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Vascular plant resources' contribution to the Vam Ho Bird Sanctuary and surrounding areas' designation as a Natural Heritage Site

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ABSTRACT

The survey of plant diversity and vegetation in the Vam Ho Bird Sanctuary and surrounding areas (Ba Tri and Binh Dai districts, Ben Tre province) was conducted in October 2024. The study aimed to build the plant diversity basics for investing and upgrading Vam Ho to the status of a Natural Heritage site. Using transect surveys and sampling, the study recorded 179 species belonging to 55 families of vascular plants. Among them, Azima sarmentosa, Oryza rufipogon, Psilotum nudum were listed in the Vietnam Red Book (2024), Avicennia marina var. rumphiana, Phoenix paludosa, Sonneratia ovata, Ceriops decandra were on the IUCN Red List (2025). In addition, a total of 158 out of 179 recorded species have had at least one of six main use groups: medicine, food, animal/poultry feed, ornamental plants, timber/charcoal/construction materials, and household items/handicrafts. The vegetation was divided into three types: the natural habitat in Vam Ho Bird Sanctuary, the Casuarina equisetifolia coastal plantation, and the estuarine-coastal mangrove forest. The establishment of the Natural Heritage Site will create positive conditions for the activities of habitat conservation and coastal protection, which help to reduce the pressure of environmental degradation on the Ba Lai estuary in the future.

1. INTRODUCTION

An estuary mangrove forest is a unique wetland formed between freshwater and seawater ecosystems (Sackey et al., 2011). The distinctive root structures of plants such as *Avicennia* spp. and *Rhizophora* spp. presented to decrease the impact of waves and water flow, which consolidated the stabilization of platform soil and effectively prevented coastline erosion (Karimi et al., 2022; Sunkur et al., 2023). Through the fragmentation and decomposition process, the leaves of mangrove plants provide the primary materials that enter the biogeochemical cycle. In there, the diversity of species and specialised structural vegetation were important factors that determined the maintenance of genetic richness, function, and resilience of the ecosystem (Asaeda et al., 2016; Macintosh et al., 2002).

The natural forest in Ben Tre province is primarily mangrove with typical plant species such as *Rhizophora apiculata*, *Avicennia alba*, *Sonneratia alba*, *Nypa fruticans*, etc (Nguyen & Parnell, 2019; Kozhikkodan et al., 2022). The estuary mangrove forest in Vam Ho Bird Sanctuary and its surroundings, located in the Ba Tri and Binh Dai districts, are important conservation areas in the east of Ben Tre province. Despite comprising only approximately 60 hectares, Vam Ho is a substantial habitat for waterbirds in the last ecological zone of the freshwater purlieus. The water source in the

sanctuary was originally brackish. However, it has been fully desalinated due to the existence of the Ba Lai dam since 2002, affecting many ecological functions of Ba Lai flow and vegetation close to the dam (Bijeesh & Ngo, 2018; Truong et al., 2017). Meanwhile, not only is it a critical habitat for waterbird species, but the area also plays crucial roles in environmental protection and climate change mitigation, e.g., carbon sequestration, pollutant filtration, and freshwater conservation.

To establish the Vam Ho Bird Sanctuary and its surrounding areas as a provincial-rank natural heritage site, which can allow for effective performance of ecological interventions for conservation activities and sustainable development, a study of species diversity and vegetation will be fundamentally important, also serving to update the status of species composition and types of plant habitats in there.

2. MATERIALS AND METHOD

2.1. Sample collection

Using the transect random sampling method (Chen et al., 2023) the vascular plant species were collected in the study area, including Ba Tri district (Tan My, An Thuy, Bao Thanh, and Bao Thuan communes) and Binh Dai district (Loi island and Thoi Thuan communes), Ben Tre province (Fig.1). The plant specimens were in the mature stage with enough flowers and fruits. Photos of these specimens were taken by Canon 7D (lens Canon EF 55-250 mm f4-5.6 and Canon EF 100 mm f2.8 macro). The plants without flowers and fruits were detailed noted and photographed, but were not sampled. All samples were processed into the specimen and stored in the Pham-Hoang Ho Herbarium of VNU.HCM - University of Science (international code: PHH).

2.2. Identification and classification

Species identification was completed by compiling morphological features. The morphology of the specimen was compared or contrasted with the standard specimen (type) from other herbariums worldwide. An Illustrated Flora of Viet Nam (Pham, 2003), Web of Flora of China (eFloras, 2008), Flora Malesiana (multi-volume), Flora of Singapore (multi-volume), GBIF (the Global Biodiversity Information Facility), monographs, books and reviews for families and genera were used for identification and classification. The scientific name of the species was standardized according to Plants of the World Online (Kew Science). The level of conservation was searched in the Vietnam Red Book - Flora section (2007, 2024) and Web of Red List of Threatened Species (2025). Information on the risk of alien species invasion was updated in accordance with Circular No. 35/2018/TT-BTNMT of the Ministry of Natural Resources and Environment.

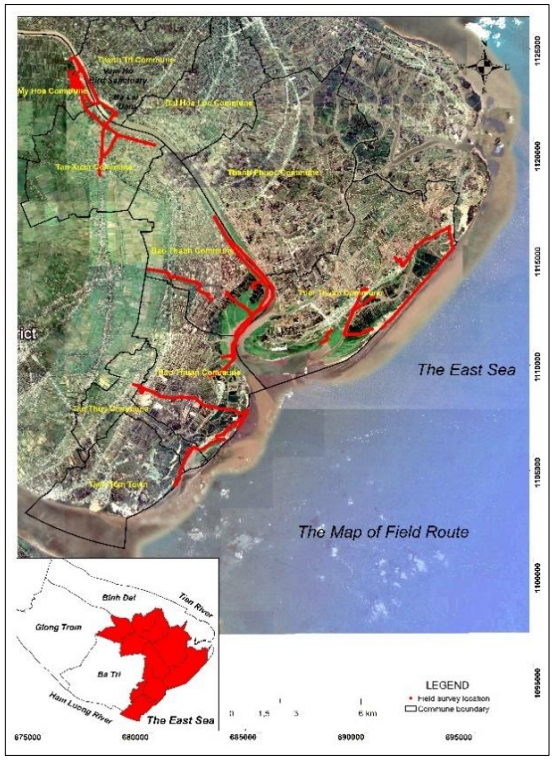

Figure 1. Survey route diagram

2.3. Establishing plant distribution map

Combining the data from Google Earth Pro and fieldwork determined the distribution of the point type of rare species in the study area. The vector data was edited and saved as a shapefile. The above steps were performed using Google Earth Pro (free) and ArcGIS version 9.0.

3. RESULTS AND DISCUSSION

3.1. Species composition

A total of 179 species belonging to 55 families were recorded in the area (Tables 1, 2, 3). In all families, Poaceae, Fabaceae, Asteraceae, and Malvaceae had the most species (Table 2). The common species of estuaries mangrove such as *Rhizophora apiculata*, *Avicennia alba*, *Avicennia marina* var. *rumphiana*, *Sonneratia caseolaris*, *Sonneratia alba*, *Excoecaria agallocha*, *Nypa fruticans*, *Phoenix paludosa*, *Lumnitzera racemosa*, *Ceriops decandra*, and

Rhizophora mucronata have also been presented in the area. Unfortunately, no individuals of the genus *Bruguiera* were recorded in the entire study area of Ba Tri and Binh Dai districts. The individuals of the genus *Xylocarpus* were quite numerous but lacked reproductive organs, so the species' name could not be determined. Some species, such as *Megathyrsus maximus*, *Cenchrus brownii*, *Cenchrus purpureus*, *Setaria parviflora*, and *Urochloa villosa*, grew quite abundantly due to local people growing them to feed cows and goats, then spreading naturally in the environment.

Table 1. Distribution of families and species within the phylum of plant species in the study area

Class	Family		Species	
	Number	%	Number	%
Polypodiopsida	5	9.1	6	3.4
Angiospermae				
Monocotyledons	9	16.4	45	25.1
Dicotyledon	41	74.5	128	71.5
Total	55	100.0	179	100.0

Table 2. Ten families with the largest number of species in the study area

Stt	Family	Number	Percent (%)
1	Poaceae	23	12.8
2	Fabaceae	18	10.0
3	Malvaceae	11	6.1
4	Asteraceae	11	6.1
5	Cyperaceae	9	5.0
6	Phyllanthaceae	8	4.4
7	Apocynaceae	6	3.3
8	Rubiaceae	6	3.3
9	Amaranthaceae	6	3.3
10	Acanthaceae	5	2.8

Notably, some species are facing endangerment such as *Azima sarmentosa* (VU), *Oryza rufipogon* (VU), and *Psilotum nudum* (VU), which belong to the Vietnam Red Book (2024). *A. marina* var. *rumphiana* (VU), *P. paludosa* (NT), *Sonneratia ovata* (NT), and *C. decandra* (NT) were the four species listed on the IUCN Red List (2025) (Figure 2). Figure 3 shows the distribution of these rare species in Vam Ho Bird Sanctuary and its surroundings. Furthermore, *Pentatropis pierrei* Costantin was an endemic species of Vietnamese flora, also present in Vam Ho Bird Sanctuary.

According to the list of invasive alien plant species in Circular 35/2018/TT-BTNMT, there were three species in the invasive alien group, including *Pontederia crassipes*, *Mimosa diplotricha*, and *Chromolaena odorata*. Additionally, *Sphagneticola trilobata*, *Leucaena leucocephala*, *Urochloa mutica,* and *Megathyrsus maximus* were the potentially invasive species.

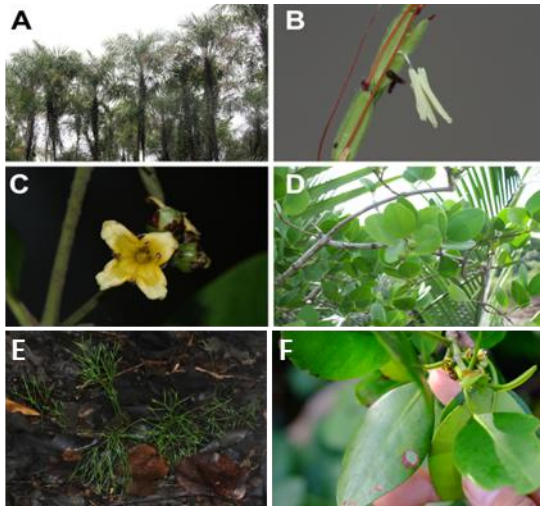

Figure 2. (A) *Phoenix paludosa,* (B) *Oryza rufipogon,* (C) *Psilotum nudum,* (D) *Ceriops decandra,* (E) *Sonneratia ovata*

3.2. Life forms

The main plant life form in the study area was herbs (98 species), accounting for 54.7% of the total number of species in the list. It is followed by the tree species (28 species), mainly the mangrove plants, accounting for 15.6% of the total number of species. There were 22 species of shrubs and small trees, accounting for 12.3% of the total. Climber species were particularly abundant in the study area (17 species), accounting for 9.4% of the total. The most species in the therophyte, phanerophyte, and hemicryptophyte categories were 61 (34.0%), 49 (27.0%), and 35 (19.5%), respectively. There were only 1 to 15 species of helophytes, aerophytes, geophytes, hydrophytes, and chamaephytes (Table 4).

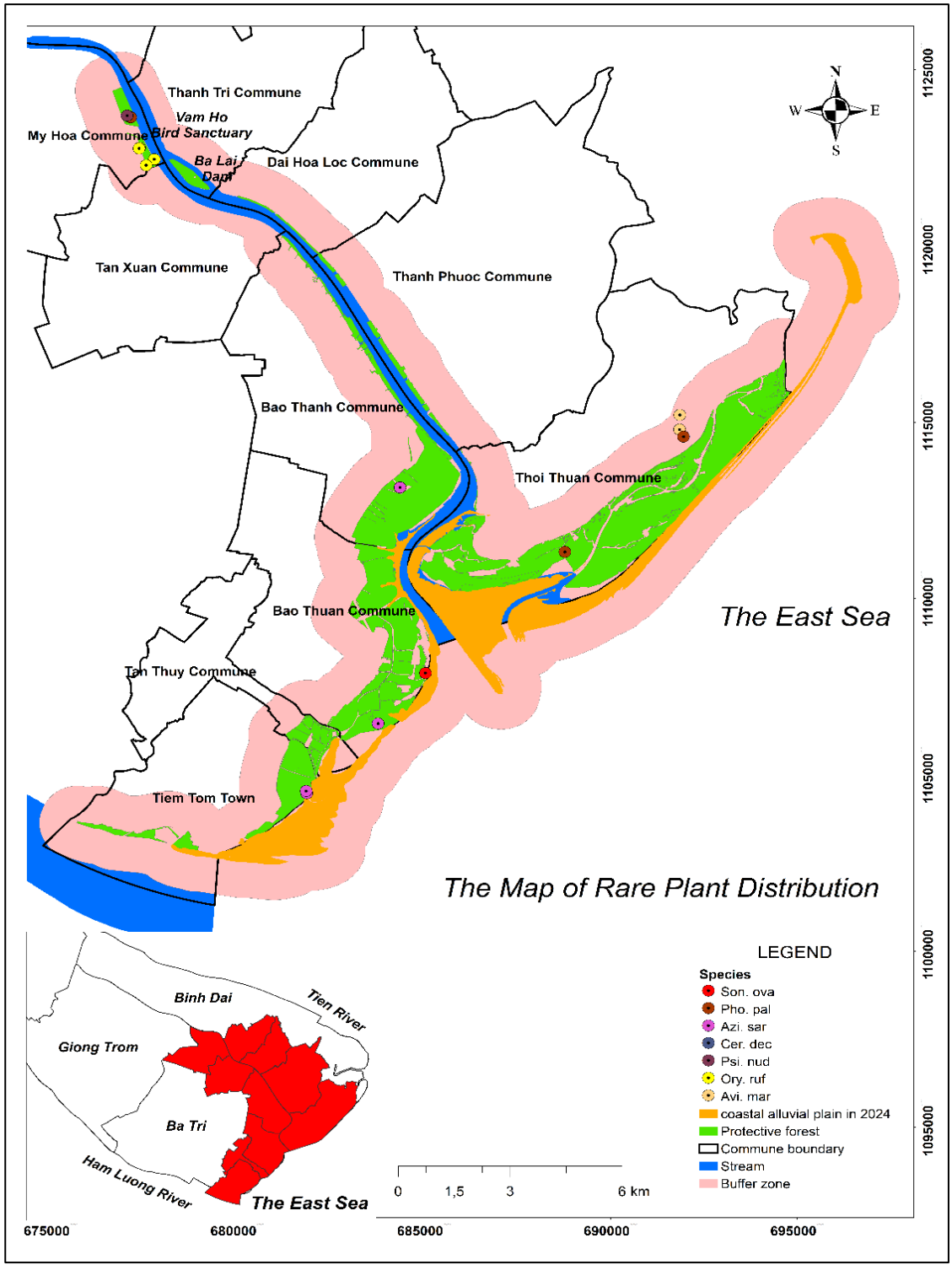

Figure 3. The rare plant spcies‘ distribution map in the study area

Note: Son. ova (Sonneratia ovata), Pho. pal (Phoenix paludosa), Azi. sar (Azima sarmentosa), Cer. dec (Ceriops decandra), Psi. nud (Psilotum nudum), Ory. ruf (Oryza rufipogon), Avi. mar (Avicennia marina var. rumphiana)

Table 3. List of present plants in the study area

Num	Scientific name	Life form	Habitats			Num	Scientific name	Life form	Habitats		
			V	B	C				V	B	C
	Acanthaceae					16	*Finlaysonia obovata* Wall.	Cli		x	x
1	*Acanthus ilicifolius* L.	S	x		x	17	*Gymnanthera oblonga* (Burm.f.) P.S. Green	Cli			x
2	*Asystasia gangetica* (L.) T. Anderson	P/H				18	*Pentatropis pierrei* Costantin	Cli	x		x
3	*Avicennia marina* var. *rumphiana* (Hallier f.) Bakh.	T			x	19	*Sarcolobus globosus* Wall.	Cli	x		
4	*Avicennia alba* Blume	T			x	20	*Vincetoxicum flexuosum* var. *tenuis* (Blume) Schneidt	Cli			x
5	*Ruellia tuberosa* L.	P/H	x		x		**Araceae**				
	Aizoaceae					21	*Aglaodorum griffithii* Schott	P/H He	x		
6	*Sesuvium portulacastrum* (L.) L.	P/H		x	x	22	*Colocasia esculenta* (L.) Schott	P/H He	x		
7	*Trianthema portulacastrum* L.	P/H			x	23	*Cryptocoryne ciliata* var. *ciliata*	P/H He	x		
	Amaranthaceae					24	*Lemna minor* L.	P/H Frf	x		
8	*Achyranthes aspera* L.	P/H		x	x	25	*Pistia stratiotes* L.	P/H Frf	x		
9	*Alternanthera paronychioides* A.St.-Hil.	P/H	x		x		**Arecaceae**				
10	*Alternanthera sessilis* (L.) DC.	P/H			x	26	*Caryota mitis* Lour.	T	x		
11	*Amaranthus viridis* L.	A/H	x			27	*Nypa fruticans* Wurmb	T He	x		x
12	*Celosia argentea* L.	A/H	x			28	*Phoenix paludosa* Roxb.	S	x		x
13	*Gomphrena celosioides* Mart.	P/H	x				**Aspleniaceae**				
	Annonaceae					29	*Stenochlaena palustris* (Burm.f.) Bedd.	Cli	x		
14	*Annona glabra* L.	St	x	x	x		**Asteraceae**				
	Apocynaceae					30	*Bidens pilosa* L.	A/H	x		
15	*Cerbera odollam* Gaertn.	T	x								

Num	Scientific name	Life form	Habitats			Num	Scientific name	Life form	Habitats		
			V	B	C				V	B	C
31	*Chromolaena odorata* (L.) R.M.King & H.Roxb.	P/H			x	46	*Cleome viscosa* L.	A/H	x		x
32	*Cyanthillium cinereum* (L.) H.Roxb.	A/H	x	x	x		**Combretaceae**				
33	*Eclipta prostrata* (L.) L.	A/H	x		x	47	*Lumnitzera racemosa* Willd.	T	x		x
34	*Launaea sarmentosa* (Willd.) Kuntze	P/H			x	48	*Terminalia catappa* L.	T			x
35	*Pluchea indica* (L.) Less.	St	x		x		**Commelinaceae**				
36	*Praxelis clematidea* R.M.King & H.Roxb.	A/H	x		x	49	*Commelina benghalensis* L.	A/H		x	x
37	*Sphagneticola trilobata* (L.) Pruski	P/H	x			50	*Commelina diffusa* Burm.f.	A/H	x		
38	*Synedrella nodiflora* (L.) Gaertn.	A/H	x	x	x	51	*Murdannia vaginata* (L.) G. Brückn.	A/H		x	
39	*Tridax procumbens* L.	P/H			x		**Convolvulaceae**				
40	*Wollastonia biflora* (L.) DC.	S		x	x	52	*Ipomoea aquatica* Forssk.	A/H		x	
	Bignoniaceae					53	*Ipomoea obscura* (L.) Ker Gawl.	P/H	x		x
41	*Dolichandrone spathacea* (L.f.) K. Schum.	T			x	54	*Ipomoea pes-caprae* (L.) R. Br.	P/H		x	x
	Boraginaceae					55	*Ipomoea pes-tigridis* L.	Cli			x
42	*Cordia subcordata* Lam.	T		x	x	56	*Ipomoea violacea* L.	P/H	x		x
	Calophyllaceae						**Cucurbitaceae**				
43	*Calophyllum inophyllum* L.	T	x			57	*Coccinia grandis* (L.) Voigt	Cli	x	x	x
	Casuarinaceae					58	*Cucumis maderaspatanus* L.	A/Cli			x
44	*Casuarina equisetifolia* L.	T		x	x	59	*Trichosanthes costata* Blume	Cli	x		
	Cleomaceae						**Cyperaceae**				
45	*Cleome rutidosperma* DC.	P/H	x			60	*Cyperus compressus* L.	A/H			x

Num	Scientific name	Life form	Habitats			Num	Scientific name	Life form	Habitats		
			V	B	C				V	B	C
61	*Cyperus distans* L.f.	P/H		x		79	*Centrosema pubescens* Benth.	Cli	x		
62	*Cyperus javanicus* Houtt.	P/H	x	x	x	80	*Derris trifoliata* Lour.	Cli	x		x
63	*Cyperus nutans* Vahl.	P/H		x		81	*Desmodium* sp.	H			x
64	*Cyperus polystachyos* Rottb.	A/H	x		x	82	*Leucaena leucocephala* (Lam.) de Wit	T	x		
65	*Cyperus stoloniferus* Retz.	P/H		x	x	83	*Mimosa diplotricha* C.Wright	P/H	x		x
66	*Fimbristylis acuminata* Vahl.	P/H		x	x	84	*Mimosa pudica* L.	P/H	x		x
67	*Fimbristylis cymosa* R.Br.	P/H			x	85	*Neptunia oleracea* Lour.	P/H Frf	x		
68	*Fimbristylis littoralis* Gaudich.	P/H	x	x	x	86	*Pithecellobium dulce* (Roxb.) Benth.	T	x		
	Dioscoreaceae					87	*Senna alata* L.	St	x		
69	*Tacca leontopetaloides* (L.) Kuntze	Tuber		x	x	88	*Senna obtusifolia* (L.) Irwin & Barneby	St			x
	Euphorbiaceae					89	*Senna siamea* (Lam.) H.S.Irwin & Barneby	T	x		
70	*Euphorbia hirta* L.	A/H	x		x	90	*Sesbania sesban* (L.) Merr.	St		x	x
71	*Euphorbia maculata* L.	A/H			x	91	*Vigna marina* (Burm.) Merr.	P/H			x
72	*Euphorbia prostrata* Aiton	A/H	x				**Flagellariaceae**				
73	*Excoecaria agallocha* L.	T	x		x	92	*Flagellaria indica* L.	Cli	x		
	Fabaceae						**Hydrocharitaceae**				
74	*Acacia mangium* Willd.	T	x			93	*Najas indica* (Willd.) Cham.	Sub			x
75	*Aeschynomene* sp.	H			x		**Lamiaceae**				
76	*Alysicarpus vaginalis* (L.) DC.	P/H		x		94	*Mesosphaerum suaveolens* Kuntze	A/H	x	x	
77	*Calopogonium mucunoides* Desv.	P/H	x			95	*Hyptis capitata* Jacq.	P/H		x	
78	*Canavalia cathartica* Thouars.	Cli	x		x	96	*Premna serratifolia* L.	St	x		x

Num	Scientific name	Life form	Habitats			Num	Scientific name	Life form	Habitats		
			V	B	C				V	B	C
97	*Volkameria inermis* L.	St		x	x	114	*Sida cordifolia* L.	P/H		x	x
	Lauraceae					115	*Thespesia populnea* (L.) Sol. ex Corrêa	T		x	x
98	*Cassytha filiformis* L.	P/H			x	116	*Urena lobata* L.	St		x	x
	Lentibulariaceae						**Meliaceae**				
99	*Utricularia aurea* Lour.	Sub	x			117	*Xylocarpus* sp.	T	x		x
	Linderniaceae						**Menispermaceae**				
100	*Bonnaya antipoda* (L.) Druce	A/H	x			118	*Nephroia orbiculata* (L.) Lian & Wei Wang	Cli			x
101	*Torenia crustacea* (L.) Cham. & Schltdl.	A/H	x	x			**Moraceae**				
102	**Loranthaceae**				x	119	*Ficus microcarpa* L.f.	T	x		
	Lythraceae					120	*Streblus asper* Lour.	St	x		
103	*Sonneratia alba* Sm.	T			x		**Muntingiaceae**				
104	*Sonneratia caseolaris* (L) Engl.	T	x		x	121	*Muntingia calabura* L.	T			x
105	*Sonneratia ovata* Backer	T			x		**Myrtaceae**				
	Malvaceae					122	*Eucalyptus* sp.	T	x		
106	*Abutilon indicum* (L.) Sweet	P/H			x		**Onagraceae**				
107	*Corchorus aestuans* L.	A/H		x	x	123	*Ludwigia hyssopifolia* (G.Don) Eell.	A/H		x	
108	*Corchorus olitorius* L.	A/H			x		**Passifloraceae**				
109	*Heritiera littoralis* Aiton	T	x		x	124	*Passiflora foetida* L.	Cli	x		x
110	*Hibiscus sabdariffa* L.	A/H		x	x		**Phyllanthaceae**				
111	*Hibiscus tiliaceus* L.	T		x	x	125	*Breynia androgyna* (L.) Chakrab. & Balakr.	St	x		
112	*Melochia corchorifolia* L.	P/H			x	126	*Bridelia stipularis* (L.) Blume	Cli/S	x		
113	*Sida acuta* Burm.f.	P/H		x	x	127	*Flueggea virosa* (Roxb. ex Willd.) Royle	St			

Num	Scientific name	Life form	Habitats			Num	Scientific name	Life form	Habitats		
			V	B	C				V	B	C
128	*Glochidion littorale* Blume	St	x			141	*Dactyloctenium aegyptium* (L.) Willd.	P/H		x	x
129	*Phyllanthus amarus* Schumach & Thonn.	A/H	x			142	*Digitaria bicornis* (Lam.) Roem. & Schult.	P/H	x	x	x
130	*Phyllanthus debilis* J.G.Klein ex Willd.	A/H		x		143	*Echinochloa colonum* (L.) Link	A/H	x		x
131	*Phyllanthus reticulatus* Poir.	S	x		x	144	*Eleusine indica* (L.) Gaertn.	P/H			x
132	*Synostemon bacciformis* (L.) G.L.Webster	P/H	x	x	x	145	*Eragrostis tenella* (L.) P.Beauv. ex Roem. & Schult.	A/H		x	x
	Piperaceae					146	*Eriochloa procera* (Retz.) C.E.Hubb.	A/H		x	
133	*Peperomia pellucida* (L.) Kunth	P/H	x			147	*Imperata cylindrica* (L.) Raeusch.	P/H			
	Plantaginaceae					148	*Leptochloa mucronata* (Mich.) Kunth	P/H	x		
134	*Scoparia dulcis* L.	A/H			x	149	*Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs	P/H	x	x	x
	Poaceae					150	*Oplismenus burmanni* (Retz.) P.Beauv.	A/H		x	
135	*Axonopus compressus* (Sw.) P.Beauv.	P/H	x			151	*Oryza rufipogon* Griff.	P/H; He	x		
136	*Cenchrus brownii* Roem. & Schult.	A/H		x	x	152	*Ottochloa nodosa* (Kunth) Dandy	P/H	x		
137	*Cenchrus purpureus* (Schumach.) Morrone	P/H	x		x	153	*Paspalum conjugatum* P.J.Bergius	P/H	x		
138	*Chloris barbata* Sw.	A/H	x		x	154	*Phragmites karka* (Retz.) Trin. ex Steud.	P/H; He	x		x
139	*Cynodon dactylon* (L.) Pers.	P/H			x	155	*Setaria parviflora* (Poir.) Kerguélen	P/H		x	x
140	*Cyrtococcum patens* (L.) A.Camus	P/H	x			156	*Urochloa mutica* (Forssk.) T.Q.Nguyen	P/H	x		x

Num	Scientific name	Life form	Habitats			Num	Scientific name	Life form	Habitats		
			V	B	C				V	B	C
157	*Urochloa villosa* (Lam.) T.Q.Nguyen	P/H	x		x	168	*Leptopetalum biflorum* (L.) Neupane & N.Wikstr.	P/H	x		x
	Polypodiaceae					169	*Morinda citrifolia* L.	St	x		x
158	*Nephrolepis falcata* (Cav.) C.Chr.	P/H	x			170	*Oldenlandia corymbosa* L.	A/H	x	x	
	Pontederiaceae					171	*Paederia foetida* L.	Cli	x		
159	*Pontederia crassipes* Mart.	P/H Frf	x			172	*Spermacoce articularis* L.f.	P/H	x		
	Psilotaceae						**Ruppiaceae**				
160	*Psilotum nudum* (L.) P.Beauv.	P/H	x			173	*Ruppia maritima* L.	Sub			x
	Pteridaceae						**Salvadoraceae**				
161	*Acrostichum aureum* L.	S	x	x	x	174	*Azima sarmentosa*	S	x	x	x
162	*Ceratopteris thalictroides* (L.) Brongn.	P/H	x				**Schizaeaceae**				
	Rhamnaceae					175	*Lygodium flexuosum* (L.) Sw.	P/H	x		
163	*Colubrina asiatica* var. *asiatica*	S		x			**Solanaceae**				
	Rhizophoraceae					176	*Physalis angulata* L.	A/H	x	x	x
164	*Ceriops decandra* (Griff.) W.Theob.	T			x		**Verbenaceae**				
165	*Rhizophora apiculata* Blume	T			x	177	*Stachytarpheta jamaicensis* (L.) Vahl	P/H	x		x
166	*Rhizophora mucronata* Poir.	T			x		**Vitaceae**				
	Rubiaceae					178	*Causonis trifolia* Mabb. & J.Wen	Cli	x		x
167	*Hedyotis uncinella* Hook. & Arn.	P/H			x	179	*Cissus triloba* (Lour.) Merr.	Cli	x		

Note: Life form consists of longevity (A = annual or biennial, P = perennial) and life form (Cli = Climber, Frf = Free floating; H = herb, S = shrub, St = Small tree, Sub= Submerged, T = tree, He= Helophyte; Habitats consist of V (Vam Ho Bird Sanctuary), B (Casuarina equisetifolia coastal plantation), and C (Ba Lai estuary coastal mangrove).

Table 4. The life forms of plant according to the growth form and Raunkiaer spectrum (1934)

	Tree	Small tree	Shrub	Liana	Herb	Free-floating plant	Submerged plant
Aerophyte	-	1	-	-	1	-	-
Chamaephyte	-	3	2	1	9	-	-
Geophyte	-	-	-	-	5	2	-
Helophyte	-	-	-	-	1	-	-
Hemicryptophyte	-	-	1	1	29	4	-
Hydrophyte	-	-	2	-	1	-	5
Phanerophyte	29	10	3	-	6	1	-
Therophyte	-	-	-	15	46	-	-

3.3. Biogeographic realm

Based on the document published by Le et al. (1999), fifteen biogeographic realms were determined to be the flora of Vam Ho Bird Sanctuary and its surroundings (Table 5) (Le et al., 1999). In these, the tropical section accounted for 60.3% of all species, notably tropical Asia (39.7%). Therefore, the flora is characteristic of the Asia tropical climate. In addition, other realms, such as Indochina, modern introductions and migrations, and East Asia, also contributed with percentages of 10.3, 8.7, and 4.8%, respectively. Nonetheless, just 2.4% presented endemic Vietnamese factors (Northern 0.8% and Southern 1.6%), which was less than the 11.49% general of the endemic Vietnamese flora (Thai, 1998).

Table 5. Some important biogeographic realm

Biogeographic realm	Percent
Tropical Asia	39.7
Neotropical and pantropical	12.7
Indochina	10.3
Modern introductions and migrations	8.7
Paleotropical	7.9
India	4.8
East Asia	4.8
Indonesia-Malaysia-Oceanic Australia	3.2
Endemic Southern	1.6
Hainan-Taiwan-Philippines	1.6
Malaysia	1.6
Southern China	1.6
Wide distribution	1.6
Endemic Northern	0.8
Indonesia-Malaysia	0.8

3.4. Usage values

At least one of the six main use groups was known for 158 out of 179 reported species, including medicine, food, animal/poultry feed, ornamental plants, timber/charcoal/construction materials, and household items/handicrafts (Table 6). Of these, 128, 86, 46, 34, 34, and 31 species were recorded for medicinal value, human food, animal/poultry feed, timber/firewood/construction materials, ornamental plants, and household items/handicrafts, respectively. This presented the abundance of plant resources in the study area, which need to be managed and exploited sustainably to support the livelihoods of local communities. Common species such as *Achyranthes aspera*, *Gomphrena celosioides*, *Cryptocoryne ciliata*, *Eclipta prostrata*, *Peperomia pellucida*, *Trichosanthes costata*, *Cyperus stoloniferus*, *Tacca leontopetaloides*, *Cassia alata*, *Sonneratia* spp., *Hibiscus* spp., *Imperata cylindrica*, *Oldenlandia corymbosa*, *Morinda citrifolia*, *Physalis angulata*, *Launaea sarmentosa* were used as medicinal herbs. Most of the species in the human food group were used as vegetables, such as *Amaranthus viridis*, *Stenochlaena palustris*, *Launaea sarmentosa*, *Pluchea indica*, *Neptunia oleracea*, *Corchorus* spp., *Passiflora foetida*, *Acrostichum aureum*, *Paederia foetida*, and *Peperomia pellucida*. The fruits of plants can be used for eating or as spices for dishes, typically *Annona glabra*, *Nypa fruticans*, *Sonneratia caseolaris*, and *Causonis trifolia*. Given the dense network of creeks in the area and the context of marine intrusion, Nypa fruticans can be a unique indigenous food source that warrants focused development and exploitation. *Nypa fructicans* has the potential to provide many valuable products such as coconut meat, coconut molasses, and especially sugar, which can achieve higher yields and sucrose content than both sugarcane and sugar beet if well managed (Giesen et al., 2007). Poaceae species are often used as livestock feed, mainly exotic species that have been grown or released into the wild, such as *Megathyrsus maximus, Cenchrus brownii, Cenchrus purpureus, Setaria parviflora,* and *Urochloa villosa*. In addition, thanks to their high

protein content, legumes have been commonly used, for example, *Canavalia cathartica* and *Leucaena leucocephala*. Moreover, *Ruppia maritima* and *Najas indica* were two seagrass species often discarded by salt farmers and shrimp pond owners. However, these two species can be completely utilised as animal feed, contributing to the effective exploitation of available resources in the area. *Rhizophora* spp. were exploited mainly to make good charcoal in addition to their timber value in construction.

Table 6. These uses values of plant resources

Uses	Number	Per. (%)
Medicine	131	73.1
Food	86	48.0
Animal/poultry feed	46	25.6
Firewood/construction	35	19.5
Ornamental	34	18.9
Household/handicrafts	21	11.7

3.5. Typical vegetation types

Three vegetation types were presented in the study area, including (1) Vam Ho Bird Sanctuary, (2) *Casuarina equisetifolia* coastal plantation, and (3) Ba Lai estuary mangrove forest.

3.5.1. Vam Ho Bird Sanctuary

The confluence of two flows from the river and the sea revealed characteristics of Vam Ho Bird Sanctuary's habitats. The vegetation was separated into two categories, cultivated forests and natural forests. The main species composition of the natural forest area (33.6 ha) was *Nypa fruticans*, *Hibiscus tiliaceus*, *Phoenix paludosa*, *Sonneratia caseolaris*, and others. Meanwhile, the planted forest (17.6 ha) included *Acacia mangium*, *Eucalyptus* sp. and *Casuarina equisetifolia*. The former vegetation of Vam Ho Bird Sanctuary was a mangrove forest on highland with limited tidal flooding, where *Phoenix paludosa* was the dominant species. Currently, this habitat has also been found in some areas of the core zone. *P. paludosa* has grown around 7 meters in height interspersed with *Hibiscus tiliaceus* in the area. Occasionally, a small number of individuals of *Heritiera tiliaceus* with a large base diameter (approximately 25 cm) grew scattered in the area. A few *Dolichandrone spathacea* were also recorded there. Furthermore, *Rhizophora apiculata* was planted in some places. The trees grew densely up to 12 m high. Understory plants were the species *Flagellaria indica, Chromolaena odorata, Phragmites karka*, and *Acanthus ilicifolius*. The riverside area had S*onneratia caseolaris* and *Nypa fruticans* mixed with a few *Avicennia alba* and *Cerbera odollam*. The roadsides and trails in the area were characterized by disturbed land with the presence of weeds such as *Chromolaena odorata*, *Megathyrsus maximus, Urochloa villosa,* and *Praxelis clematidea*. The study specifically recorded the population of *Oryza rufipogon*, a rare species of freshwater wetland in the Viet Nam Red Book (2024), which grew abundantly along the canal bank. On the Ba Lai River, adjacent to the planted forest, *Oryza rufipogon* also flourished on a floating raft of *Pontederia crassipes*.

The Loi islet was separated from Thanh Tri commune of Binh Dai district after the construction of the Ba Lai dam in 2002. Currently, this area is a small islet with the upper-dominated vegetation including *Avicennia alba* and *Sonneratia caseolaris*. The trees were quite tall, approximately 12-15m. Nypa fruticans and Hibiscus tiliaceus dominated the understory plants. This area has had the main road across Ba Lai dam, so the weeds that were distributed along the road were especially abundant and diverse, such as *Chromolaena odorata*, *Setaria parviflora*, *Megathyrsus maximus*, and *Mimosa diplotricha*.

3.5.2. Casuarina equisetifolia coastal plantation

The area of woodland inside a clam-farming mudflat in An Thuy village was planted and dominated by *Casuarina equisetifolia*. The high-dense planting of *Casuarina* led to decreasing light density under the canopy. There was the presence of some small trees, such as *Terminalia catappa* and *Annona glabra*, under this canopy. The grasses and herbs, including *Commelina benghalensis*, *Sida acuta*, *Mesosphaerum suaveolens*, *Sesuvium portulacastrum*, and *Achyranthes aspera* were grown under the canopy of these trees. A carpet of *Ipomoea pes-caprae* with sporadic patches of grasses predominated nearly entirely in the sand beach inside of the mudflat. Some shrubs and herbs such as *Pluchea indica*, *Commelina diffusa*, *Launaea sarmentosa*, *Desmodium* sp., and *Sesbania sesban* dominated along the *Casuarina* woodland route. They were perennial plants that lived persistently and adapted well to frequently disturbed environments.

3.5.3. Estuarine and coastal mangrove forests

According to Phung and Chau (1987), in estuaries with small flows in the dry season and high salinity such as the Ba Lai estuary, the salt-tolerant species were dominant with *Sonneratia alba* growing on the

outside facing the sea mixed with *Avicennia alba*, creating populations up to 10 m in height, scattered with *Bruguiera parviflora*, *Rhizophora mucronata*, and *Xylocarpus* sp. on the formed forest floor directly behind the mudflats. *Excoecaria agallocha*, *Thespesia populnea*, and *Lumnitzera racemosa* were dominated in the high ground inside (Phung & Chau, 1987). Currently, the estuary and coastal mangrove forests in the Ba Lai estuary area have significantly changed compared to the description more than 30 years ago. The Ba Lai estuary area has spread out with the mudflat planted *Sonneratia caseolaris* and *Avicennia alba*, mixed with a few individuals of *Sonneratia alba*. They were newly planted, about 5 years old, and approximately 3-4 m in height. A narrow band of riverine mangroves (ranging in thickness from 10 to 30 meters) adjoins this mudflat, mostly composed of *Avicennia* spp. and *S. caseolaris*. The predominant tree groupings along the countless large and small creeks were also *Avicennia* spp., *R. apiculata*, and *S. caseolaris*. Behind this strip of mangrove trees along the creeks were quite large ponds, probably used for aquaculture. The mangrove forests along the creeks in Thoi Thuan commune were thicker and dominated by *Avicennia* spp., *S. alba*, and *S. caseolaris*. In particular, the wonderful forest in Thoi Thuan commune, with the advantage of *Avicennia alba* mixed with *S. alba*, *Lumnitzera racemosa*, and *Ceriops decandra*, can be a good tourist destination to learn about the mangrove forests of the area.

3.6. Threats to vegetation

3.6.1. Ba Lai Dam and natural habitats along Bird Sanctuary and surrounding areas

The Ba Lai Dam has shown a concerning influence in addition to preventing salinity, preserving freshwater, and enhancing natural soil in the northern part of Ben Tre province. According to these reports of environmental and social impact assessments conducted along the Ba Lai River between 2006 and the present, the vegetation along the river has gradually altered and the upstream flow has been substantially silted (Tran et al., 2022; Veettil et al., 2019). A significant volume of upstream freshwater that carried alluvium downstream has been trapped by the dam. The silt buildup would eventually cause the flow to constrict. Furthermore, because of its proximity to Ba Lai Dam, the mangrove forest at Vam Ho Bird Sanctuary and the adjacent areas would be directly impacted if the freshwater is not discharged efficiently due to changes in soil and water characteristics. Long-term changes in the ecosystem functions of the Bird Sanctuary would unavoidably result from the deterioration of plant community structure, even at the habitat level. In the meantime, this region has an effective protective function for the surrounding areas.

3.6.2. Deforestation to make aquaculture ponds

Due to the advantage of being in a coastal area, aquaculture has also quickly developed, accelerating the conversion of large areas of mangroves into ponds. As a result of the loss of natural forests, biodiversity, and important ecosystem functions could decline or be lost. After the conversion, the land would become degraded, less fertile, or unsuitable for the regeneration of native plant species. This could be a good opportunity for invasive alien species to be introduced, grow, and displace native populations. Furthermore, leftover food, antibiotic residues, medication residues, and agricultural waste could pollute water sources when released into the environment. This has been harmful to aquatic plants and could prevent them from growing normally. Not only that, the deforestation has increased greenhouse gas emissions, interfered with the cycles of water and nutrients, and lost its capacity to control the temperature.

3.7. Vam Ho Bird Sanctuary and surrounding areas as a Natural Heritage Site

As mentioned above, Vam Ho Bird Sanctuary and the surrounding areas are important wetlands and natural habitats for many valuable aquatic species. These vegetations reduce the impact of waves, currents and riverbank and coastal erosion thanks to the special root systems of plants such as *Avicennia* spp., *Sonneratia* spp., *Rhizophora* spp.. The leaves of mangrove trees are a primary material source, through fragmentation and decomposition, providing nutrients that enter the aquatic ecosystem. This process has formed a characteristic habitat for many endemic and rare species in the area.

Climate change is becoming increasingly evident and severe in the coastal areas of Ben Tre province. Coastal mudflats and mangrove forests are buffer zones that help mitigate the harmful effects of climate change. The mangrove forests stretching from Binh Dai to Thanh Phu are of great significance in protecting coastal residents from storms. Designating these areas as conservation areas for natural heritage will ensure the

sustainability of the ecosystem and the safety of people living near the sea.

Evidently, Vam Ho Bird Sanctuary and the surrounding areas have had the unique natural landscape of estuarine and coastal mangrove forests and have been home to many rare species. These habitats have played an important role in maintaining ecosystem balance, protecting the environment and providing natural ecosystem services. Therefore, Vam Ho Bird Sanctuary and the surrounding areas will meet the criteria to become a provincial natural heritage site. Not interfering with local people's production activities, maintaining the existing forest area and planting more forests on the muddy plains will be a long-term conservation and development strategy for the area.

4. CONCLUSION

The study recorded and collected specimens of 179 species belonging to 55 families. Of these, the Vietnam Red Book (2024) listed *Oryza rufipogon*, *Psilotum nudum* and *Azima sarmentosa* as Vulnerable (VU). *Phoenix paludosa*, *Sonneratia ovata*, *Ceriops decandra* were assessed as Near Threatened (NT) and *Avicennia marina* var. *rumphiana* was in the Vulnerable (VU) status in the IUCN Red List (2025). The flora here was a typical vegetation of the subtropical-tropical geographical region in Asia-Pacific and the contribution from many other regions such as tropical and subtropical of Old World, Australia, Africa, Indian subcontinent-ocean. In addition, a total of 158 out of 179 recorded species has been used for at least one of six main use groups, medicine, food, animal/poultry feed, ornamental plants, timber/ charcoal/ construction materials, and household items/ handicrafts. In general, three typical habitats were found including Vam Ho Bird Sanctuary, *Casuarina equisetifolia* coastal plantation, and estuarine-coastal mangrove forests. The Bird Sanctuary and its environs were located at the end zone of the downstream, provided a haven for aquatic resources, and effectively protected the Ba Lai estuary mangrove forest region. The establishment of the Natural Heritage Site would create positive conditions for the activities of habitat conservation (including waterbird) and coastal protection, which help to reduce the pressure of environmental degradation for the Ba Lai estuary in the near future.

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CONFLICT OF INTEREST

The authors declared that they had no conflicts of interest.

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