



# Flora in Truong Sa Islands, Khanh Hoa Province, Viet Nam

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**Abstract:** The flora of Truong Sa islands has a number of features of tropical island flora. The research results had recorded 265 species, belonging to 200 genera and 74 families of vascular plants, in which 146 new species were added to the flora of Truong Sa islands. Representatives of the dominant families such as Fabaceae, Poaceae, Malvaceae, Cyperaceae or Asteraceae had the most species-rich genus- *Cyperus* (8 species). The flora of Truong Sa islands had a quite even proportion of lifeforms, Phanerophytes occupied the highest proportion with only 33.58%, while Hemicryptophytes made up 23.40%, and Therophytes accounted for 21.51%. Species were distributed mainly in biotopes of island (H1) (88 species), 57 species that were divided into 2 biotopes were widely distributed. The study had counted 157 natural and naturalized species, accounting for 59.25% of the total species investigated on the islands. The flora of Truong Sa islands had typically tropical characteristics with 57.74% of the species belonging to the tropical element group. The flora had a relatively high conservation value with 39.24% of species and 66.21% of plant families listed on the IUCN Red List. There were 3 species were vulnerable (VU) in IUCN Red List 2021, 1 species was endangered (EN) and 1 species was vulnerable (VU) in Viet Nam Red Data Book 2007.

**Keywords:** Conservation, Diversity, Flora, Truong Sa islands

There were about 684,865 floating islands in the world which were located mostly in 50 countries and territories and account for about 5% of the global land area ([www.worlddata.info](http://www.worlddata.info) 2020). Although the island's biodiversity was assessed to be poorer than that of the neighboring mainland due to many different natural conditions (isolation, shape, size, topography, climate, geology, etc.), but species on islands and peninsulas had a higher degree of endemism. It was estimated that more than 20% of the world's endemic vascular plant species were found on islands (Whittaker & Fernandez Palacios 2007, Holger et al 2008, [www.biodiversity.europa.eu](http://www.biodiversity.europa.eu)). The populations of species on the island were also the most vulnerable to climate change, sea level rise, and the invasion of alien species, in which the species belonging to terrestrial ecosystems were being destroyed seriously affected. Even so, the biological world on the island still had a lot of new things for scientists to discover (Pys̆ek & Richardson 2006, Buckley and Jetz 2007). Truong Sa islands (Spratly Islands) belongs to Truong Sa district, Khanh Hoa province is a part of Viet Nam's territory, associated with the development of Viet Nam for thousands of years. The research results showed that Truong Sa islands had the highest level of biodiversity in the Asia-Pacific region (Thanh 2001, Thung et al 2014). Although research on biodiversity in Truong Sa islands started in the 20th century, the database is still limited so far. The first relatively

systematic and complete study on flora of Truong Sa islands in 1997 mainly at 4 islands, Truong Sa island (Spratly island), Nam Yet island (Namyit island), Song Tu Tay island (Southwest Cay island) and Son Ca island (Sand Cay island) had recorded 119 species of vascular plants (Khoi and Phuong 2001). Over the past two decades, there had been natural and human impacts on terrestrial ecosystems, so a comprehensive study of terrestrial flora characteristics was conducted to find solutions for conserving species and terrestrial ecosystems in the region in the context of climate change, sea level rise for 3-year from 2020 to 2022.

## MATERIAL AND METHODS

**Study area:** Truong Sa islands is located from 6°30' to 12°00' North latitude and 111°20'-117°20' East longitude. The islands had about 130 islands, shoals and sandbars, scattered in an area of about 170,000 square kilometers, with a length of about 800 kilometers from east to west and 600 kilometers from north to south (Cuong et al 2020). The area had the following meteorological and tidal characteristics: the average annual temperature was about 27.7°C, the average annual humidity was about 83%. The average wind speed was about 6 m/s, the strongest was about 34 m/s (in thunderstorms and storms), the wind usually gets strong from November to February the next year. Prevailing winds were from the southwest in summer and from the northeast in winter.

Thunderstorms and tornadoes can happen at any time of year. The average annual rainfall was about 176.0 mm, the highest rainfall was about 104.7 mm (November) and the lowest was about 0.1 mm (February and March). The islands in Truong Sa islands were strongly affected by waves. The average monthly wave height in Song Tu Tay island and Truong Sa island was 2.1 m and 1.9 m respectively. In March, April and May there are usually small waves while in January, August, and December there are usually big waves. The salinity of seawater in Truong Sa islands area was almost uniform, its variation was low. Surface seawater salinity in summer was 33.5‰, and in winter 33 - 33.5‰ (Luong et al 2016). The study was carried out on 9 floating islands of Truong Sa islands, including: Truong Sa Dong island (Central Reef ), An Bang island (Amboyna Cay ), Truong Sa island (Spratly island), Sinh Ton Dong island (Grierson Reef), Sinh Ton island (Sin Cowe island), Phan Vinh island (Pearson Reef), Son Ca island, Nam Yet island and Song Tu Tay island (Fig. 1).

**MATERIAL AND METHODS**

**Material:** Research subjects are vascular plants.

**Methods**

**Field investigation method:** 5 main survey routes with 10m wide were designed across each island: Route 1 surrounds

the outermost edge of the island, the remaining 4 routes follow 4 directions East, West, South and North, counting from the position of the island's centre until it meets Route 1. Depending on the shape and area of each island, herringbone-shaped auxiliary routes were additionally designed so that the investigated area covers all the biotopes and habitats of the species on the islands. Collecting specimens, information, and taking photos of the plant species under the study according to the research methods of Thin (2007) and Chung (2009).

**Method of data processing:** Handling and preserving the collected plant specimens according to the guidelines of Thin (2007). Identifying, assessing samples and looking up the scientific names of species by morphological comparison and expert methods on the basis of documents of Ho (2003), Ban (2003, 2005). Preserving specimens after being processed and classified at the Viet Nam - Russia Tropical Center, Ha Noi, Viet Nam. Assessing conservation value according to the IUCN Red List in 2021. Determining lifeform characteristics and geographical elements of species based on the documents of Raunkiaer (1934), Chan (1999) and Thin (2004).

**RESULTS AND DISCUSSION**

**Diversity of Plant Taxon**

**Floristic composition:** The survey results recorded 265 species of vascular plants belonging to 200 genera, 74 families, 36 orders, 5 classes and 3 phyla, in which 146 new species of higher plants were added to Truong Sa islands's flora according to the most recently published study of Khoi and Phuong (2001). Polypodiophyta, Gymnospermae and Angiospermae are the representatives of the three phyla, in which Polypodiophyta had only 1 species, accounting for 0.38% of the total species, Gymnospermae possessed 3 species (1.13%). Angiospermae dominated with 261 species (98.49%), 196 genera (98%), 70 families (94.59%), 33 orders (91.67%) from the total species, genera, families and orders recorded, respectively (Table 1). Most of the taxa of Truong

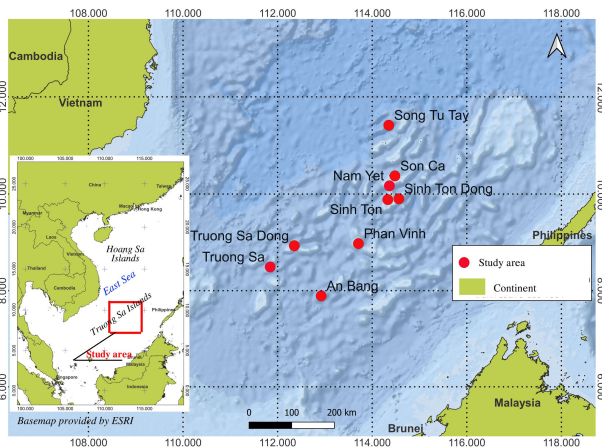


Fig. 1. Study area

Table 1. Diversity of plant taxon in Truong Sa islands

Division	Class		Order		Family		Genus		Species	
	N	N	%	N	%	N	%	N	%	
Polypodiophyta	1	1	2.78	1	1.35	1	0.50	1	0.38	
Gymnospermae	2	2	5.56	3	4.05	3	1.50	3	1.13	
Angiospermae	2	33	91.67	70	94.59	196	98.00	261	98.49	
Dicotyledones		25	69.44	55	74.32	152	76.00	199	75.09	
Monocotyledones		8	22.22	15	20.27	44	22.00	62	23.40	
Dicotyledones/Monocotyledones			3.13		3.67		3.45		3.21	
Total	5	36	100	74	100	200	100	265	100	

Sa islands's flora were distributed in Angiospermae, in which the taxonomic ranks of Dicotyledones were 3.13 to 3.67 times higher than those of Monocotyledones (Table 1). This ratio is similar to that of the inland flora of Viet Nam (3.2 to 3.8) (Chan 1999, Ho 2003). On the other hand, when assessing taxonomic diversity by the ratio between the number of species, families and genera, the results showed that the Truong Sa islands flora had a family diversity index of 265 species/74 families in proportion to the ratio of 3.58/1, or each family had 3.58 species. The genera diversity index was 265 species/200 genera, corresponding to the ratio of 1.33/1, or each genus had 1.33 species. As for the flora of Con Co island, the ratio was 2.86/1 and 1.26/1, respectively (Cam 2008). Thus, the flora in Truong Sa islands had a higher diversity index in terms of species composition than that in Con Co island.

**Diversity of plant families and genera:** The 10 most species-rich families of Truong Sa islands flora only accounted for 13.5% of the total families, they had 126 species, belonging to 86 genera, corresponding to 47.55% of the total species and 43% of the total genera recorded. Fabaceae dominated with 21 species (7.92%), Poaceae with 18 species (6.79%), Malvaceae and Cyperaceae with 15 species (5.66%) and Asteraceae with 13 species (4.91%). Some families such as Rubiaceae, Euphorbiaceae, Moraceae, Lamiaceae, Convolvulaceae had from 8 to 10 species. The 10 most species-rich genera owned 46 species, accounting for 17.36% of the total species, of which *Cyperus* had the most species with 8 species (3.02%) (Table 2). Most of the recorded families were considered to be the most species-rich ones of the flora in Viet Nam. Besides, some of the species-rich families such as Cyperaceae, Malvaceae, Convolvulaceae, and of the genera such as *Cyperus*, *Fimbristylis*, *Ipomoea* have reflected the characteristics of

the flora of Truong Sa islands and the obvious influence of geographical and geological conditions, and marine climate on the flora species composition of the islands.

**Diversity of plant life forms:** Phanerophytes (Ph) accounted for the highest percentage at 33.58% of the total species, in which the number of species are mainly Microphanerophytes (Mi) with 17.36% and Mesaphanerophytes (Me) with 9.06% (Table 3). However, the proportion of Ph group of Truong Sa islands flora was much lower than that of typical tropical flora, such as Kon Tum province's flora (65.35%) (Cuong et al 2020), Xuan Nha nature reserve (78.85%) (Hoa and Sam 2016). Instead, species belonging to the group

**Table 3.** Statistical results of plant lifeforms in Truong Sa islands

Life form	Code	No. of species	Percent
Phanerophytes	Ph	89	33.58
<i>Megaphanerophytes</i>	<i>Mg</i>		
<i>Mesaphanerophytes</i>	<i>Me</i>	24	9.06
<i>Microphanerophytes</i>	<i>Mi</i>	46	17.36
<i>Nanophanerophytes</i>	<i>Na</i>	9	3.40
<i>Epiphytes</i>	<i>Ep</i>	3	1.13
<i>Parasitaphanerophytes</i>	<i>Pp</i>		
<i>Lianophanerophytes</i>	<i>Lp</i>	5	1.89
<i>Herbacephanerophytes</i>	<i>Hp</i>	1	0.38
<i>Succulentphanerophytes</i>	<i>Sp</i>	1	0.38
Chamaephytes	Ch	29	10.94
Hemicryptophytes	Hm	62	23.40
Cryptophytes	Cr	28	10.57
Therophytes	Th	57	21.51
Total		265	100

**Table 2.** Most diverse families and genera in the flora of Truong Sa islands

Family	Genus		Species		Genus	Species	
	N	%	N	%		N	%
Fabaceae	18	9,00	21	7,92	<i>Cyperus</i>	8	3.02
Poaceae	15	7,50	18	6,79	<i>Fimbristylis</i>	6	2.26
Malvaceae	11	5,50	15	5,66	<i>Ficus</i>	6	2.26
Cyperaceae	3	1,50	15	5,66	<i>Euphorbia</i>	5	1.89
Asteraceae	12	6,00	13	4,91	<i>Ipomoea</i>	5	1.89
Rubiaceae	9	4,50	10	3,77	<i>Citrus</i>	4	1.51
Euphorbiaceae	4	2,00	9	3,40	<i>Plumeria</i>	3	1.13
Moraceae	3	1,50	9	3,40	<i>Cleome</i>	3	1.13
Lamiaceae	7	3,50	8	3,02	<i>Sida</i>	3	1.13
Convolvulaceae	4	2,00	8	3,02	<i>Syzygium</i>	3	1.13
Total	86	43	126	47.55	Total	46	17.36

Hemicryptophytes (Hm), Cryptophytes (Cr), Therophytes (Th) accounted for a relatively high proportion, from 10.57%-23.40%. The lifeform spectrum formula of the flora in Truong Sa islands was as follows:

$$SB = 33.58 Ph + 10.94 Ch + 23.40 Hm + 10.57 Cr + 21.51 Th.$$

The research results have shown the high adaptation of flora to the hot weather, hoarfrost and dry land of the Truong Sa islands.

**Immigration pattern and habitats:** The immigration pattern

of plant species recorded in Truong Sa islands can be divided into 2 main groups: (1) Group N - Natural species (from ocean currents, from wind, from birds, from humans, etc.) or Naturalized; (2) Group C - Cultivated species. As a result of the investigation, there were 157 species of group N, accounting for 59.25% and 108 species of group C accounting for 40.75% of the total 265 species of vascular plants recorded in Truong Sa islands (Table 4 and 5). The species of group N dispersed by ocean currents, wind, and

**Table 4.** Immigration pattern and habitats of vascular plants in Truong Sa islands

Division	Immigration pattern		Habitats			
	N (Natural and naturalized species)	C (Cultivated species)	H1	H2	H3	≥ 2 Habitats
Polypodiophyta	1					1
Gymnospermae		3	3			
Angiospermae	156	105	85	59	61	56
Dicotyledones	121	78	71	46	45	38
Monocotyledones	35	27	14	13	16	18
Total	157	108	88	59	61	57

H1: Natural, naturalized and cultivated species - on open place near/beside/between constructions or in the campus;

H2: Cultivated species - on the incremental garden

H3: Natural, naturalized species - on the island's edge, on open places, beach or hanging on coastal trees/shrubs

**Table 5.** The distribution patterns of species of vascular plants in Truong Sa islands

Distribution pattern	Immigration type				Total (%)
	N (Natural and naturalized species)		C (Cultivated species)		
	No. of species	Percent	No. of species	Percent	
Endemic element	3	1.13	5	1.89	3.02
Bac Bo endemic	2	0.75	1	0.38	1.13
Trung Bo endemic		0.00		0.00	0.00
Nam Bo endemic	1	0.38	1	0.38	0.75
Viet Nam endemic		0.00	3	1.13	1.13
Tropical element	103	38.87	50	18.87	57.74
Indochina endemic	10	3.77	9	3.40	7.17
Southern China endemic	0	0.00	3	1.13	1.13
Haiman, Taiwan, Phillipines element	3	1.13	2	0.75	1.89
Himalaya element		0.00		0.00	0.00
India element	14	5.28	7	2.64	7.92
Malaysia element		0.00		0.00	0.00
Indonesia Malaysia element		0.00	1	0.38	0.38
Indonesia Malaysia Ocean Australia element	3	1.13		0.00	1.13
Tropical Asia element	35	13.21	22	8.30	21.51
Palaeotropical element	24	9.06	3	1.13	10.19
Newtropical and circum tropical element	14	5.28	3	1.13	6.42
Temperate element	15	5.66	4	1.51	7.17
East Asia element	2	0.75	1	0.38	1.13
Asia element	13	4.91	3	1.13	6.04
Northern temperate element		0.00		0.00	0.00
Other elements	36	13.58	49	18.49	32.08
Wide disposing element	9	3.40	8	3.02	6.42
Midern imported and migrant element	27	10.19	41	15.47	25.66
Total	157	59.25	108	40.75	100.00

birds had characteristics including fruit with light and sticky seeds such as *Triumfetta repens*, *Sida rhombifolia*, *Bidens pilosa*, *Chromolaena odorata*, *Xenostegia tridentata*, etc. The species, which are naturalized for the purpose of landscape and protection consist of *Casuarina equisetifolia*, *Calophyllum inophyllum*, *Heliotropium arboreum*, *Coccoloba uvifera*, *Cocos nucifera*, etc. Group C was relatively diverse with species with different values which were used for ornament (*Bougainvillea spectabilis*, *Combretum indicum*), and serve as food (*Carica papaya*, *Benincasa hispida*, *Zingiber officinale*, etc.). There were 88 species of plants only found in open places, constructions or campus on the islands. Up to 59 species of plants were grown in incremental gardens, 61 species distributed on the island's edge were mainly herbaceous, shrubs, vines found in bare ground, coral sand, coastal trees or shrubs, and 57 species were widely distributed throughout the island (Table 4).

**Diversity of geographic elements:** The results of classification of geographical elements according to the classification framework of Chan (1999) have indicated that the flora of Truong Sa islands had the characteristics of tropical flora with 57.74% of the recorded species belonging to the tropical element group, in which the group of natural and naturalized species accounted for 38.87%, most concentrated in tropical Asia (13.21%). The endemic element group in Truong Sa islands accounted for 3.02%, of which endemic species with natural distribution occupied 1.13% (Table 5). In comparison with the endemic rate of the flora of Viet Nam in the mainland (11.49%) (Chan 1999), the flora of Truong Sa islands had a very low endemic rate. However, due to the different conditions in the islands, the flora was less diverse than that in the mainland, so the endemic species such as *Ruellia tuberosa*, *Acalypha lanceolata*, *Portulaca pilosa* need special attention for research and conservation in Truong Sa islands.

**Diversity of conservation value:** Although the flora of Truong Sa islands had a low species diversity, 104 species belonging to 49 families have been counted, accounting for 39.24% of the total species and 66.21% of the total families listed on the IUCN Red List (iucnredlist.org 2021-3). In which, there were 3 species at vulnerable level (VU) of IUCN 2021, 1 species at endangered level (EN) and 1 species at vulnerable level (VU) in Viet Nam Red Data Book 2007 were in urgent need of conservation actions, especially natural species on the islands, such as: *Tribulus terrestris*, *Barringtonia asiatica* and *Euphorbia atoto*.

## CONCLUSIONS

Although the flora of Truong Sa islands was not very diverse, it had the characteristics of tropical island flora. The

study recorded 265 species, belonging to 200 genera, 74 families and 3 phyla of vascular plants (ferns, gymnosperms and angiosperms). As a result, 146 species were added to the flora in the Truong Sa islands. The proportion of lifeform groups Hemicryptophytes (23.40%), Cryptophytes (10.57%), Therophytes (21.51%) was relatively high, which reflects the dry, hot character through the flora of Truong Sa islands. The flora of Truong Sa islands was relatively diverse in terms of geographical elements, the tropical element group accounted for the highest proportion with 57.74% of the total species. Two main immigration types of species were identified (N - natural and naturalized and C - cultivated). In which, the natural and naturalized species were dominance, with accounting for 59.25% of the total species. Recorded species were distributed in many different biotopes including 3 main groups: island's edges; incremental gardens: shelves or pots; and islands or constructions. There were 57 species widely distributed from the 2 groups of biotopes. The total species were listed on the IUCN Red List up to 39.24%, some of which were endangered and need to be preserved. The flora of Truong Sa islands still had many unknowns that need to be further investigated, researched and monitored for changes in the coming time, which contributes to the conservation of flora in particular, as well as the biodiversity of terrestrial ecosystem in Truong Sa islands in general.

## ACKNOWLEDGEMENT

This study was conducted within the framework of the Project: "Research on biodiversity of terrestrial ecosystems in the Truong Sa islands, proposing solutions for sustainable management, conservation and exploitation for military missions, national defense (Project code: KCB-TS-04).

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Received 12 June, 2022; Accepted 12 July, 2022