Scolopia*	Salicaceae	Eudicots	Divaricate Shrub
Scoparia dulcis L.	*Scoparia*	Plantaginaceae	Eudicots	Herb
Sesuvium portulacastrum (L.) L.	*Sesuvium*	Aizoaceae	Eudicots	Creeping
Shorea falcata J. E. Vidal	*Shorea*	Dipterocarpaceae	Eudicots	Tree
Sida cordifolia L.	*Sida*	Malvaceae	Eudicots	Virgate Shrub
Sida rhombifolia L.	*Sida*	Malvaceae	Eudicots	Decumbent Shrub
Sida subcordata Span.	*Sida*	Malvaceae	Eudicots	Decumbent Shrub
Sindora siamensis Teysm. ex Miq. var. *siamensis* (Teysm. ex Miq.) Bake	*Sindora*	Fabaceae	Eudicots	Tree
Solanum americanum Mill.	*Solanum*	Solanaceae	Eudicots	Herb
Solanum torvum Sw.	*Solanum*	Solanaceae	Eudicots	Virgate Shrub
Spermacoce articularis L.f.	*Spermacoce*	Rubiaceae	Eudicots	Herb
Spermacoce setidens (Miq.) Boerl.	*Spermacoce*	Rubiaceae	Eudicots	Herb
Spinifex littoreus (Burm. f.) Merr.	*Spinifex*	Poaceae	Monocots	Stoloniferous
Stachytarpheta jamaicensis (L.) Vahl.	*Stachytarpheta*	Verbenaceae	Eudicots	Ascending Shrub
Sterculia foetida L.	*Sterculia*	Malvaceae	Eudicots	Tree
Streblus ilicifolius (S. Vidal) Corner	*Streblus*	Moraceae	Eudicots	Intricate Shrub
Streptocaulon juventas (Lour.) Merr.	*Streptocaulon*	Apocynaceae	Eudicots	Climber
Suaeda maritima (L.) Dumort.	*Suaeda*	Amaranthaceae	Eudicots	Sucker
Syzygium cumini (L.) Skeels	*Syzygium*	Myrtaceae	Eudicots	Tree
Tephrosia coccinea Wall.	*Tephrosia*	Fabaceae	Eudicots	Ascending Shrub

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Table 4. Checklist of Halophytes in the south-central coast of Vietnam

Scientific names	Genus	Family	Group	Habits
Tephrosia villosa (L.) Pers.	*Tephrosia*	Fabaceae	Eudicots	Ascending Shrub
Terminalia catappa L.	*Terminalia*	Combretaceae	Eudicots	Tree
Thespesia populnea (L.) Sol. ex Corrêa	*Thespesia*	Malvaceae	Eudicots	Tree
Torenia oblonga (Benth.) Hance	*Torenia*	Linderniaceae	Eudicots	Herb
Toxocarpus wightianus Hook. & Arn.	*Toxocarpus*	Apocynaceae	Eudicots	Climber
Trianthema portulacastrum L.	*Trianthema*	Aizoaceae	Eudicots	Decumbent Shrub
Tribulus terrestris L.	*Tribulus*	Zygophyllaceae	Eudicots	Decumbent Shrub
Tridax procumbens L.	*Tridax*	Asteraceae	Eudicots	Creeping
Tripogon aff. *thorelii*	*Tripogon*	Poaceae	Monocots	Herb
Triumfetta grandidens Hance	*Triumfetta*	Malvaceae	Eudicots	Creeping
Uvaria siamensis (Scheff.) L.L.Zhou, Y.C.F.Su & R.M.K.Saunders	*Uvaria*	Annonaceae	Eudicots	Tree
Vatica mangachapoi Blanco	*Vatica*	Dipterocarpaceae	Eudicots	Tree
Vitex rotundifolia L.f.	*Vitex*	Lamiaceae	Eudicots	Creeping
Volkameria inermis L.	*Volkameria*	Lamiaceae	Eudicots	Divaricate Shrub
Waltheria indica L.	*Waltheria*	Malvaceae	Eudicots	Virgate Shrub
Wikstroemia dolichantha Diels	*Wikstroemia*	Thymelaeaceae	Eudicots	Divaricate Shrub
Wikstroemia indica (L.) C.A. Mey. indica	*Wikstroemia*	Thymelaeaceae	Eudicots	Divaricate Shrub
Wollastonia biflora (L.) DC.	*Wollastonia*	Asteraceae	Eudicots	Ascending Shrub
Xantolis baranensis (Lecomte) P.Royen	*Xantolis*	Sapotaceae	Eudicots	Ascending Shrub
Xantolis maritima (Pierre) P. Royen	*Xantolis*	Sapotaceae	Eudicots	Decumbent Shrub
Xyris complanata R.Br.	*Xyris*	Xyridaceae	Eudicots	Rosette
Zoysia matrella (L.) Merr.	*Zoysia*	Poaceae	Monocots	Herb
Zoysia seslerioides (Balansa) Clayton & F.R.Richardson	*Zoysia*	Poaceae	Monocots	Herb

species), creeping (7.18%, 14 species), and climber (6.67%, 13 species), accounting for 79.49% (Fig. 3). Procumbent shrubs and suckers represent the least with two species per type, 1%, respectively These herbs and prostrate shrubs are predominantly distributed in sandbanks or drought foredunes near shorelines where the landscape resembles to the semi-desert in a much smaller scale (Fig. 4). These findings align closely with Ho et al. (2018) reported the most dominant growth forms in coastal dune vegetation are the herbaceous group (34.4%, 33 species), the shrubs (21.9%, 21 species) and the large trees (19.8%, 19 species). The climber plants and parasitic plants are the least contributing groups in Ho et al., 2018. In the other hand, in present study, climbing plant is ranked seventh among habit forms, while parasitic plants are absent from halophytic composition. In general, the shrub forms (decumbent shrub, virgate shrub, ascending shrub, intricate shrub, divaricate shrub, prostrate shrub, erect shrub, and procumbent shrub) comprise the most significant number of species, accounting for 71% of the shrub total.

Halophytic distribution on foredunes: The halophytic communities of coastal dunes contribute significantly to biomass production, sand surface stabilization, and dune integrity. Several halophytic species and habit forms widespread distribution and frequent occurrence across study sites (Table 3).

The incipient foredunes develop pioneer plant communities, predominantly consisting of herbaceous species, creepers, prostrate forms, rhizomatous plants, and stoloniferous species. Notably, creeping species are particularly dominant (Fig. 3) in this study. Hesp, 2002, and Martínez et al.,., 2008, observed that low-growing creepers are more diverse in tropical incipient foredunes, whereas taller grasses and sedges are more prevalent in temperate regions. This trend is evident in the South-Central Coast, *Ipomoea pes-caprae*, *Canavalia cathartica*, Apocynaceae predominant on the foredune flora. In contrast, temperate incipient foredunes are characterized by grasses and sedges such as *Ammophila arenaria*, *A. littoralis*, *Panicum* spp., *Spartina* spp., and *Sporobolus* spp. (Hesp and Walker 2013, Martínez et al., 2008). The findings of this study align with

Hesp's discussion, reaffirming the distinct vegetation patterns between tropical and temperate regions.

The established foredunes, in contrast, are predominantly composed of shrub forms, woody species, and climbers (Table 3). Some woody species, such as *Heliotropium foertherianum*, *Scaevola taccada*, *Calophyllum inophyllum*, *Guettarda speciosa*, and *Thespesia populnea*, are capable of surviving in wave-exposed zones, demonstrating their resilience to harsh coastal conditions. More stable foredunes, particularly in landward zones, support the development of taller shrubs (Fig. 4b). This landscape presents dwarf shrubs from sparse to dense vegetation in foredunes. The composition of habits indicates the distinguished vegetation between incipient dune and established foredune.

CONCLUSIONS

The halophytic composition on the foredunes of the South-Central Coast of Vietnam is characterized by high species diversity within the families Fabaceae, Asteraceae, Malvaceae, and Poaceae, followed by Apocynaceae, Lamiaceae, Amaranthaceae, Euphorbiaceae, Rubiaceae, Cyperaceae, and Phyllanthaceae. These families grow in the harsh conditions, particularly in drought and saline environments. In these extreme habitats, ecological features often limit adaptation to only a few taxa, frequently represented by a single genus and single species, emphasizing the narrow ecological amplitude and restricted distribution of many halophytic plants in the region. The habit spectrum of foredune flora reveals that herbaceous species predominate among recorded taxa. However, the shrub forms (decumbent shrub, virgate shrub, ascending shrub, intricate shrub, divaricate shrub, prostrate shrub, erect shrub, and procumbent shrub) exhibits the most diversity of the growth forms, where the stable foredunes support to develop the higher shrubs. The foredunes landscape is characterized by a gradient of vegetation structure, ranging from sparse herbaceous and prostrate forms in the shoreline to dense dwarf shrubs in landward zone. These findings suggest that the halophytic composition of foredunes in the South-Central Coast of Vietnam exhibits similarities to tropical desert regions in Southwest Asia, China, Pakistan. The composition of habits indicates the distinguished vegetation between incipient dune (creepers, prostrate, herbs, rhizomatous, stoloniferous) and established foredune (shrubs, woody, climbers). Given the ecological significance of these plant communities support further conservation efforts to mitigate the impacts of climate change and human activities on coastal biodiversity.

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