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CLASSIFICATION AND MAPPING OF LANDSCAPE OF TRUONG SA ISLANDS, VIETNAM AT THE SCALE OF 1:250 000

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Аннотация: Marine landscapes study is a new direction of modern geography, formed and developed in Western countries and Russia and other countries. In Vietnam, research on marine landscapes is still very limited. On the basis of clarifying the concept, applying remote sensing — GIS and complex field methods, a classification system has been established and a landscape map of the Truong Sa Islands has been drawn at a scale of 1:250 000. The study area includes 1 system, 1 sub-system, 4 classes, 7 sub-classes and 20 landscape types. The highest diversity is the marine landscapes, with 3 classes, 6 sub-classes and 19 landscape types. The island landscape class only includes 1 landscape type of tropical island vegetation. The offshore shallow marine landscape class (0–200 m) covers a small area but is differentiated, consisting of 2 classes (50 % of the total classes) and 9 types (45 % of the total types). The landscape of tropical islands is strongly changed in both solid vegetation cover and hydrological regime, in which many entities have soil cover, and a mixed vegetation of both continental and island flora. The landscape of the offshore shallow sea, especially 100 m uppermost layer, is mainly composed of corals and other reef organism groups. The landscape structures of the Truong Sa Islands represent not only the characteristics of their constituent components but also the dynamics of the landscape, especially in the marine domain.

Keywords: Marine landscape, Truong Sa Islands, corals, landscape classification, reef biodiversity.

Introduction

Marine landscape study is considered a brand-new direction of modern geography [Arzamastsev, Preobrazhenskii, 1990; Preobrazhensky, Zharikov, Dubeikovsky, 2000]. The differences between marine and terrestrial landscapes are mostly due to the lack of surface substrate on the seafloor and distinct biological nutritional characteristics of marine flora compared to the terrestrial domain [Arzamastsev, Preobrazhenskii, 1990]. Polynov (1956) represented the marine landscape as a complex body of landscape constituents and connections, including heat, wave dynamics, circulations, icebergs, coral reefs, islands and islets, flora and fauna in the surface water layer. Berg L. S. proposed the concept of «mershaft» as an equivalent to «underwater landscape» [Berg, 1945]. One of the most conceptual comprehensive classifications for submerged landscape which identically comparable to the terrestrial domain had been proposed by Milkov F. N. (1966), in which the marine landscape was classified into two classes: the tidal zone and shallow sea (up to the depth of 200 m on the continental shelf).

In Europe and North America, the marine landscape has been a research issue for quite a long time. As defined in the Oxford English Dictionary, a «seascape» is a picture of sea scenes or with a view toward the sea. Later, the definition had been expanded for the littoral and the adjacents of the open water [Hill et al., 2001]. Roff and Taylor assumed the aforementioned definition could be applied to the water column and the seafloor, by using temperature, bathymetry, light attenuation and steepness [Laffoley et al., 2000; Roff, Taylor, 2000]. Golding and his colleagues issued the concept of «marine landscape»

as a representative stage buffer between seas and environments in a given area that endures a homogeneous setting of physical and ecological conditions, thus providing a reasonable measurement for anthropogenic activities, including fishery. Such activities require a conservation act which is in sync with the relative sensitivity of seafloor substrate disturbances, and the fluctuation/mixing of water column features.

Landscape and marine landscape study in Vietnam occurs later than in the world. Nguyen Ngoc Khanh et al [Nguyen Ngoc Khanh, Nguyen Cao Huan, Pham Hoang Hai, 1996] introduced a landscape classification for Vietnam territory at the scale of 1:1 000 000 (including both terrestrial and marine domains), of which the marine landscape consists of 2 sub-systems: marine landscape under influences of a cold winter and complicated, diverse biomes (i), and under influences of warm, humid climate (ii). Another landscape classification system for the sea and islands of Vietnam was proposed by Nguyen Thanh Long et al [Nguyen Thanh Long, Nguyen Van Vinh, 2012] mentioned the rule set and methodology, which resulted in 1 system, 2 classes, 5 sub-classes and 56 kinds of landscapes. Tran Anh Tuan studied the marine landscape of the Truong Sa Islands and presented a 5-level landscape classification system for mapping at the scale of 1:1 000 000 [Tran Anh Tuan, 2013]. Dang Thi Ngoc et al [Dang Thi Ngoc et al., 2020] suggested a classification system for the littoral zone of Quang Ngai province on the central coast of Vietnam, using featured climate conditions and marine biome as a basis to determine typology, and ecological characteristics as criteria for marine landscape classification. A high resolution study of the marine landscape of Cat Ba Islands on the northern coast of Vietnam was conducted by authors from the Institute of Pacific Geography, Russian Academy of Science represented a 4 split-level landscape units, including (i) outcrop landscape on upper slopes, 0.5–1 m, up to 4 m of depth; (ii) non-classified coarse sediment, 0.7–2 m of depth, 15–30 m of width; (iii) coral reefs, 1.5–2.5 m of depth, 20–30 m of width; and (iv) soft muddy, 4.5–6.5 m of depth [Lebedev et al., 2019].

In general, studies on the marine landscape, particularly on the pelagic zone and islands of Vietnam are still restricted due to the inconvenience in accessibility to such study sites, and the lack of research means and equipment. This study aims to clarify the concept of marine landscape, the establishment of the classification system and its application to marine landscape mapping for the Truong Sa Islands region at a scale of 1:250 000. The outcomes can be served as basis for further planning, administration and utilisation of marine — island resources in the remote region of Truong Sa Islands.

Materials and methods

Dataset

In this study, we collected several available maps of the Truong Sa Islands region, including nautical charts scaled at 1:250 000 established by the Vietnamese People Navy; a set of maps on geology, seafloor substrate, geomorphology, and hydrography. On the field of ecology, we established a biome classification map on the major featured communities. Other datasets were provided by Project KCB-TS.03 funded by the Vietnam Ministry of Defense. Field surveys at the study sites were taken in 2020–2022 (Sept.–Oct. 2020; Apr.–May 2021; Oct.–Nov. 2021, and Apr.–May 2022) by the scientists from the Vietnam–Russia Tropical Center, VN-MOD and the Institute of Marine Geology and Geophysics, VAST.

Study methods

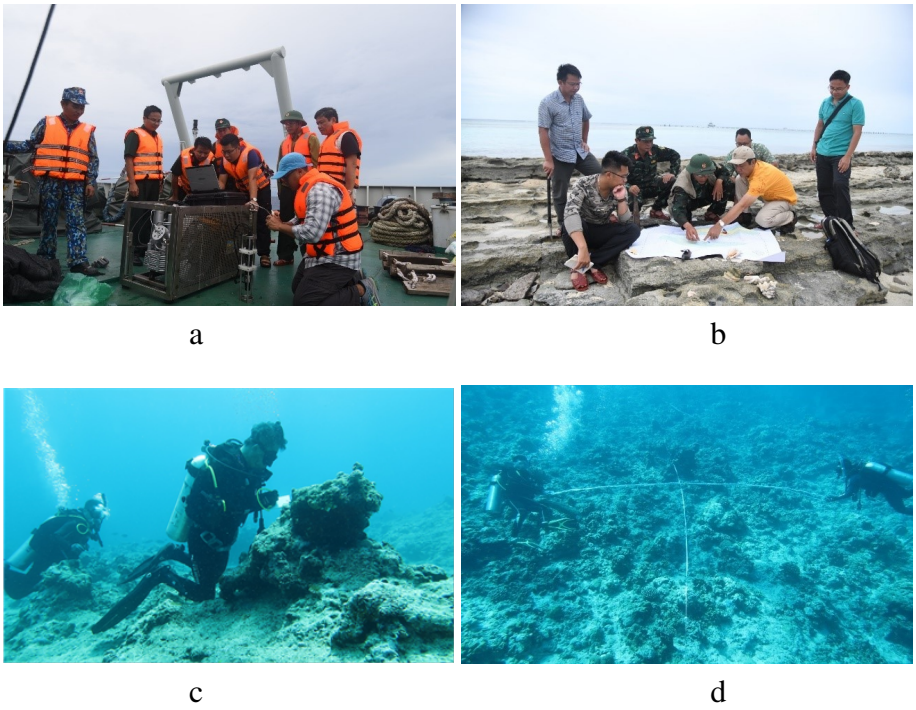
Field survey and data processing: during field surveys at the study sites on the Truong Sa Islands, dataset on physical components, literature, and thematic maps of physical settings and resources, environment, and socio-economic conditions were collected. Survey also included questionnaire to local forces and residents to gather information on the management and monitoring of surface ships activities

(both domestic and foreign nation forces), fisheries, environmental protection and other specific actions; data acquisition for water and environmental parameters; and for other research goals follow the marine science program KCB-TS funded by VN-MOD.

Due to the complicated environment in the study area, we implemented a series of field survey methods for both subaerial and subaqueous domains to measure, describe, collect samples along transects and quadrats. Survey routes were predesigned using nautical charts, islands, cays and reefs distribution sketches and land cover maps (for subaerial islands/cays). 4 surveys were conducted from 2020 to 2022 (Sept.–Oct. 2020; Apr.–May 2021; Oct.–Nov. 2021, and Apr.–May 2022) to gather data:

(i) on subaerial islands/cays: physical morphology, geological and petrological characteristics; nearshore hydrographic conditions; soil structures and compositions; describe vegetation and substrate covers; and collect samples of surface sediment, and fauna/flora communities;

(ii) on the shallow water: the use of scuba diving and snorkelling methods. Standard scuba diving team includes 2–3 divers who observe from -3m to -40m depth to measure and determine benthic substrate compositions, morphology, sediments and major population of the habitats.



a b

c d

Fig. 1. Field of survey: a — measurement of hydrographic factors; b — survey of solid soil structure; c — scuba diving describing the shallow marine landscape; d — survey of topography, bottom base and biomes according to sample plots
(photo: Nguyen Thien Tao, Nguyen Dang Hoi, 2021)

Snorkelling was performed in the shallow water from 0–10 m to specify general seabed morphology, sediments, and typical organism populations (corals, fishes or seagrasses) with theirs extension along across-reef transects (or perpendicular to the reef limit). In each study site, the number and position of survey locations/transects were described in detail on satellite imagery and on-site after pilot observation. In each survey location, we implemented 4 transects of 25 m each and 15m intervals. Transect survey was performed using an underwater camera to take 25 photos of 0.5 × 0.5 m for each transect. Species taxonomy was directly performed during dives, and after dives using on-site photos. The extent and dominant type of benthic habitat/substrate, including coral and seagrass, were determined using image analysis.

Remote sensing, GIS and cartography: in this study, we used thematic maps to represent physical components of the marine landscape, as well as the contents and results of the study. The thematic maps on physical settings include geology, geomorphology, seabed substrate, oceanography and habitat distribution of the Truong Sa Islands region. Remote sensed imagery was very-high resolution images acquired by the Pleiades-1A/B system during 2019–2020 provided by Airbus Intelligence Agency, with one 2 m resolution multispectral band of RGB-NIR and one 0.45 m resolution of panchromatic band were used for benthic habitat classification, establishment and correction of geomorphic map, and vegetation cover — benthic substrate mapping on the shallow water domain (up to 30 m). Software was used for implementing image and terrain analysis, feature mapping and editing, including GEObject-based image analysis — image classification using ArcGIS Desktop v10.8/eCognition Developer v9, and MapInfo 15 for map establishment. This software allows users to perform multiple works including data layering, geospatial management and analysis, and other cartographic tasks in order to produce a synthetic landscape map at the scale of 1:250 000. The result was displayed as marine landscape units combining data from oceanography, seabed geomorphology, topology, substrate and major groups of organisms.

Results and Discussion

The concept of marine landscape: the definition of marine landscape is diverse and no unified method for classification is available so far. As one of the first nations with a long history of marine landscape study, the standard at the state level for marine landscape mapping is not yet available. In terms of interest, there are differences among subjects, such as geomorphologists' issues on the terrain morphologies and sedimentation, whereas biologists organise marine landscape according to benthic habitat extents. Zhivago A. V. (1951) suggested a definition of marine landscape as «Marine landscape is a part of the seabed or ocean floor and adjacent water border, in which the detail, correlated and physio-dependent complex of the benthic mosaic is being observed with the relevant geologic setting, chemical physics features, water column characteristics and organism forms».

The concept of marine landscapes was developed by Roff and Taylor (2000) in their study on the Canadian waters as well as Laffoley et al. in the United Kingdom [Nguyen Thanh Long, Nguyen Van Vinh, 2012; Preobrazhensky, Zharikov, Dubeikovsky, 2000]. Roff and Taylor assumed the concept of marine landscape could be applied to water bodies and the seafloor, where seafloor landscape represents the medium extension between sea domains and environments with homogeneous physical and ecological conditions [Golding, Vincent, Connor, 2004]. The concept of marine landscape was adapted for the relevant scheme in the UKSeaM maps and MESH projects to illustrate the marine environment with corresponding seafloor and water column. Technological advantages, including Geographic Information System and remote sensing, has been a significant advance toward marine ecology study, exclusively marine landscape and the littoral zone.

Consequently, there are various definitions of marine landscape globally, in which some authors distinguish the marine landscape with the incorporation of the water column and seafloor landscapes. This depends either on the expertise of the scientists or their research methodologies. In a recent study on marine landscape classification and mapping for the Nam Yet Island reef of Truong Sa Islands, scaled at 1:10 000, Nguyen Dang Hoi et al (2022) examined the marine landscape as a physical synthesis body of both the water column and the solid soil on the seafloor, or «The marine landscape is a complex, homogenous in origin and development dynamics, but heterogeneous in terms of geological settings and seabed substrates, morphology, climatic-hydrographic type, organism community in a harmonious connection between hydrographic-biological condition and the coast in the shallow water, and between the water column and seabed substrates and its typical organism community in the deep water» [Nguyen Dang Hoi et al., 2022].

The landscape classification of the Truong Sa Islands

Principles for the classification system: the landscape of the Truong Sa Islands was determined according to prescribed principles as follows:

a/ Morphogenetic: each landscape unit is classified on the basis of feature similarity, including the homogeneity of morphology, physical structure, and homology. The morphology is classified using the distribution pattern of the surface substrate.

b/ Relative homogeneity: landscape should be homogeneous and diverse. The homogeneity of the landscape is defined by a set of criteria which represents the interaction among landscape components, whereas the internal diversity could be used for further classification into lower rank units, or finer scale.

c/ Superior element: applies for internal classification of each rank. While the superior element explains the fundamental division of units of the same level, its implementation must be flexible to avoid infringing on the generalisation and subjectivity of the classification process.

Criteria and classification system: landscape taxonomy of the Truong Sa Islands — including cay, reef and bathymetric-based marine landscape. Those aforementioned landscapes are differentiated due to constituent components. On a scale of 1:250 000, the landscape classification system of the study area includes 5 taxons: System, Sub-system, Class, Sub-class, and Type of landscape (Table 1).

Table 1

Landscape taxonomy and classification criteria for the region of Truong Sa Islands (applied to map scaled at 1:250 000)

No.	Taxonomy	Classification criteria		Landscape alias
		Marine landscape	Island/cay landscape	
1	System	Solar irradiation/Insolation and thermal regimes of atmospheric circulation on the sea/ocean		Marine tropical monsoon landscape
2	Sub-system	The synergy of tropical monsoon circulations and sea surface determines the distribution pattern of annual thermal-humidity		Oceanic tropical monsoon landscape (immune to terrestrial influences)
3	Class	Featured by the seabed morphology and water column via erosion-sedimentation	Featured by the islands/cays morphology (either natural or anthropogenic) via abrasion/erosion - deposition	4 classes: - Pelagic island/cay - Epipelagic (photic zone) - Bathypelagic - Abyssalpelagic
4	Sub-class	attenuation due to depth and physical characteristics of the water column	Differentiation of exogenetic processes on the low elevation surfaces and their marine features	7 sub-classes: - Pelagic island/cay - Upper Epipelagic (0–100 m) - Lower Epipelagic (100–200 m) - Mesopelagic (200–1000 m) - Upper Bathypelagic (1000–2000 m) - Lower Bathypelagic (2000–4000 m) - Abyssalpelagic (4000 + m)
5	Type	Featured organism groups (communities) of a given thermal — salinity regime	Featured land covers of quantified marine bioclimate	21 types

Description of Landscape taxons of Truong Sa Islands

Landscape classification system: the landscape map of the Truong Sa Islands, scaled at 1:250 000 (Fig. 2, 3) was synthesized using the aforementioned principles, classification criteria and overlapping component thematic maps (geological map, geomorphological map, ocean salinity map, ocean temperature map, and distribution map of major organism groups). The landscape classification system of the study area includes 5 taxons (ranks) of 1 system, 1 sub-system, 4 classes, 7 sub-classes and 21 types of landscape. The map legend does not show the system and sub-system ranks as they entirely cover the study area.

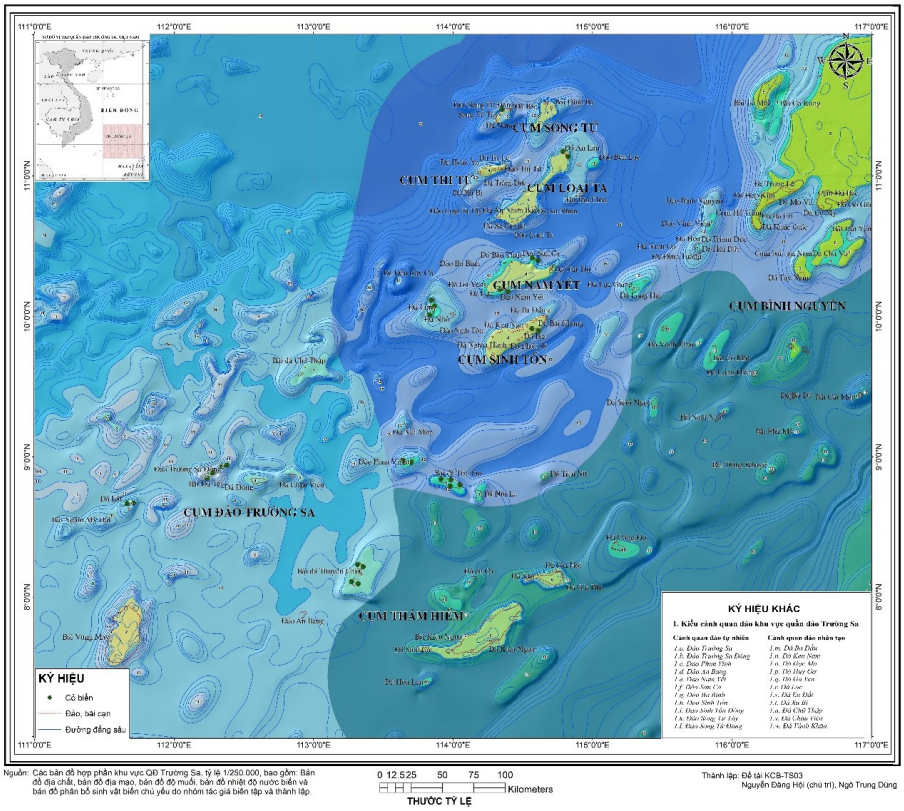


Fig. 2. The landscape map of the Truong Sa Islands, Vietnam at the scale of 1:250 000

Classes and sub-classes of landscape:

The landscape of the Truong Sa Islands is divided into 4 classes of pelagic island/cay (1 class) and marine landscape (3 classes). The morphology of island/cay (both artificial and native features) is homogeneous in terms of morphodynamics, with similar geomorphological processes: abrasion, erosion — deposition, hence the island/cay landscape class is not diversified and has only one sub-class of pelagic island/cay which covers all original cays and artificial islands.

The marine landscape is differentiated into 6 sub-classes and 19 types, according to light attenuation determined by water depth and physical characteristics. The class of bathypelagic landscape (200–4000 m) is the most diverse one with 3 sub-classes, and 9 types (type ID = 2–10), whereas abyssalpelagic landscape has only 1 sub-classes of 2 types (ID = 19, 20).

Types of landscape in the Truong Sa Islands region:

The sub-class of island/cay landscape includes 1 type which represents the tropical island vegetation landscape on both artificial islands and original cays. The Upper Epipelagic subclass (0–100 m) consists of 6 types that differ in open ocean habitat and sheltered lagoons with different oceanographic conditions.

Class	Type / Sub-class	Climate condition - Annual temperature: 27oC (28,2 oC and 26,8oC in the summer and winter respectively). Rainfall of 1800-2000mm annually.	Oceanography conditions Sea surface temperature/salinity: 27,27oC/ 33,50‰ and 27oC/ 33,25‰ in the summer and winter respectively			Oceanography conditions Sea surface temperature/salinity: 28oC/ 33,75‰ and 27,5oC/ 33,25‰ in the summer and winter respectively			Oceanography conditions Sea surface temperature/ salinity: 27,5oC/34‰ and 27,25oC/ 33‰ in the summer and winter respectively		
		Island/cay tropical vegetation cover	Corals, reef fishes and seagrasses of the sheltered lagoon	Corals, reef fishes and seagrasses of the open ocean	Deep-sea organism groups (over -200m)	Corals, reef fishes and seagrasses of the sheltered lagoon	Corals, reef fishes and seagrasses of the open ocean	Deep-sea organism groups (over -200m)	Corals, reef fishes and seagrasses of the sheltered lagoon	Corals, reef fishes and seagrasses of the open ocean	Deep-sea organism groups (over -200m)
Island	Island	1									
Epipelagic	Upper Epipelagic (0-100m)		2	3		4	5		6	7	
	Lower Epipelagic (100-200 m)			8			9			10	
Bathypelagic	Mesopelagic zone (200-1000m)				11			12			13
	Upper Bathypelagic (1000-2000m)				14			15			16
	Upper Bathypelagic landscape (2.000 – 4.000m)				17			18			
Abyssalpelagic	Abyssalpelagic (>4000 m)				19			20			

Fig. 3. Legend of the landscape map of the Truong Sa Islands, Vietnam, scaled at 1:250 000

The division of major organism groups is due to the thermal — salinity regimes, hence the sub-class of Upper Epipelagic is characterized by the combination of 3 organism groups of corals, fish and seagrass of the open ocean with corresponding types of 8, 9, and 10. Type 8 landscape distributes on the continental slope and continental rise to the west of the Dangerous Ground mini-plate (DGM), type 9 on the deep-water plains and coral reef topped seamounts of Sinh Ton — Co Rong (Sin Cowe/Union Bank — Reed Bank/ST-CR) area, and type 10 lies on the depression plain of Tham Hiem — Trang Khuyet (Investigator Shoal — Half Moon Shoal/ TH-TK) area.

The sub-class of the mesopelagic zone (200–1000 m) includes 3 types of landscape (type ID = 11–13) on the western part of the DGM, and on the ST-CR and TH-TK areas. The sub-class of upper Bathypelagic (1000–2000 m) includes 3 types of landscape (type ID = 14–15). The sub-class of Upper Bathypelagic landscape (2000–4000 m) consists of landscape types 17 and 18 on the continental slope and rise to the west of the DG miniplate, seamounts and deep-water basin of ST-CR area.

The abyssalpelagic subclass is subdivided into 2 types, 19 and 20, according to the criterion of a large group of organisms, differentiated according to the criteria of the thermal-salinity regime between the surface layer (depth up to –200 m) and underground.Therefore, both 19 and 20 types of landscape units refer to the major organism groups of a depth greater than –200 m but distribute on the continental slope and rise to the west of the DGM (type 19), and on the ST-CR area.

Structural characteristics of landscape units:

In the region of the Truong Sa Islands, the class and sub-class of island/cay landscape consists of all the subaerial features of native cays/vegetated cays (Truong Sa/Spratly Island, Truong Sa Dong/Central London Reef, Phan Vinh/Pearson Reef, An Bang/Amboyna Cay, Nam Yet/Namyit Island, Ba Binh/Itu Aba Island, Sinh Ton/Sin Cowe Island, Sinh Ton Dong/Grierson Reef, Loai Ta/Loaita Island,...) and artificial islands (Xu Bi/Subi Reef, Gac Ma/Johnson South Reef, Len Dao/Lansdowne Reef, Chữ Thập/Fiery Cross Reef, Ga Ven/Gaven Reef...). Native cays and vegetated cays are characterized by the original formation and processes under the influences of the tropical monsoon climate of the oceanic Vietnam East Sea via wave actions and tropical cyclones and have been modified recently due to anthropogenic

activities. At the time of the study, the soil layer of cay/vegetated cay was either autochthonous and was altered alongside construction installations onto surface substrates, or allochthonous from exogenous material, such as manufactured soil from the mainland to improve self-sufficient capability of local communities. Current land covers of such features are the mixture of flora communities including both indigenous and exogenous species (migrated from the mainland), such as *Barringtonia asiatica*, *Calophyllum inophyllum*, *Coccoloba unifera*), *Casuarina equisetifolia*, *Heliotropium foertherianum*, *Terminalia catappa*, *Morinda citrifolia*, *Cocos nucifera*, *Scaevola taccada*, and constructions (buildings, concrete roads, and structures for specific purposes) (Fig. 4a). Artificial islands are reclaimed areas, composed from dredged reefal material exploited on nearby reefs and lagoons. Land covers of artificial islands are constructions (civil and military structures) and exogenous flora communities (Fig. 4b).

a b

Fig. 4. Class of island/cay landscape on the Truong Sa Islands, Vietnam:
a — mixture of specific purpose structure with indigeneous and exogeneous plants on the Song Tu Tay (Southwest Cay) of the Song Tu (North Danger) Reef;
b — military-grade structure and exogeneous plants on the artificial Huy Go (Hughes) Island of the Sinh Ton (Union) Bank
(photo: Nguyen Dang Hoi)

The marine landscape of the Truong Sa Islands is divided into 6 sub-classes and 19 types. The subclass of Upper Epipelagic landscape refers to the topmost 100 m layer of the water column, consisting of 6 types of the open ocean and the sheltered lagoon. Marine landscape types 2 and 3 represent the organism communities of the open ocean and the sheltered lagoon, with similar thermal-salinity conditions: mean value of surface temperature in the summer and winter are 27,27 °C and 27 °C, respectively; surface salinity in summer and winter are 33,5 ‰ and 33,25 ‰, respectively.

The major organism groups of the marine landscape of the Truong Sa Islands are corals and seagrasses, of which are dominated by coral species belonging to Acroporidae and Faviidae, relatively diverse and entirely distributed on the shallow peaks of seamounts rising from the slope and rise of DGM. Marine landscape types 4 and 5 distribute on the peak of seamounts rising from the deep-water plain of ST-CR area, in the topmost water layer where thermal and salinity conditions are 28 °C, 33,75 ‰, and 27,5 °C, 33,25 ‰, respectively. Coral communities consist mostly of reef-building species such as *Acropora plumosa*, *A. bifurcata*, *A. divaricata*, *A. subglabra*, *A. echinata*, *A. granulosa,...*, with extraordinary diversity, whereas seagrasses (*Thalassia hemprichii*, *Halophila ovalis...)* are common in shallow waters up to 10 m. These identical marine landscapes are common on the reefs of Nam Yet — Sinh Ton (Tizard Bank — Union Bank) cluster (Fig. 5a, 5b). Reef platforms in this sub-class are characterized by exposed dead coral skeletons with coralgal coatings, reefal microbial crusts and a few shelled mollusk communities (Strombidae, Conidae, Tridacnidae). Crown-of-thorns (Acanthasters) is seldom distributed across the reef, and commonly observed on the reef of Song Tu Tay (Northwest) Cay (Fig. 5c).

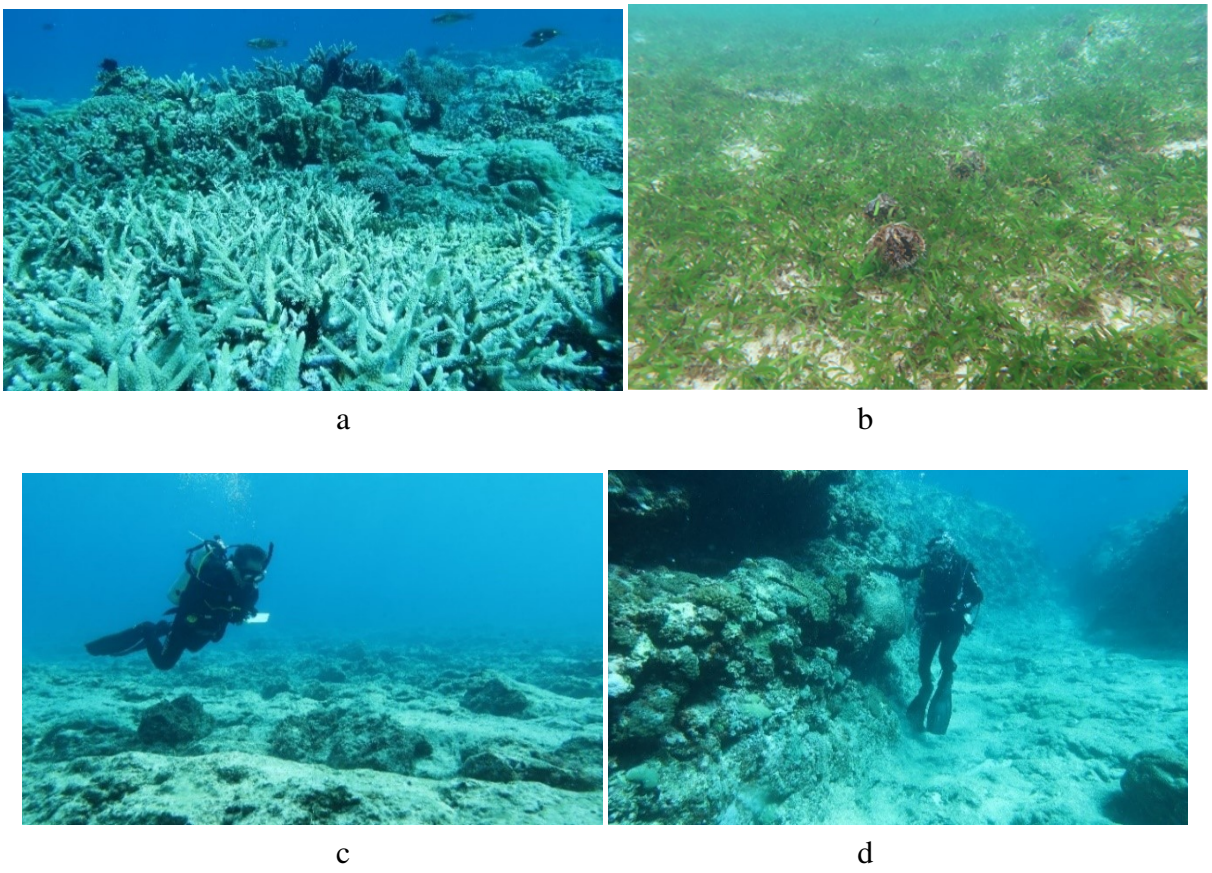


Fig. 5. Upper Epipelagic (0–100m depth) landscapes of the Truong Sa Islands, Vietnam:
a — coral communities on the reef front of the Sinh Ton (Sin Cowe) Island reef, Sinh Ton (Union) Bank;
b — seagrass meadows on the Nam Yet (Namyit) Island reef, Nam Yet (Tizard) Bank;
c — coral platform sculptured by parallel, shallow grooves on the Song Tu Tay (Northwest) Cay reef, Song Tu (North Danger) Reef; d — 2.5–3 m grooves of the Toc Tan (Alison) Reef
(photo: Nguyen Dang Hoi)

Spurs and grooves (SaGs) formation of various sizes and depths appear on the open ocean side of shallow reefs (such as Truong Sa (Spratly) Island, Sinh Ton (Sin Cowe) Island, Da Lon (Discovery Great) Reef, Toc Tan (Alison) Reef), vary from 1–4 m of width, less than 1m to approx. 6 m of height (Fig. 5d). SaGs tend to appear on the north-northwest side of reefs, implying the influence of predominance of wind-wave hydrodynamic in the study area.

Circulation and thermal-salinity regimes of the Truong Sa Islands region fluctuate in seasonal pattern and show minor difference in the deep-water domain. These suggest the indifference in dominance of organism groups for the marine landscape beneath –200 m, particularly in the domain greater than 1000 m depth. Representative organisms of these landscapes are large, widely dispersed fish of families Scombridae, Lutianidae, and Acanthuridae, along with reptiles of the family Chelonioidea and mammals of the Delphinidae.

the sub-class of abyssalpelagic landscape (deeper than –4000m) includes 2 types: the topmost layer of type 19 landscape is characterized by large organism groups, and seasonal thermal — salinity mean values in summer and winter are 28 °C, 33,75 ‰ and 27,5 °C, 33,25 ‰ respectively, and cover over 25,445 km^2.

Table 2

Main features of landscapes of the Truong Sa Islands

Class of landscape	Sub-class of landscape	Type of landscape			Area (ha)
		Climate/oceanography conditions	Featured organism communities	ID	
Island	Pelagic island/cay	Annual temperature: 27,25 °C (28,2 °C and 26,8 °C in summer and winter, respectively). Rainfall of 1800–2000 mm annually.	Island/cay tropical vegetation cover	1	3 067
Epipelagic	(Upper Epipelagic (0–100 m)	Sea surface temperature/salinity: 27,27 °C/33,50 ‰ and 27 °C/33,25 ‰ in summer and winter, respectively	Corals, reef fishes and seagrasses of the sheltered lagoon	2	95 374
			Corals, reef fishes and seagrasses of the open ocean	3	3 478
		Sea surface temperature/salinity: 28 °C/33,75 ‰ and 27,5 °C/33,25 ‰ in summer and winter, respectively	Corals, reef fishes and seagrasses of the sheltered lagoon	4	267 098
			Corals, reef fishes and seagrasses of the open ocean	5	796 771
		Sea surface temperature/ salinity: 27,5 °C/34 ‰ and 27,25 °C/33 ‰ in summer and winter, respectively	Corals, reef fishes and seagrasses of the sheltered lagoon	6	161 915
			Corals, reef fishes and seagrasses of the open ocean	7	7 923
	Lower Epipelagic (100–200 m)	Sea surface temperature/ salinity: 27,27 °C/33,50 ‰ and 27 °C/33,25 ‰ in summer and winter, respectively	Deep-sea organism groups (over -200m)	8	176 431
		Sea surface temperature/salinity: 28 °C/33,75 ‰ and 27,5 °C/33,25 ‰ in summer and winter, respectively	As above	9	322 262
		Sea surface temperature/ salinity: 27,5 °C/34 ‰ and 27,25 °C/33 ‰ in summer and winter, respectively	As above	10	192 932
	Mesopelagic (200–1000 m)	Sea surface temperature and salinity: 27,25 °C/33,5 ‰ and 27 °C/33,25 ‰ in summer and winter, respectively	As above	11	721 017
		Sea surface temperature/ salinity: 28 °C/33,75 ‰ and 27,5 °C/33,25 ‰ in summer and winter, respectively	As above	12	1 149 211
		Sea surface temperature/ salinity: 28 °C/33,75 ‰ and 27,5 °C/33,25 ‰ in summer and winter, respectively	As above	13	1 651 937

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Class of landscape	Sub-class of landscape	Type of landscape			Area (ha)
		Climate/oceanography conditions	Featured organism communities	ID	
Bathypelagic	Upper Bathypelagic (1000–2000 m)	Sea surface temperature/ salinity: 27,25 °C/33,5 ‰ and 27 °C/33,25 ‰ in summer and winter, respectively	As above	14	6 751 687
		Sea surface temperature/ salinity: 28 °C/33,75 ‰ and 27,5 °C/33,25 ‰ in summer and winter, respectively	As above	15	3 127 637
		Sea surface temperature/ salinity: 27,5 °C/34 ‰ and 27,25 °C/33 ‰ in summer and winter, respectively	As above	16	8 981 889
	Bathypelagic (2000–4000 m)	Sea surface temperature/ salinity: 27,25 °C/33,5 ‰ and 27,25 °C/33,25 ‰ in summer and winter , respectively	As above	17	4 246 715
		Sea surface temperature/ salinity: 28 C/33,75 ‰ and 27,5 °C/33,25 ‰ in summer and winter, respectively	As above	18	4 318 219
Abyssalpelagic	Abyssalpelgic (4000+ m)	Sea surface temperature/ salinity: 27,25 °C/33,5 ‰ and 27 °C/33,25 ‰ in summer and winter, respectively	As above	19	2 544 513
		Sea surface temperature/ salinity: 28 °C/33,75 ‰ and 27,5 °C/33,25 ‰ in summer and winter, respectively	As above	20	1 129 264

Significance of landscape research in the Truong Sa Islands region

the significance of landscape study on the sea and island domains of the Truong Sa Islands is expressed in both theoretical and practical manners. Essentially, the definition of characteristics, diversification and structure of marine landscape contributes to the theoretical basis of the formation, development and evolution of the landscape in a given region. The motivation rules of the shallow water landscape and island/cay landscape of the Truong Sa Islands are inseparable from socio-economical rules, including the marine spatial planning and development strategy of Khanh Hoa province, as well as the national offshore territorial administration.

The definition of characteristics, classification of physical collective components, and physical — artificial synthetical bodies following an hierarchical rank could be used as a basis for spatial planning in terms of resource management and environmental preservation. The class of Epipelagic landscape, particularly the topmost sub-class of Upper Epipelagic marine landscape includes the typical coral reef and seagrass meadow ecosystem of the Truong Sa Islands region, with extraordinary biodiversity which is indigenous and valuable (in both ecological and economical senses). Consequently, the administration, exploitation, as well as preservation and improvement of biotic resources, should be revised under the landscape view in general and multiscalar approaches. The preservation of native and pristine landscape units, alongside with restoration of degraded landscapes should include the protection of marine creatures, marine ecosystems and biodiversity to contribute to marine resource administration and environmental protection of the Truong Sa Islands and neighbouring territories of central and southern parts of the Vietnam East Sea.

The study of features and dynamics of marine landscapes in the context of climate change provides a practical solution for regional administration. This could be used as a scientific basis for stakeholders (e. g. the government of Khanh Hoa province, Vietnam People Navy) to propose policies, directions for spatial use, establish monitor — manage — manoeuvre solutions for the Truong Sa Islands

region, including military units and affiliates, in terms of economic development, strengthen resource management, environmental preservation and national defense fortification. For each given condition of the Truong Sa Islands, these aforementioned headlines should be included in the establishment of sea-island defensive warfare, as well as treatments for non-traditional security issues such as maritime security and safety, biodiversity preservation, search-and-rescue mission, and sea-borne pollution events.

Conclusion

The marine landscape is complex, homogenous in origin and development dynamics, but heterogeneous in terms of geological settings and seabed substrates, morphology, climatic-hydrographic type, organism community in a harmonious connection between hydrographic-biological condition and the coast in the shallow water, and between the water column and seabed substrates and its typical organism community in the deep water.

In this study, we established a synthetical classification system and applied it to the marine landscape map of the Truong Sa Islands region, scaled at 1:250 000 with 5 hierarchical ranks. Each rank has a corresponding criteria collection which is feasible to its classified features and components which make the marine landscape. Therefore, the marine landscape of the Truong Sa Islands region includes 1 system, 1 sub-system, 4 classes, 7 sub-classes and 20 types of landscape.

The marine landscape of the area under study is divided into 3 classes, 6 sub-classes and 19 types of landscape. The island/cay landscape is unified with only one type of tropical island vegetation landscape. Despite the emergence of a limited area, the shallow water landscape (Epipelagic class) is differentiated and variant, including 2 classes and 9 types (45 % of the total amount of types) of the marine landscape.

The island/cay landscape is remarkably altered, with many features (soil, vegetation) blended between maritime and terrestrial components. The topmost sub-class of the Upper Epipelagic landscape is featured by corals and reef creatures, as well as seagrasses and mollusks on the sand flats and/or coral flats. The structure of the marine landscape of the Truong Sa Islands is illustrated by the landscape components characteristics, with an obvious seasonal dynamic of the pelagic sea which is freed from mainland geohydrodynamic influences.

The study on the landscape of the Truong Sa Islands provides theoretical and practical understanding and contributes to the scientific basis of the formation, development and evolution of the marine landscape. The outcomes of the marine landscape study could be applied to policy development, resource management, environmental preservation, as well as strengthening national defense, creating a regional sea-island defensive warfare and solving other non-traditional security issues.

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КЛАССИФИКАЦИЯ И КАРТИРОВАНИЕ ЛАНДШАФТА ОСТРОВОВ ЧЫОНГ ША (ВЬЕТНАМ) В МАСШТАБЕ 1:250 000

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Abstract: Изучение морских ландшафтов — новое направление современной географии, сформировавшееся и развивающееся в странах Запада, в России и других странах. Во Вьетнаме исследования морских ландшафтов всё ещё очень ограничены. На основе концепции применения дистанционного зондирования — ГИС и комплексных полевых методов была создана система классификации и составлена ландшафтная карта островов Чыонг Ша в масштабе 1:250 000. Исследуемая территория включает 1 систему, 1 подсистему, 4 класса, 7 подклассов и 20 типов ландшафта, на которой морские ландшафты отличаются большим разнообразием: 3 класса, 6 подклассов и 19 типов ландшафтов. Класс островного ландшафта включает только 1 ландшафтный тип тропической островной растительности. Морской мелководный ландшафтный класс (0–200 м) занимает небольшую площадь, но дифференцирован и состоит из двух классов (50 % от общего числа классов) и девяти типов (45 % от общего числа типов). Ландшафт тропических островов сильно изменён как сплошным растительным покровом, так и гидрологическим режимом, при котором многие образования имеют почвенный покров, смешанный с растительностью материковой и островной флоры. Ландшафты прибрежного мелководья, особенно ландшафты в диапазоне глубин 0–100 м, в основном состоят из кораллов и других групп рифовых организмов. Ландшафтные структуры островов Чыонг Ша отражают не только характеристики составляющих их компонентов, но и динамику ландшафта, особенно морского.

Ключевые слова: морской ландшафт, острова Чыонг Ша, основная группа организмов, классификация, кораллы.

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