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The seahills and seahills ecosystems in the nearshore of Thua Thien-Hue Province (Central Vietnam)

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ABSTRACT

At the seabed in the nearshore, Vietnam has sandbars, shoals, bedrock knobs, rock reefs, and other landforms with elevations a few to several tens of meters higher than the seabed, which is always under the lowest astronomical tide (chart datum) and material structure of diverse compositions such as sands, gravel, boulders, blocks, etc. They have determined and warned on the chart map for the safety of navigation and the navy. These areas are significant fishing grounds due to abundant fish, shrimp, and benthic organisms. However, until now, investigation, research, and knowledge regarding these landforms environment, biomes, and naturals have yet to be explored. This paper presents some initial results of natural features (morphology, genetic terrain, material compositions, and types), environmental features, ecological community features (diversity, major groups of organisms, marine fish resources), and their significance in marine biomes (distribution of organisms, ecological linkage, habitats of endemic species) of a sandbar, bedrock in the nearshore in Thuan An, Tu Hien - Chan May and Lang Co - Hai Van - Son Cha of Thua Thien-Hue Province in the framework project of Thua Thien-Hue Province and National Independent Project belongs to the National Program 562 with Code Number is ĐTĐLCN.78/22 and Vietnam Academy of Science and Technology Project with Code Number is ĐL0000.01/23–24. Based on these findings, the authors proposed naming this terrain "seahill" and the accompanying ecosystem "seahill ecosystems" in the nearshore of Vietnam while continuing to investigation, survey, and research.

Keywords: Seahill, Seahill ecosystems, the nearshore of Thua Thien-Hue Province.

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INTRODUCTION

In the nearshore [1], many elevated landforms can be observed on the seabed, including sandbars, shoals, bedrocks, reefs, etc. These formations exhibit vertical elevations ranging from a few meters to tens of meters above the seabed. Despite their small size and limited distribution, they have the potential to cause shipping accidents and marine environmental incidents [2], as well as substantial fishing grounds, personal communications [3], fish habitats, and nursery areas for marine endemic animals [4], potentially leading to the restoration of biomes [5] and benthic animal diversity [6]. Therefore, they were examined and assessed for the community [3], marine environmental incidents, navigation hazards, fauna, and orientation to usage by numerous previous studies [7]. With a challenging passage to severe maritime naval safety, Vietnam has been examined to ascertain positions, depths, and distributions that were indicated on the charts. Because of the abundance of fish, shrimp, and benthic animals that live in their areas, it is an important fishing ground for fishermen. However, the investigation and study of this object have been limited; they are only addressed briefly in previous studies in biome, morphology, sedimentation, etc [8]. It is required to analyze, study, and research to comprehend them.

This paper gives some preliminary findings and an understanding of characteristics such as nature, environment, and biomes, as well as their roles in marine biomes of landforms. We also proposed calling this terrain type “sea hill”, and the accompanying “seahill ecosystem” in Vietnam’s nearshore.

MATERIALS AND METHODS

Study areas

This study examined that the sandbar in Thuan An is 0.5–2.0 meters above the seabed at approximately 5 m/chart datum (0 m CD) (Figure 1-A); the reef in Tu Hien - Chan May is 2–5 m above the seabed at approximately 20–25 m/0 m CD (Figure 1-B); and the bedrock in Lang Co - Hai Van - Son Cha is 3–5 m above the seabed at approximately 50–60 m/0 m CD (Figure 1-C), in the nearshore of Thua Thien-Hue Province in the rainy season in November 2015 and the dry season in June 2016 and supplemented in November 2016 (after the Formosa Environmental Incident), supplemented surveying and research in the framework of National Independent Project belongs to Program 562 with Code number is ĐTĐLCN.78/22 and Vietnam Academy of Science and Technology with Code Number is ĐL0000.01/23–24.

Materials and methods

Materials

Materials are mainly the result of the provincial project Thua Thien-Hue, the national project and Vietnam Academy of Science and Technology with code numbers TTH.2015-KC.04, ĐTĐLCN.78/22 and ĐL0000.01/23-24, respectively, and related materials[1,2,3,4] and

[1]Tran Duc Thanh, 2009. Inventory, evaluating areas and objects with natural wonder and heritage values in the coastal zone of Thua Thien-Hue province. *Technical report. Store at the Institute of Marine Environment and Resources, Vietnamese Academy of Science and Technology*.

[2]Vu Van Phai, 2012. Establishing geomorphological mapping in the nearshore and submarine from Dien Huong to Tu Hien inlet (0–60 m in depth). *Thematic report. Store at the Northern Center for Planning and Investigation of Marine Resources and Environment, The Viet Nam Agency of Seas and Islands, Ministry of Natural Resources and Environment*.

[3]Bui Van Vuong, Nguyen Dac Ve, 2017. Morphological characteristics and sedimentary environment quality of the hills underwater ecosystem in the nearshore Thuan An inlet, Tu Hien inlet, and Lang Co of Thua Thien-Hue Province. *Store at the Institute of Marine Environment and Resources, Vietnamese Academy of Science and Technology*.

[4]Vu Van Phai, Dang Van Bao, Nguyen Hieu, 2001. Establishing geomorphological mapping in the nearshore (0–30 m in depth) of Vietnam, scale 1/500,000. *Store at the Vietnam Geological Department, Ministry of Natural Resources and Environment*.

serial Chart 1:25,000 in scale with sheets I-25-169, I-25-173, and I-25-174, published by the Vietnam People's Navy in 2011.

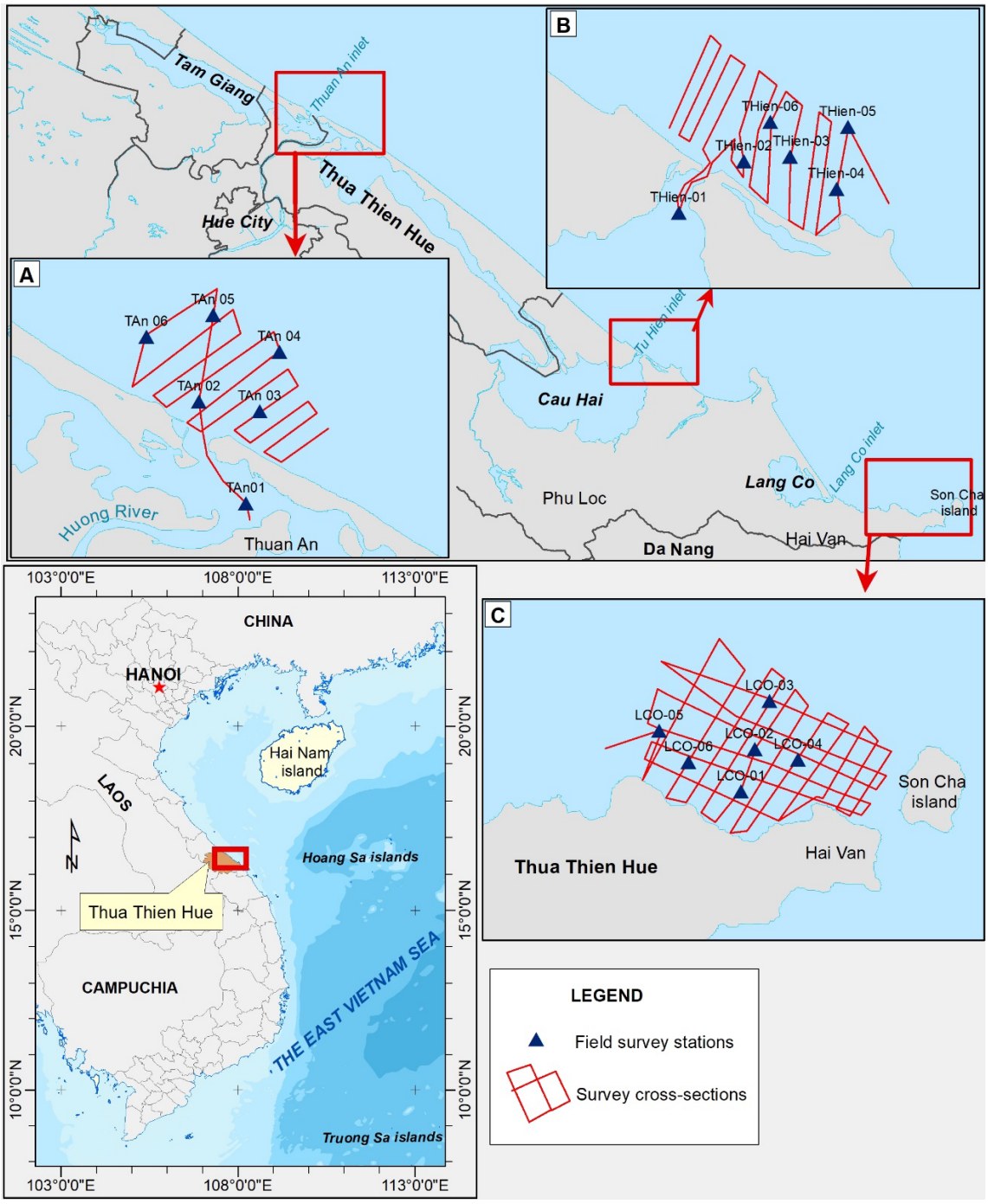

Figure 1. Transections and field survey stations in the nearshore Thua Thien-Hue Province: (A)- Thuan An (TAn05-sandbars area); (B)- Tu Hien - Chan May (Thien-05-bedrocks area); (C)- Lang Co-Hai Van-Son Cha (LCO-02-bedrocks area; LCO02-1, LCO02-2, LCO02-3, LCO02-4 and LCO02-5 are field survey stations adjacent to LCO-02 that are surveyed in detail)

Methods

Surveying methods

Surveying and collecting samples in the field were carried out in accordance with the marine surveying process and norm [12, 13]:

Using the reef check method with SCUBA diving equipment, we surveyed to film, take pictures, and collect samples such as benthic, fish, algae, seagrass beds, morphology, and sediment in plots of 100 m square, with each transection measuring 10 × 2 m in sandbars, bedrock, and reefs [14] (Figure 2, 3).

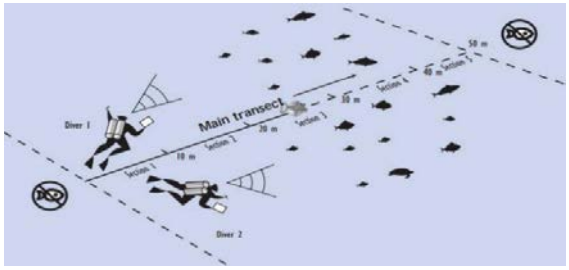

Figure 2. Reef check method [14]

Figure 3. Using the reef check method with SCUBA diving equipment to survey reef rock in the nearshore area of Son Cha Island [*Photo by:* Nguyen Van Quan, 2016]

Benthic animals and surface sediment were collected using Van Veen Grab with a 25 × 25 cm sample area.

Hydrotrac II equipment used echo-sounding bathymetry to measure the study areas.

After collecting, the bathometer quickly measured the temperature, salinity, pH, and dissolved oxygen (DO) of water quality samples on the boat.

Qualitative and quantitative phytoplankton and zooplankton were collected by surface net with 20–25 mm mesh size and 315 mm, respectively. Fish eggs and fish larvae were collected by net with a rectangular mouth (40 × 60 cm), 2 m in length, and a mesh size of 350 µm to give a pull against the flow direction at a speed of 2–3 km/h for about 10 minutes.

Sample analysis in the laboratory

Samples include the following flowing parameters: grain size, total phosphate (TP), total nitrogen (NT), and total sulfur (TS) in surface sediment; nitrite, nitrate, ammonia, and phosphate in seawater; zooplankton, phytoplankton, and benthos that were analyzed at the laboratory of the Institute of Marine Environment and Resources.

The underwater topography was simulated using ArcGIS, Corel Draw, and Surface Software's Underwater Digital Elevation Modes (UDEMs).

The goal of *Epinephelus coioides* was detected at the laboratory of Kagoshima University in Japan.

Jeffrey M. Leis (2004)'s [15] approach was used to analyze fish eggs and larvae.

The Measuring Ecological Index contains a similarity index to detect species content similarity and a diversity index to detect species content diversity in this study region [16, 17].

The SONTEK ADCP equipment was used to record the currents and waves.

MAIN RESULTS

Based on the surveying, analyzing, and the Digital Elevation Model (DEM) topographic seafloor data[5] and connected materials[6], the following are indicated.

[5]Bui Van Vuong, Nguyen Dac Ve, 2017. Morphological characteristics and sedimentary environment quality of the hills underwater ecosystem in the nearshore Thuan An inlet, Tu Hien inlet, and Lang Co of Thua Thien-Hue province. *Institute of Marine Environment and Resources, Vietnamese Academy of Science and Technology*.

[6]Vu Van Phai, Dang Van Bao, Nguyen Hieu, 2001. Establishing geomorphological mapping in the nearshore (0–30 m in

Sandbars and rocks on the seafloor in the nearshore Thua Thien-Hue Province

Sand bars on the seafloor in the nearshore closed Thuan An inlet

Figure 4. The surface sandbar on the seafloor in the nearshore closed Thuan An inlet [*Photo by:* Nguyen Van Quan, 2016]

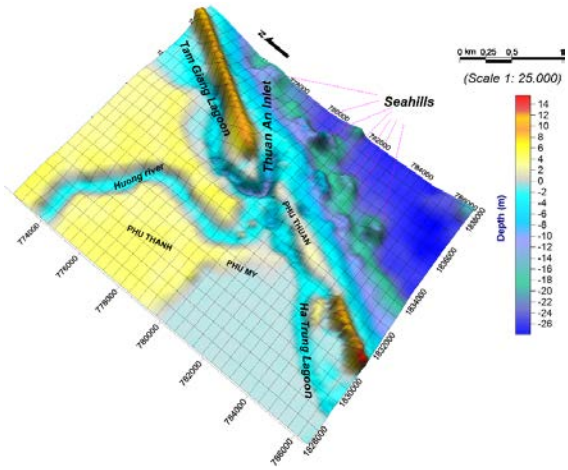

Figure 5. The UDEM topographic seafloor in the nearshore closed Thuan An inlet [*Photo by:* Bui Van Vuong, 2016]

The sandbar on the seafloor in the nearshore closed Thuan An inlet was discovered at the TAn-05 station, which is roughly 0.5–2 m higher above the bottom. The sandbar was formed by the wave action that caused sand transport. The flat sand bed is unstable for ripple formation. Ripples develop and adjust over a time scale of hours. It is composed primarily of yellow sand and mixed shell (Figure 4), is around 50–100 m broad and 500 m long, and has proven highly stable throughout two seasonal surveys. Several generations of sandbars in the nearshore Thuan An, distributed roughly at 10 m/0 m CD, 20 m/0 m CD, and 30 m/0 m CD, paralleling the coastline (Figure 5).

The rocks on the seafloor at the nearshore Tu Hien - Chan May

At the Thien-05 station in the nearshore Tu Hien, the number of granite rocks with a size of roughly 2–5 m × 1-2 m × 2–5 m, which is higher than the seafloor of 1–2 m (Figure 6), and a scattered distribution of around 100–200 square meters is approximately 25 m/0 m CD (Figure 7).

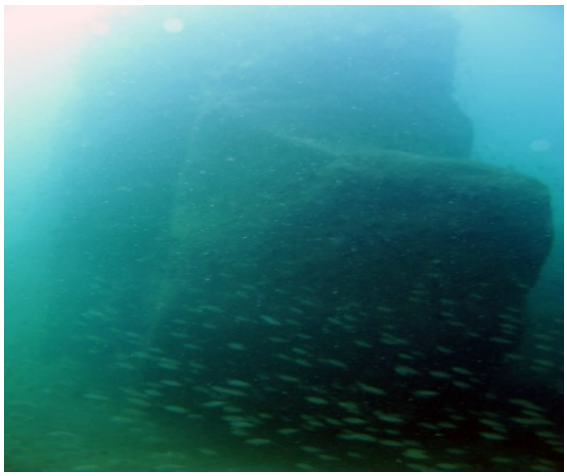

Figure 6. Rocks on seafloor in the nearshore Tu Hien-Chan May [*Photo by:* Nguyen Van Quan, 2016]

The rocks on the seafloor at the nearshore Lang Co-Hai Van-Son Cha

On the seafloor at about 40–50 m/0 m CD in the nearshore of Lang Co - Hai Van - Son Cha, the LCO-02 station has granite rocks with dimensions of 1–3 m × 1–2 m x 1–2 m (Fig. 8),

depth) of Vietnam, scale 1/500,000. *Vietnam Geological Department, Ministry of Natural Resources and Environment*.

alternate medium sand, and smaller rocks. Its distributed location spans 150–300 square meters. They are surrounded by mud. Another distribution of rocks on the seafloor is aquatic of the rocky capes (such as Bai Chuoi rocky cape, Hai Van rocky cape, Son Cha Island, et cetera) that go down to approximately 60–100 m/0 m CD (Figure 9).

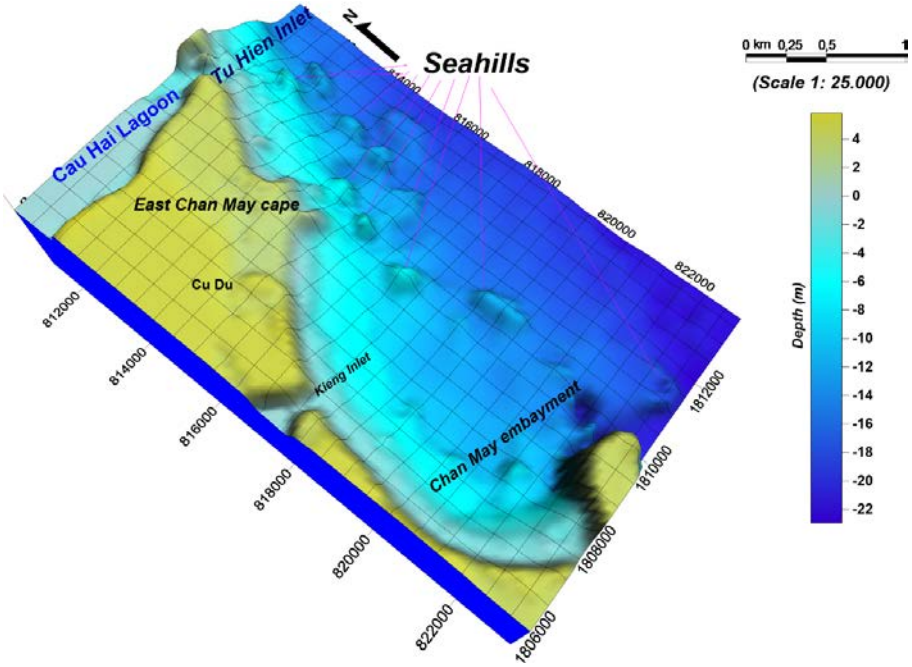

Figure 7. The UDEM topographic seafloor in the nearshore Tu Hien - Chan May area [*Photo by:* Bui Van Vuong, 2016]

Figure 8. Rocks on the seafloor in the nearshore Lang Co - Hai Van - Son Cha [*Photo by:* Nguyen Van Quan, 2016]

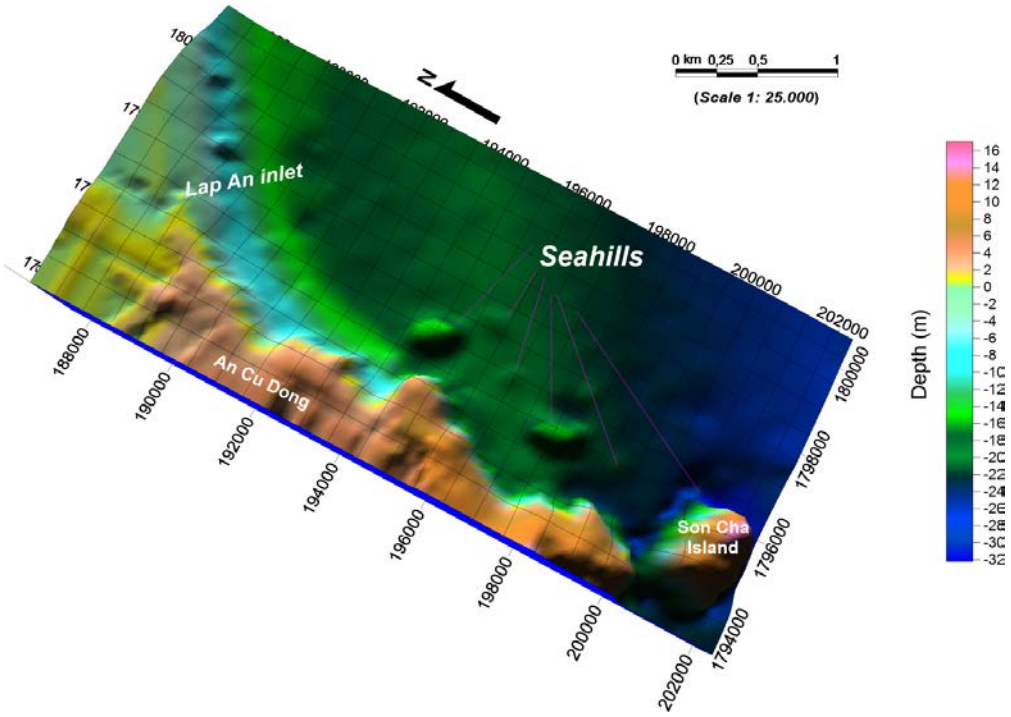

Figure 9. The UDEM topographic seafloor in the nearshore Lang Co - Hai Van - Son Cha [*Photo by:* Bui Van Vuong, 2016]

Environmental sandbars and rocks

Environmental water

The water temperature

The temperature of the water at each station changed according to the season. During the dry season, the water temperature ranges between 20.2–25°C and 28.0–35.2°C. Surface water temperature is higher than bottom water temperature by around 1–2°C and 2–3°C in the rainy and dry seasons. However, in the lagoon sandbars, and rocks on the seafloor, surface water is warmer than bottom water by around 2–4°C and 3–5°C in the rainy and dry seasons, respectively.

Depending on the season, the temperature of the surface water is higher than that of the bottom water at each station, resulting in: In the rainy season, the TAn-01 station in Tam Giang lagoon has 25°C, 22.5°C, and 3.5°C; in the dry season, it has 35°C, 30.5°C, and 5°C. In the rainy season, the temperature of the TAn-05 station is 24°C, 22°C, and 3°C; in the dry season, it is 34°C, 30°C, and 4°C. In the rainy season, the temperature of Thien-01 station in the Cau Hai lagoon is 24°C, 22°C, and 3°C; in the dry season, it is 34°C, 30°C, and 4°C. The rainy season at Thien-05 station in the granite rock is 23.5°C, 20°C, and 3.5°C; the dry season is 33.3°C, 29.5°C, and 4.0°C. The rainy season at LCO-02 station in the granite rock is 24.5°C, 20.5°C, and 4.0°C; the dry season is 34.5°C, 29.5°C, and 5.0°C.

In summary, the temperature in surface water is warmer than that in bottom water in both seasons, in lagoons, sandbars, and rock on the seabed; in the rainy season, it is about 4–5°C, and in the dry season, it is around 2–4°C. Meanwhile, in the dry season, the surface water temperature at each station is about 1–2°C higher than the bottom water temperature and 2–3°C higher in the rainy season.

Salinity

The salty water in the nearshore province of Thua Thien-Hue changes according to water layers and seasons. At the time of sampling in

November 2015, during the rainy season, sanity in the water ranged from 5‰ to 32‰, with an average of 27‰. The saltiness of the bottom layer's water was higher than that of the surface layer, which was about 2–5‰. The sanity in the surface layer is around 10‰ with the number of stations in the lagoon; otherwise, it is approximately 20‰; towards the sea, the sanity in the surface water is lower than in the bottom water layer. Repeat sample collection at the same station as the previous year. At the time of collecting samples in June 2016, during the dry season, the water sanity ranged from 23‰ to 33‰, with an average of 30‰. Water sanity in the bottom layer is always more stable than that in the upper layer, which ranges between 2 and 4‰. However, nothing changed the water's sanity in the sandbars, rocks, and surrounding area.

Dissolved Oxygen (DO) concentration

Based on data from all samples collected in the nearshore Thua Thien-Hue Province between November 2015 and June 2016, the DO concentration in the water ranges from 5.79 mg/L to 9.76 mg/L, with the surface water having a higher concentration than the bottom water, which has a lower value of 0.5 mg/L to 2.0 mg/L. However, nothing changed the DO concentration of the water in the sandbars, rocks, and surrounding environment.

Nutrient matters

Nitrite concentrations in the rainy season range from 7.29 µg/L to 15.68 µg/L, with an average of 11.52 µg/L; in the dry season, they range from 7.22 µg/L to 14.05 µg/L, with an average of 10.05 µg/L. Nitrite concentrations are lower in the dry season than in the rainy season, and those in the surface water layer are always higher than those in the bottom water layer, ranging from 5.03 µg/L to 7.20 µg/L. Nitrite concentrations in the interaction of sandbars, rocks, and water are higher than in the surrounding area throughout both the dry and rainy seasons, and those in the interaction of sandbars and water range between 8.22 and 10.10 µg/L at TAn-05 station; 10.18 µg/L to 11.31 µg/L in the interaction of rocks and water at Thien-05 station; and 9.07 µg/L to 10.36 µg/L in the interaction of water and rocks at LCO-02 station, respectively. Nitrate concentrations at another station range between 7.22 and 8.05 µg/L.

Nitrate ($N\text{-}NO_3^-$) concentrations in the rainy season range from 91.95 µg/L to 158.15 µg/L, with an average of 115.50 µg/L, which in the dry season range from 74.2 µg/L to 137.4 µg/L, with an average of 101.38 µg/L. Nitrate concentrations in the surface water are higher than in the bottom water of year. The nitrate concentrations in the interaction sandbar, rocks, and water are higher than in the surrounding region. As the same nitrite, the nitrate concentrations in the interaction of sandbar and water range between 130.34 and 145.23 µg/L at TAn-05 station; 120.35 µg/L to 140.20 µg/L in the interaction of rocks and water at Thien-05 station; and 135.04 µg/L to 140.03 µg/L in the interaction of water and rocks at LCO-02 station, respectively. At another station, nitrate concentrations range between 91.95 and 100.15 µg/L.

Ammonia ($N\text{-}NH_4^+$) concentrations in the rainy season range from 47.25 µg/L to 97.55 µg/L and 36.25–97.55 µg/L in the dry season, which is higher in the surface water than that in the bottom water layer. Ammonia concentrations in the interaction of sandbar and water range between 80.14 and 97.03 µg/L at the TAn-05 station; 85.00 to 94.01µg/L in the interaction of water and rock at the Thien-05 station; and 82.04 µg/L to 92.03µg/L in the interaction of water and rocks at LCO-02 station, respectively. At another station, nitrate concentrations range between 47.05 and 60.10 µg/L.

Phosphate ($P\text{-}PO_4^{3-}$) concentrations in the rainy season range from 23.91–39.65 µg/L, and 21.23–33.50 µg/L in the dry season, which is higher in the surface water than that in the bottom water layer. Ammonia concentrations in the interaction of sandbar and water range between 90.25 and 111.03 µg/L at the TAn-05 station; 80.00–90.01 µg/L in the interaction of water and rock at the Thien-05 station; and 22.04 µg/L to 101.03 µg/L in the interaction of

water and rocks at LCO-02 station, respectively. At another station, nitrate concentrations range between 57.05 and 65.10 µg/L.

Sedimentary environment

Sedimentary mechanics

The surface sediment of the sandbar at Tan-05 station in the nearshore Thuan An is fine sand, but it varies between muddy and fine sand at other stations. Sediment at the nearshore Tu Hien - Chan May at Thien-05 includes rock, medium sand, coarse sand, silt, and shells. Surface sediment at another station comprises medium and coarse sand. Surface sediment at the nearshore Lang Co - Hai Van - Son Cha station LCO-02 includes rock mixed with fine sand, slits, and shells; at another site, surface sediment is primarily fine sand.

P_{ts}, N_{ts}, S_{ts}, $C_{organic}$ concentrations

P_{ts}, N_{ts}, S_{ts}, and $C_{organic}$ concentrations in surface sediment at stations vary from 32.08–130.18 mg/kg dried; 33.6–503.60 mg/kg dried; 67.83–878 mg/kg dried; and 137–670 mg/kg dried, respectively. P_{ts}, N_{ts}, S_{ts}, and $C_{organic}$ at stations are sandbars. P_{ts}, N_{ts}, S_{ts}, and $C_{h/c}$ concentrations are the same in the surrounding area. P_{ts}, N_{ts}, S_{ts}, and $C_{organic}$ concentrations are higher at stations that are slit, rock, coarse and medium sand, and shells than in the surrounding area.

Characteristic currents and velocity waves in sandbars and rocks

According to the monitoring results for current and waves at the station with sandbar and rock in the nearshore Thuan An, Tu Hien, the current is split into layers and changes direction faster rate than the surrounding ranges of 0.3–0.7 m/s. The velocity wave at the station with sandbars and rocks constantly changed from 0.04 m/s at the bottom to 0.12 m/s at the top of the sandbars or rocks. However, Lang Co - Hai Van - Son Cha did not detect the varying currents and waves at the station with rocks in the nearshore. It explains why the seafloor is deep (40–60 m) and has flat terrain.

Biological community at sandbars and rocks on the seafloor

Biological species diversity

Five hundred twelve biological species that live on sandbars and rocks on the seafloor: phytoplankton has the most species (183 species and 35.7%), followed by marine fish (98 species and 19.14%), zooplankton (74 species and 14.5%), marine birds (66 species and 12.89%), benthic (42 species and 8.2%), and seaweed (38 species and 7.42%).

Characteristic biological community and leading biological group at the sandbars and rocks

Phytoplankton

Phytoplankton density at the nearshore in Thuan An, Tu Hien-Chan May, and Long Co - Hai Van - Son Cha ranges from several hundred to 4 × 10^3 cells/liter. In the rainy season, the medium density of phytoplankton is between 1.5 and 4.0 × 10^3 cells/litter, in the dry season, which from hundreds to 2 × 10^3 cells/litter. The cells density in the water bottom layer is more than 2–3 times that in the surface water layer. Among three areas, Thuan An area, in both rainy and dry seasons, phytoplankton density is the highest and lowest in the Lang Co area. At the Tan-05 station (sandbar), at the sampling time in the rainy season, in the bottom water layer, the Silic *Hemiaulus indicus* species had a high density of 1.2 × 10^4 cells/litter, forming a biomass peak. Although this species is common in coastal water, it is rarely seen at such high densities.

Zooplankton

There are 74 zooplankton species in the nearshore Thua Thien-Hue Province, divided into 46 genera, 37 families, 10 orders, 6 classes, phyla, and 17 groups of larval shrimp, crab, molluscs, echinoderms, corals, and benthic crustaceans. The zooplankton species

on sandbars and rocks outnumber those in the Tam Giang - Cau Hai lagoon by more than 137%. The findings suggested that zooplankton communities are diversified and numerous in the nearshore Thua Thien-Hue Province.

Diversity of marine fish species composition

Based on specimen analysis, pictures, and videos of two survey trips in the rainy season of 2015 and the dry season of 2016. The composition of marine fish species on sandbars and rocks is higher than that in coastal water, where 98 species belong to 48 families and 71 genera. There are 9 species of the Groupers in the family *Serranidae* (9.18%), the Macropodus in the family *Pomacentridae,* and the Scad in the family *Carangidae* all of which have 7 species (7.14%), the Goatfish in the family *Mullidae* has 6 species (6.12%), the Rabbitfish in the family *Siganidae* has 5 species (5.1%), the Snapper in the family *Lutjanidae,* and the Butterflyfish in the family *Chaetodontidae* have 6 species (4.08%). The snowflake-patched moray, in the family Gymnothorax niphostigmus, lives on the rocks in the coastal waters of Tu Hien-Chan May and Lang Co-Hai Van-Son Cha [18].

Density, distribution, and diversity of Juvenile fish

According to the results of two survey trips conducted during the rainy season of 2015 and dry season of 2016, 369 individual juvenile fish were discovered. They are mainly in the pre-flexion substage, with a size of 2–3 mm. There are few larger juvenile fish in the post-flexion and juvenile substages. The analysis result detected five orders and 15 families: The order of Bass is 94.85% in the family *Perciformes*, with 10 families. The order of Globefish in the family *Tetraodontiformes* is 2.44%, with 1 family. The order of Flatfish in the family *Pleuronectiformes* is 2.17%, with 2 families. The order of Herring in the family *Clupeiformes* is 0.27% with 1 family. The order of Mullet in the family *Mugilliformes* is 0.27% with 1 family. The Juvenile fish component is more diversified on sandbars and rocks than in adjacent areas.

Marine fish resources

At the rocks on the seafloor, 75 species of economic fish have been found, including the Grouper family: *Epinephelus coioides, Epinephelus quoyanus, Epinephelus merra*, et cetera, which are the principal catch of diving in the Tu Hien-Chan May area as well as the Lang Co - Hai Van - Son Cha area. The Rabbitfish family, such as *Siganus fuscescens, Siganus javus, Siganus guttatus,* etc., are mainly caught by trammel fishing nets. Particularly, migratory marine fish, such as the Carangidae family: Longfin trevally (*Carangoides armatus*) and Slender queenfish (*Scomberoides tol*), are frequently found in the nearshore Thuan An. The Giant catfish (*Netuma thalassina*) frequently concentrates on rocks on the seafloor in the nearshore Tu Hien - Chan May, providing fishermen with enormous fishing resources. For example, on the night of August 6, 2017, fishermen caught 70 tons of Giant catfish[7].

Zoobenthos

The average density of zoobenthos on sandbars and reefs is higher than in surrounding areas, ranging from 44 individuals/sq m to 90 individuals/sq m, and the biomass ranges from 20 g/sq m to 240 g/sq m, according to the analyzed data. The density of zoobenthos is maximum at reefs in the nearshore Lang Co - Hai Van - Son Cha, with an average of 90 individuals/sq m, including amount of species Moon Snail (*Turbo argyrostomus*) and Maculated top shell (*Trochus maculatus*). On the other hand, large-sized and mass-producing Sea Cucumbers (*Holothuria*) and Rock Clams (*Barbatia deccusata*). Zoobenthos, however, has an average density of 44 individuals/sq m and a biomass of 40 g/sq m at the sandbar in the nearshore Thuan An.

[7]http://vnexpress.net/tin-tuc/thoi-su/ngu-dan-trung-me-ca-hon-70-tan-tri-gia-gan-4-ty-dong-3232378.html (accessed in 21 h 30, 30 August, 2021)

Reproductive ground and habitat of marine biology

The mature gonad of the species Orange-spotted grouper (*Epinephelus acroiides*) (*Figure 10*), according to analyzed results at Kagoshima University, Japan, shows that this fish breeds on reefs every year from June to August.

The surveying and analyzing results revealed that two groups of fish that reside in reefs in the nearshore Tu Hien - Chan May: *The first group consists of fish that spend their entire lives on reefs*, such as species of grouper, red snapper, and sea eel families. *The second group* consists of fish that live to emigrate, such as groups of fish that live offshore or fish that spend a partial cycle of life in reefs, such as Giant catfish (*Netuma thalassina)* and Red reef bream (*Lutjanus argentimaculatus*) which are living in reefs during the dry season to reproduce and migrate back out to sea.

Additional surveys conducted in November 2016 in the nearshore of Lang Co - Hai Van - Son Cha (after the Formosa Environmental Disaster in June 2016) discovered that at the foot of the rocky reef, fish density of the fish species *Siganus fuscescens* up to hundreds of individuals per 10 m sq; and 5 parent individuals (30 cm) of the species *Epinephelus merra* per 100 m sq. The natural coral reef was entirely devastated, about 1 km from the rocky reef; however, no individuals from the economic fish families were found.

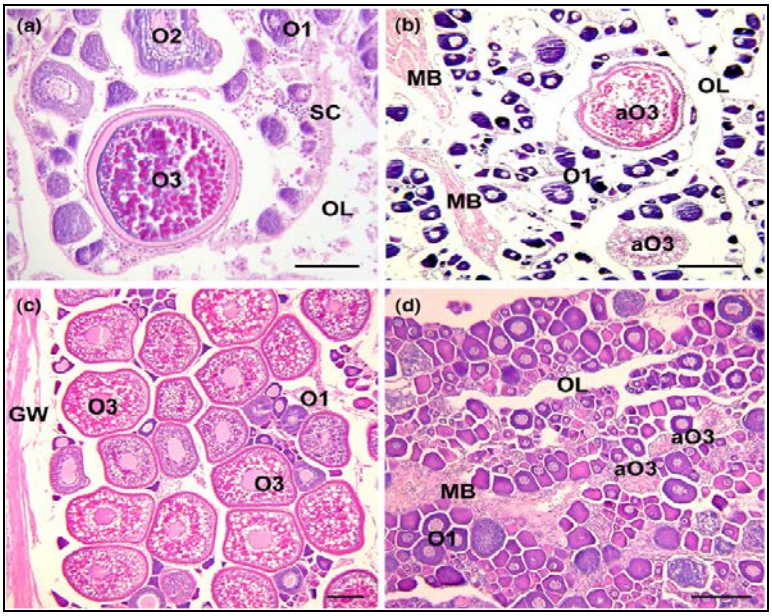

Figure 10. The Orange-spotted grouper (*Epinephelus acroiides*) gonal was captured at Reef on Thu Hien in June 2016 (a, b- preparing to spawn) and November 2016 (already spawning)

DISCUSSION

The main characteristics of sand bars, rocks, and reefs in the nearshore Thua Thien-Hue Province

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According to the survey data, sand bars, boulders, and reefs in the nearshore Thua Thien-Hue Province range from 0 m to around 30 m, with some reaching 50 or 60 m per Chart Datum [1]. This deep equivalent of a half-wavelength is in the spread wave zone, where the wave barely affects it [19]. Sand bars, boulders, and reefs form in the following conditions:

Sand bars are formed by coastal hydrodynamics

Sand bars are generated in the accretion zone by the bottom currents and waves

Under the influence of wave break conditions and sea level variations, the coarse sediment (mostly coarse sand) has formed several generations of sand bars in the coastal zone, distributed from above to below the modern sea level. They begin by dispersing sard bars in shallow nearshore areas (for example, shallow sand bar Thuan An) and then expand into the sea as sard bars on the seabed (for example, sand bar on the seabed in Dien Huong). Sand bars, which range from a few meters to approximately 20 m per 0 chart, are sand beds extending wavy surfaces in the direction of east-northeast or sub-parallel. The surface sediment of the sand bars is mainly coarse-grained, mostly sand; sometimes, it is mixed sand and grit. The surface sediment of the sand bars is mainly coarse-grained, mostly sand; sometimes, it is mixed sand and grit. These sand bars can also be found in many other areas of the world, such as the multiple generations of sand bars in the coastal zone of the Gaza Strip, Palestine [20].

Underwater sand bars include (sand) dunes, sand bars, or sand dikes, which are ancient coastal sand dike facies of the early-middle Holocene (Q_2^{1-2})

These sand bars are composed of sand (over 90%) and quartz minerals (over 90%). They form because of oceanic wave movements and develop due to tectonic uplifts. Sand bars vary from 20 to 30 m per 0 chart and are several meters above the seabed to the north of Thuan An inlet, with a restricted distribution to the southeast. Surface sediment in sand bars is mostly fine, including slit-sand and sand-slit. These sand bars could represent ancient lagoon systems that arose during the Flandrian transgression, or they could be submerged or modified shorelines as the water level steadily rose from the Late Pleistocene to the present. These sand bars are spaced approximately 20–30 m apart, with some exceeding 40–60 m per 0-m chart and rising 3–5 m above the seabed. This type of sand bar is also available in the nearshore area of Dorset, England [21].

Reefs form because of geological structures

The reefs are formed by exposed rocks or boulders of granite from the Late Triass complex ($\gamma a T_3 hv$) close to the shore, around 2 m to 5 m above the seabed. On the Hai Van peninsula (from the mouth of Lang Co lagoon to Son Cha island), the reefs are dispersed near the shore at a depth of around 20–30 m per 0 m chart. They can also be found at depths of 20–30 m between West Chan May Cape and East Chan May Cape.

The distribution density and diversity of fish larvae, marine fish resources, and benthic animals in sand mounds and reefs are also more affluent and diverse than in the surrounding areas. Some research results also demonstrate that environmental parameters at sand bars and reefs differ from the surrounding areas will affect marine life. The coefficient of seasonal temperature difference in bottom water on reefs on the West Coast of Scotland affects the density, life cycle, egg survival, and immigration of juvenile Atlantic cod (*Gadus morhua*) [4].

The role of sand bars and reefs in marine biological biomes

Some environmental effects on marine biological biomes in sandbars and reefs

There are differences in some parameters in the water and sediment environment at the sand bars and reefs with their surroundings in the nearshore Thua Thien-Hue Province. Some parameters are temperature, nutrient content, and flow velocity.

In the water environment, the temperature varies depending on the water layers and seasons. In the rainy season, the temperature in the surface water layer is 2–4^{o}C higher than in the bottom water layer. In the dry season, the temperature in the surface water layer is 2–5^{o}C higher than in the bottom layer. Meanwhile, at neighboring stations, the temperature in the water layers and the seasons: In the dry season, the temperature in the surface water layer is 2–5^{o}C higher than in the bottom layer and 2–5^{o}C. The flow velocity

is faster than the surrounding, and the wave propagation speed also changes.

In the sedimentary environment, nutrients (Nitrite, Nitrate, Ammonite, and Phosphate), P_{ts}, N_{ts}, S_{ts}, and $C_{organic}$ content are higher than those in the surrounding environment.

Even though this study has yet to demonstrate the impact of water and sedimentary conditions on marine biomes, the survey and analysis results, on the other hand, demonstrate that the marine biome near the sand bars and reef is more diversified than in the surrounding areas. For example, during the rainy season, the alga Silic Hemiaulus Indicus has a high density of 1.2×10^4 cells/liter in the bottom water layer at station TAn-05 (sand bar), resulting in a biomass peak.

Sand bars and reefs are habitats and breeding grounds for marine biology

Species diversity, density, topography, and bottom sediment can all be used to explain the interaction between sand bars, reefs, and biological communities [22], and it can be stated in four ways: (1) depth and brightness of light; (2) marine dynamic circumstances (waves and currents); (3) mixing of water masses; and (4) turbidity. These four variables influence the ecology of rocky subtidal areas near Brest [23]. Depth and season are important biological determinants for community structure; benthic community structure diminishes with depth and varies seasonally [24].

Some parameters (temperature, wave, and current velocities) in the water, sedimentary environment (Nutrients, P_{ts}, N_{ts}, S_{ts}, and $C_{organic}$), componential matter (rocks, boulders, sand, mud, clay, or/and shells), and morphological relief (burrows, furrows, creeks, etc.) at sand bars and reefs differ from the areas surrounding them. For example, sand bars and reefs live and develop marine biological species in the exposed sea. There are orange-spotted groupers (*Epinephelus acroiides*) and group fish that spend their entire lives on reefs, as well as fish that reside in the reefs seasonally and migrate back out to sea, demonstrating that marine biology lives in the sand bars and reefs. Furthermore, sand bars and reefs serve as reproductive grounds, nurseries, and dispersion locations for larvae and juveniles of both inshore and offshore fish species.

About 3 months after the Formosa Environmental Disaster, our team, using the reef check method with SCUBA equipment diving and an underwater camera, examined biodiversity at a coral reef and rocks close to the nearshore Hai Van - Son Cha. According to the findings, the number of fish individuals in rocks was higher than in coral reefs. This phenomenon can infer that the recovery speed of some fish species in rock is faster than that in coral reefs. Thus, the natural environment in rocks recovers faster than in coral reef areas (in fact, we need more research data to prove this inference).

Seahills and seahills ecosystem

Sand bars, rocks, and rocky reefs are widely distributed in the nearshore; they play a role in fishing grounds, breeding, and development places for some fish and shrimp species [3] and/or pose a danger to ships and boats [2]. They only have basic information from nautical charts and maritime sketch maps, such as coordinates, depth, and distribution. They are present and have specific details depending on their size, significance, map scale, etc.

Until now, this terrain and its associated ecosystems have been investigated and researched littel in Vietnam. According to the findings of this study, this terrain is only a few meters above the bottom in the nearshore, with material components of rock, sand, mud, clay, and/or biological shell debris. That may be why this sort of terrain is known by several names based on its morphology and material composition, such as rocky reefs, sandbars, shoals, bedrock knobs, bed knobs, and so on [7, 20, 21]. Because this landform is only found nearshore and has the features of source, morphology, and material composition indicated above, it is necessary to give it a unified name to avoid misunderstandings with seamounts found at the bottom of the open sea and ocean[8,9]. Furthermore, because these

[8]hrsbstaff.ednet.ns.ca/pellers/pages/Oceans/Ocean%20Topography.ppt

landforms are similar to terrestrial hills in terms of morphology and material composition, the authors propose using the term "seahills" to refer to the name of these landforms, and the accompanying ecosystem is the "seahill ecosystem" on the seabed in the nearshore. Seahills are one of the places in the nearshore where biological communities live and exchange matter and energy [1, 26–28].

According to the Coastal and Marine Ecological Classification Standards of the US. Federal Geographic Data Committee [25], seahill ecosystems are considered coral reefs, seagrasses, and tidal flat ecosystems. Accordingly, seahill and seahill ecosystems are understood as follows:

Seahill is a type of terrain in the nearshore that is always found below the 0-m chart datum and higher than the seabed, ranging in size from a few meters to many tens of meters, and can consist of single or multiple rocky reefs, sandbars, shoals, bedrock knobs, bed knobs, and so on. Seahills have formed due to exposed bedrock on the seafloor, boulders have fallen at rocky capes, and ocean dynamics have resulted in unconsolidated sediments mixed with biological shells. The morphology of the unconsolidated sediments with biological shells is wavy, but the rock that formed the seahill features caves, tunnels, furrows, creeks, and others.

The seahill ecosystem is one of the nearshore habitats for biological communities that exchange matter and energy. Temperature, salinity, light, nutrition, terrain, bottom sediment, and dynamic regime are distinct from those in the surrounding area, resulting in a diversified biome on the seahill. It is a place of lifelong residence and migration for several species, a breeding ground, a spawning ground, and a place to incubate and disperse larvae to coastal waters.

CONCLUSION

Seahill is a type of terrain in the nearshore that is always found below the 0-m chart datum and higher than the seabed, ranging in size from a few meters to many tens of meters, and can consist of single or multiple rocky reefs, sandbars, shoals, bedrock knobs, bed knobs, and so on. Seahills have formed because of exposed bedrock on the seafloor, boulders have fallen at rocky capes, and ocean dynamics have resulted in unconsolidated sediments mixed with biological shells. The morphology of the unconsolidated sediments with biological shells is wavy, but the rock that formed the seahill features caves, tunnels, furrows, creeks, and so on.

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There are three types of seahills in Thua Thien-Hue Province's nearshore: seahills formed as a result of exposed bedrock on the seafloor, boulders that fell at rocky capes, or ocean dynamics that resulted in unconsolidated sediments mixed with biological shells. Temperature, pH, DO, nutrients, topography, bottom sediment, flow, and other parameters differ from their surroundings at seahills. As a result, marine animals in seahills have a high density, diversity, and biomass, and they serve as habitats, spawning grounds, nursery grounds, and dispersion grounds for larvae and juveniles of native and migratory fish species.

This study provides the first result and understanding of seahills and seahil ecosystems in Thua Thien-Hue Province's nearshore. Therefore, systematic surveys in both academic and practical terms should be done throughout Vietnam's nearshore to increase understanding of seahills and seahill ecosystems for the management, exploitation, use, and protection of these territories and ecosystems.

[9]http://www.whoi.edu/main/topic/seamounts

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REFERENCE

[1] Federal Geographic Data Committee, 2012. Coastal and marine ecological classification standard. *Publication# FGDC-STD-018-2012*.

[2] Piper, E., 1993. The Exxon Valdez oil spill: final report, State of Alaska response. *Anchorage, AK: Alaska Department of Environmental Conservation*.

[3] Cox, J., 1998. Personal communication, Sport Fishing Charters, Loch Lomond Marina, San Rafael. CA 94915.

[4] Magill, S. H., and Sayer, M. D. J., 2004. Abundance of juvenile Atlantic cod (Gadus morhua) in the shallow rocky subtidal and the relationship to winter seawater temperature. *Journal of the Marine Biological Association of the United Kingdom*, *84*(2), 439–442. https://doi.org/10.1017/S0025315404009415h

[5] Krutwa, A., 2014. Small-scale differences in tropical subtidal rocky reef communities of Floreana Island, Galápagos. *Doctoral dissertation, Universität Bremen*.

[6] Villalobos, V. I., Valdivia, N., Försterra, G., Ballyram, S., Espinoza, J. P., Wadham, J. L., Burgos-Andrade, K., and Häussermann, V., 2021. Depth-dependent diversity patterns of rocky subtidal macrobenthic communities along a temperate fjord in Northern Chilean Patagonia. *Frontiers in Marine Science*, *8*, 635855. https://doi.org/10.3389/fmars.2021.635855

[7] Carlson, P. R., Chin, J. L., and Wong, F. L., 2000. Bedrock knobs, San Francisco Bay; do navigation hazards outweigh other environmental problems?. *Environmental & Engineering Geoscience*, *6*(1), 41–55. https://doi.org/10.2113/gseegeosci.6.1.41

[8] Latypov I. V., 1982. Species composition and distribution of hard corals on coral reefs in Khanh Hoa Province. *Marine Biology*, (6). (in Russian).

[9] Ken, L. V., and Yet, N. H., 1989. Hard coral reef in Truong Sa islands. *Journal of Vietnamese Navy I,* P158. (in Vietnamese).

[10] Vuong, B. V., Thanh, T. D., and Nhon, D. H., 2009. Some results of research on the terrain and sediments of the Truong Sa islands. *Vietnam Journal of Marine Science and Technology*, *9*(Supplement I), 77–92. (in Vietnamese).

[11] Ngai, N. D., 2014. Study on the structure of hard coral communities and their interactions with benthic animals and reef fish on Nam Yet, Thuyen Chai, and Da Nam islands in the Truong Sa islands. *Doctoral dissertation*.

[12] Marine Resources and Environment Investigation Process, 2014. Institute of Marine Environment and Resources. *Publishing House for Science and Technology*.

[13] English, S., Wilkinson, C. and Baker, V., 1997. Survey Manual of Tropical Marine Resources. *2nd Edition, Australian Institute Resources, Townsville*, 385 p.

[14] Hill, J., and Wilkinson, C. L. I. V. E., 2004. Methods for ecological monitoring of coral reefs. *Australian Institute of Marine Science, Townsville*, *117*.

[15] Leis, J. M., 2004. Vertical distribution behaviour and its spatial variation in late-stage larvae of coral-reef fishes during the day. *Marine and freshwater behaviour and physiology*, *37*(2), 65-88. https://doi.org/10.1080/10236240410001705761

[16] Sorensen, T., 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. *Biologiske skrifter*, *5*, 1–34.

[17] Magurran, A. E., 2004. Measuring biological diversity. *Oxford: Blackwell*.

[18] Huang, W. C., Nguyen, V. Q., and Liao, T. Y., 2018. First record of the snowflake-patched moray *Gymnothorax niphostigmus* Chen, Shao, & Chen, 1996 (Anguilliformes; Muraenidae) in Vietnam and its validity confirmed by DNA barcoding. *Journal of Applied Ichthyology*, *34*(3), 687–690. https://doi.org/10.1111/jai.13684

[19] Bird, E. C., 2008. Coastal geomorphology: an introduction. *John Wiley & Sons*.

[20] Abualhin, K., 2016. Mapping of underwater seabed morphology of the gaza strip coastal zone using remote sensing technique. *Earth Sciences Research Journal*, *20*(2), 1–7. https://doi.org/10.15446/esrj.v20n2.50256

[21] Bastos, A. C., Collins, M., and Kenyon, N. H., 2003. Morphology and internal structure of sand shoals and sandbanks off the Dorset coast, English Channel. *Sedimentology*, *50*(6), 1105–1122. https://doi.org/10.1046/j.1365-3091.2003.00596.x

[22] Marengo, M., Iborra, L., Leduc, M., Lejeune, P., Boissery, P., and Gobert, S., 2021. Assessing spatial and temporal trends in a Mediterranean fish assemblage structure. *Diversity*, *13*(8), 368. https://doi.org/10.3390/d13080368

[23] Castric, A., and Chassé, C., 1991. Factorial analysis in the ecology of rocky subtidal areas near Brest (west Brittany, France). *Journal of the Marine Biological Association of the United Kingdom*, *71*(3), 515–536. https://doi.org/10.1017/S0025315400053121

[24] Garrabou, J., Ballesteros, E., and Zabala, M., 2002. Structure and dynamics of north-western Mediterranean rocky benthic communities along a depth gradient. *Estuarine, Coastal and Shelf Science*, *55*(3), 493–508. https://doi.org/10.1006/ecss.2001.0920

[25] Federal Geographic Data Committee, 2012. FGDC-STD-018-2012: Coastal and marine ecological classification standard. *FGDC, Reston, VA*.

[26] Tang, V. T., 2000. Fundamental Ecology. *Vietnam National University Press, Hanoi*. 264 p. (in Vietnamese).

[27] Higano, J., 2004. Influence of environmental changes in tidal flats on the filtration and respiration of bivalve mollusks. *Bulletin-Fisheries Research Agency Japan*, 33–40.

[28] Zektser, I. S., Rogachevskaya, L. M., Marker, B., Ridgway, J., and Vartanyan, G., 2006. Geology and ecosystems: International union of geological sciences (IUGS) commission on geological sciences for environmental planning (COGEOENVIRONMENT) commission on geosciences for environmental management (GEM). In *Geology and Ecosystems: International Union of Geological Sciences (IUGS) Commission on Geological Sciences for Environmental Planning (COGEOENVIRONMENT) Commission on Geosciences for Environmental Management (GEM)* (pp. 1–392). doi: 10.1007/0-387-29293-4