Original Research Article

Ecological zoning of *Paratapes undulatus* in estuaries of Da Nang, Vietnam

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ABSTRACT

Bivalves play a significant role in providing food for humans. The bivalve, *Paratapes undulatus* (Born 1778) living in the Da Nang estuary in central Vietnam has been used as a live food for many years. Based on the results of the field survey in 2021-2022, this study has clarified the ecological and environmental properties of the studied area for ecological zoning of the distribution of this species. The results show that the bottom water and sediments in the Da Nang estuaries were suitable for the distribution and development of undulate venus clam. Moreover, the influence of river discharge in the rainy season has limited the distribution of clams in the river and mount areas compared to others. Clams were not found distributed in sandy or muddy areas, they were observed in areas with sand/mud deposits. This article also showed the clam stock in the studied areas however, and size of scallops at the time of the study was smaller than the first mature size, so for sustainable exploitation, there should be mandatory policies on the season and harvest size as well.

Keywords: Bivalve, Da Nang, undulate clam, venus clam, distribution

1. INTRODUCTION

Bivalves, a mollusk group of common species, with more than 10,000 living species were widely distributed in marine and freshwater habitats, from the intertidal zone to the deepest water as well [1,2,3]. They live buried deep in the sand and mud, cling to shells and rocks, burrow in wood and coral rocks, crawl on sheets of sea grass, and even cling to leafy mangroves [2]. Marine bivalves (including estuarine and brackish water species) represent about 8,000 species, of which the South China Sea has the most diverse bivalve fauna in the world with about 802 species [4], and in the marine waters of Vietnam recorded 814 bivalve species.

Bivalves play vital roles in ecosystems as well as providing food for humans [1,5]. Bivalves are involved in performing important ecological functions of estuarine and coastal marine ecosystems by filtering large amounts of water volume, including plankton, planktonic larvae, detritus and inorganic substances, and then converting them into sediments settling to the bottom [6,7,8,9]. In addition, bivalves can help to improve ecosystem services of marine and coastal ecosystems such as stabilizing substrates, reducing erosion, and enhancing habitat complexity [1,10]. In addition, bivalves also contribute a significant volume of food for humans. According to FAO [11], the marine capture production of mollusks was about 5,923 thousand tons, whereas their aquaculture production reached 17.7 million tons, mainly bivalves.

Paratapes undulatus (Born 1778), common name's undulate venus clams, is a bivalve (family Veneridae, the Venus clams) living in shallow coastal waters, sandy bottoms, and distributed mainly in tropical and subtropical waters of Indo-West Pacific [12]. According to EOL [13], undulate venus clam is a suspension feeder and distributed in shallow waters to the water depth of 9.88 – 73.9 m. The maximum size is 42 mm in body length, and 11.5 g in wet body mass [13]. In Vietnam, undulate venus is distributed mainly in the shallow waters from Da Nang to Binh Thuan provinces (Central Vietnam) and Kien Giang, Ca Mau (Southwest region) [14,15], but their distribution areas have been reduced due to over-exploitation for local and exported food demands [15].

Therefore, this study implemented the survey for ecological characteristics and zoning distribution of undulate venus clams in the estuaries of Da Nang City, Vietnam, thisarticlereported on ffoundation scientific information for orienting the protection and exploitation of their resources and building a process to culture venus clams in the locality and habitat.

2. MATERIAL AND METHODS

2.1 Study area

Da Nang Bay, located in Da Nang City, is a large bay in Central Vietnam, with an area of 116 sq. km, a circumference of 46 km, , The bay is seriously influenced by discharge from the Han and the Cu De rivers,surrounded by 30km of bow-shaped coastline from the south of Hai Van mountain to Son Tra peninsula in the northeast.

The climate is a tropical monsoon with a transformation from a subtropical climate in the north to tropical savanna in the south. There are two distinct seasons: The rainy season, from October to December, is often threatened by floods and inundation, and sometimes has weak and short winter cold period. The dry season is from January to September. The average temperature is about 25°C. The total radiation in the year is about 147.8 kcal/cm^2/year with the sunny hours of 2,156 hours/year.

The tidal regime in Da Nang Bay is irregular semi-diurnal tide with a tidal amplitude of about 0.6 - 1.0m. The main direction of the coastal current is the southeast direction with an average speed of about 20-25 cm/s. In the northeast monsoon season, two small vortices are located in the northern area and the middle of the bay in opposite directions. Along the northwest shore of the bay, there is a downward current and an upward current along the southwest shore of the bay. Their currents meet at the mouth of Cu De River and then enter the middle of the bay.

2.2 Surveys and collecting samples

The surveys were carried out at 20 sites in Da Nang Bay, from Feb2021 to Jan 2022 (Fig. 1). The living samples of *Paratapes undulatus* (Born 1778) were monthly collected, whereas the water and sediment samples were collected in April 2021.

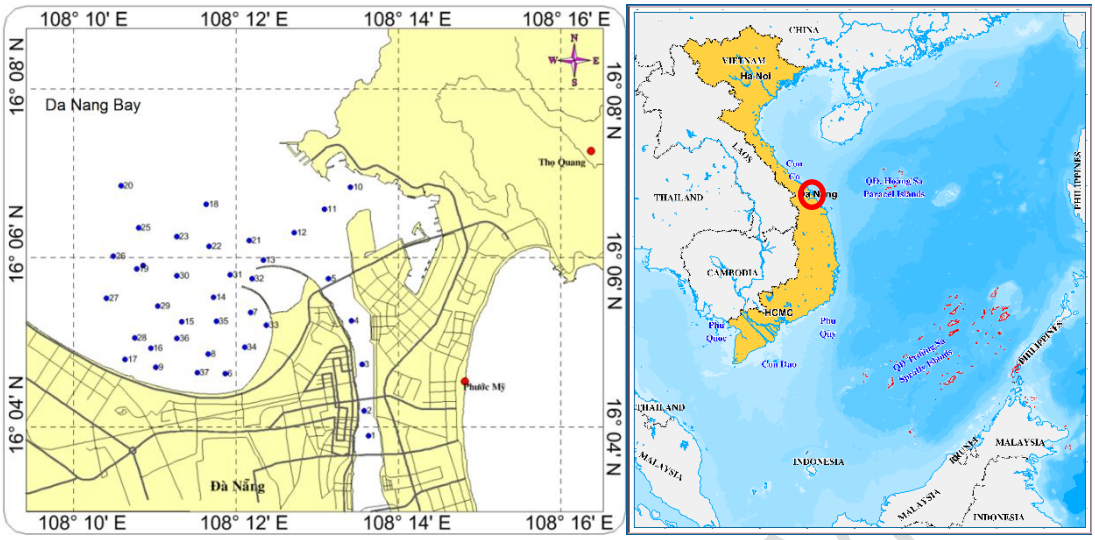

Fig. 1. Sampling sites (# station name) in Da Nang Bay, Vietnam

A total of 37 stations were surveyed for living samples. At each site, all Venus clams within the 3-5 bottom ground replicate with an area of (50 x 50 cm) were taken by scuba divers and then measured the number of clams, weight and size, immediately. The weight was measured by the electronic balance with an accuracy of 0.01 g, whereas the size was measured by the absolute electronic digital caliper Mitutoyo 500-150-30 with a resolution of 0.01 mm. These results were mapped the distributions of density and sizes of the clams in the estuary by MapInfo software (Ver. 17).The instantaneous stock of the clams was estimated by the method of English et al. [16].

The bottom water and sediment samples were collected at 20 stations (stations #1-5 in the river transect, #10-13 in the estuarine transect, and #5-9 and 14-20 in the Bay). Water samples nearby the ground were taken by the 5L Niskin bottler for measuring temperature, pH, DO, salinity, turbidity, Chlorophyll concentration, TSS (total suspended sediment), and TOM (Total organic matter). The sediment samples were collected by the Ponar 'Grab' Sampler (Standard size) for grain size, TSOM (total sediment organic matter), and TSOC (total sediment organic carbon). Temperature, pH, DO, salinity, and turbidity were measured by the YSI ProDSS Multi-Parameter Water Quality Meter. Chlorophyll concentration was analyzed by Jeffrey et al. [17], and TSS and TOM were analyzed by weight method afterheating samples at 105 °C and burning at 500 °C, respectively [18]. The grain size was analyzed byusing a standard sieve system for particles larger than 0.063 mm and the pipetting method for particles less than 0.063 mm (slurry, clay) [19]. TSOM was used the weight method after being burned at 500 °C in the Lindberg/Blue high-temperature furnace (1,100°C Box Furnace, models: BF51800 Series) [20,21].

3. RESULTS AND DISCUSSION

3.1 Environmental features

3.1.1 Bottom water

The quality of the bottom water environment in study areas are shown in Table 1. The values of temperature, pH, DO, salinity, turbidity, TSS, and TOM were less variation, whereas

chlorophyll-a concentration ranged ten times with the highest found at stations #1-3, and then reduced to the bay (Fig. 2).

Table 1. Bottom water properties of estuaries in Da Nang

Factors	Temp.	pH	DO	Sal.	Tur.	Chl.	TSS	TOM	TOM
	(°C)		(mg/l)	‰	(NTU)	(µg/l)	(mg/l)	(mg/l)	(%TSS)
Min	21.1	7.90	4.57	31.60	1.9	0.23	3.10	1.10	25.60
Max	22.8	8.21	6.57	33.24	4.2	2.34	8.60	2.70	48.70
Average	22.1	8.06	5.48	32.38	2.8	0.83	5.51	1.88	35.02
±SD	0.4	0.10	0.61	0.55	0.6	0.59	1.81	0.51	5.59

Notes: Temp.: water temperature, DO: Dissolved Oxygen, Sal.: Salinity, Tur.: Turbidity, Chl.: Chlorophyll concentration, TSS: total suspended sediment and TOM: Total organic matter (p=0.05)

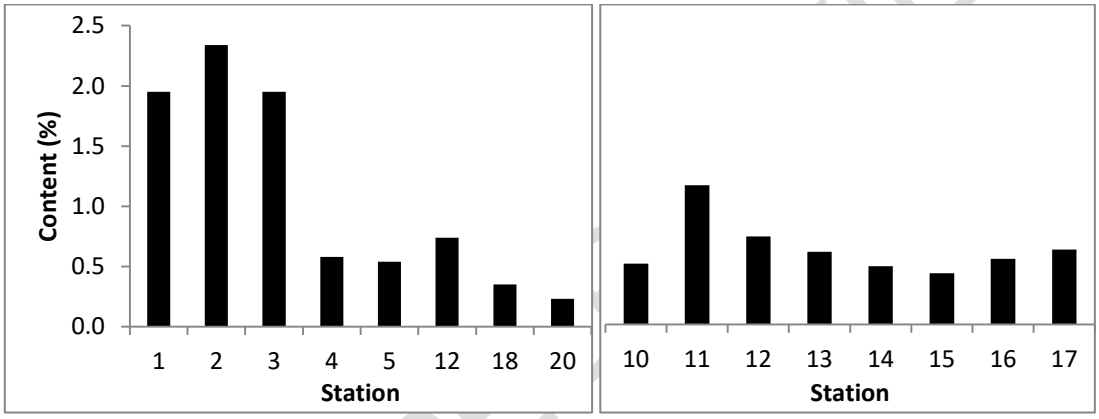

Fig. 2. Chlorophyll-a concentration in the river (left) and estuarine (right) transects

3.1.2 Sediments

The value of sediment factors was strongvariation (Table 2 and Fig. 3). The ratio of sand/mud in the sediment varies on the cross-section from the river to the sea. At station 1, the sediment is sand (gain size over 0.25mm accounting for 64.33%). The sand/mud size ratio gradually decreased at the estuary and outside stations. At station 12, the sand/mud ratio is 35.5/64.5, whereas at station 20 (in the middle of the bay), the sediment wasmostly mud. In the estuary, the sludge material at the shoreline stations (stations #13, 17) was less than that at the stations in the middle of the river mouth (stations #11 and 12) or the middle of the bay (stations #14-16). In the middle of Da Nang Bay, mud material prevails.

Table 2. Sediment properties of in estuaries in Da Nang

Stations	% of the gain size in weight		TSOM	TSOC
	>0.063mm	<0.063mm	%	%
1	96.9	3.1	0.7	0.17
2	67.6	32.4	2.3	0.57
3	66.7	33.3	6.9	1.72
4	72.6	27.4	2.0	0.49
5	50.4	49.6	1.7	0.43
6	29.8	70.2	7.5	1.87

7	52.3	47.7	2.9	0.72
8	16.3	83.7	5.0	1.24
9	45.3	54.7	3.5	0.88
10	8.4	91.6	8.7	2.18
11	5.1	94.9	8.4	2.09
12	35.5	64.5	5.0	1.25
13	58.9	41.1	2.8	0.70
14	7.4	92.6	8.0	1.99
15	13.3	86.7	6.6	1.65
16	25.8	74.2	2.8	0.70
17	79.9	20.1	1.8	0.44
18	7.4	92.6	10.8	2.69
19	2.2	97.8	8.0	1.99
20	1.8	98.2	10.5	2.69
Min	**1.8**	**3.1**	**0.7**	**0.17**
Max	**96.9**	**98.2**	**10.8**	**2.69**
Average	**37.2**	**62.8**	**5.3**	**1.32**
±SD		**29.6**	**3.2**	**0.80**

Total sediment organic matter (TSOM) ranged from 0.7 to 10.8%, with an average of 5.3 ± 3.2 %. Total sediment organic carbon (TSOC) ranged from 0.17 to 2.69, with an average of 1.32 ± 0.8 %, accounting for only 24.91 ± 0.3% TSOM. The concentrations of TSOM and TSOC gradually increased from river to sea, there was a significantdifference between stations in the river and outside stations (p=0.05).

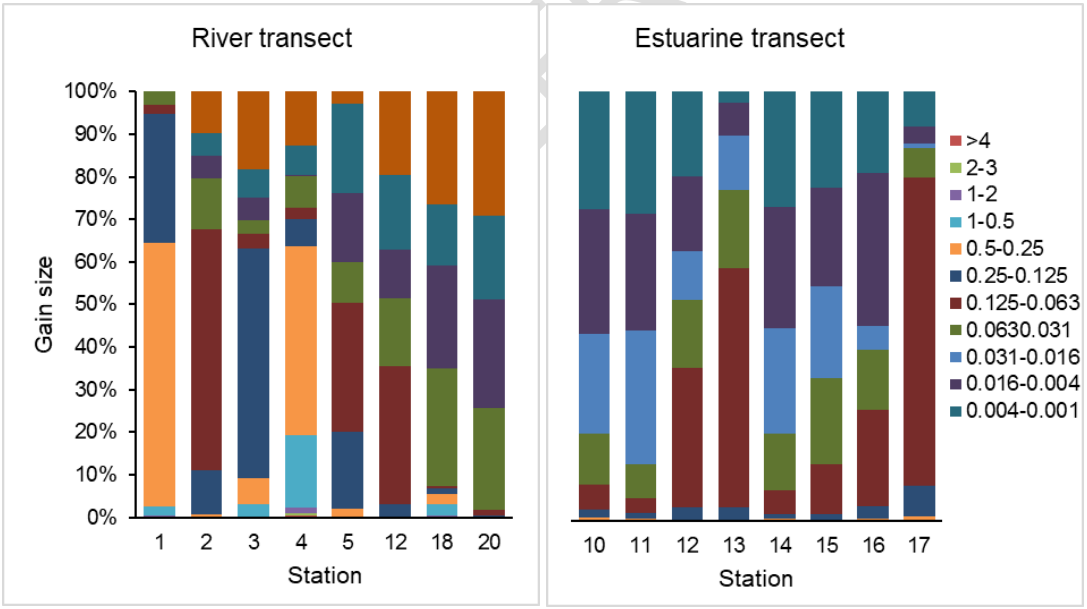

Fig. 3. Grain size of sediment in the river (left) and estuarine (right) transects

3.2 Distribution of Venus clams

Based on surveyed results of density and size (Fig. 4), Venus clams were found in 21/ 37 survey stations with a number of 1-7 ind./frame plots. These stations were located in the western part of the studied areas. The clams were distributed in 5 m of waters from the

shoreline to a water depth of about 10-11 m. The clams were not been found in the deeper water.

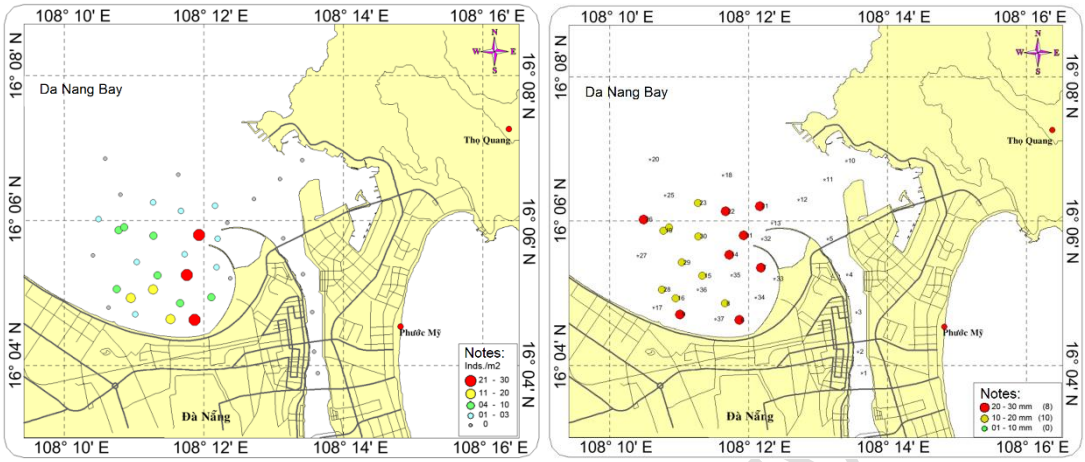

Fig. 4. Distribution of Venus clams in Da Nang Estuaries (left: density and right: width size)

The average density of Venus clams was observed at 4.81 ± 1.85 ind./m^2, and in especially the areas having the clams, the density was 8.09 ± 3.09 ind./m^2. The clams were unevenly distributed in the study waters. Their highest density was observed at the stations 6, 31, and 35 with more than 20 ind./m^2. The stations 16, 36 and 37 had a density of 11-20 ind./m^2; seven stations had a density of 4-10 ind./m^2 and nine stations had a density of 1-3 ind./m^2. The clams in the southwestern waters of the study area are more dense than in other areas (Fig. 4).

The average width of the clams was 19.67 ± 1.66 mm, the largest was observed at 26 mm and the smallest was 16 mm, and thus the small size was dominant in the collection population. Fig. 4 shows that the distribution of clam size was similar to the pattern in density, in the southwestern waters of the study area, the size of Venus clams was larger than in the offshore one. At station 26 the clam had a large size but only one individual was been observed.

3.3 ecological zoning of Venus clams

The growth of filter feeders in general, and the Venus clams in particular in a marine habitat depends on a number of factors of the water environment, food sources and the bottom ground. Based on the observed results, the water quality in Da Nang estuaries was potently suitable for the growth of the clams andthe bivalve, especially an abundant food sources for filter feeders. The chlorophyll-a and TOM concentrations were measured at 0.83 ± 0.59 mg/m^3 and 1.88 ± 0.51 mg/L, respectively (Table 1). These factors were a potentially rich resource for the growth of the clams and bivalves. Additionally, the salinity of seawater is a limited factor in the distribution of clams. According to EOL [13], the clams could be living in the seawater of 35.354-35.444 psu. In the case of estuaries in Da Nang, the salinity was a range of 31.60 - 33.24 psu in the dry season, including in the estuary area. Thus, the Venus clams are distributed in this area. However, in the rainy season, due to river discharge, the reduced salinity inside the river area could cause clam death.

In terms of bottom grounds, the clams were been foundin shallow waters and sandy bottoms, especially where being a suitable source of organic matter in the sediment. According to Hyland et al. [22], the content of TSOC with less than 0.6 % or more than 3% by weight of sediment could reduce the abundance and biomass of soft benthic organisms as well as cause their stress. The TSOC concentration in the range of 0.6 -2.5% would be a “optimal ecological conditions” for benthic organisms, especially bivalves. In this study, the TSOC content, ranging from 0.17 to 2.69%, in which 13/20 observed stations having the “conditional ecological optimum” TSOC, indicated that the study area is very suitable for the development of benthic organisms

The density of venus clams are noted in Fig 5. The intense distribution areas were covered in 10 sq. kilometers in the southwest of studied areas, (108°10'16"- 108°12'28” E and 16°04'30”-16°06'29” N) . With an average density of 8.09 ind./m^2 and the range of 5.18-11.18 ind./m^2, the immediate stock of clams is estimated about 80,900,000 inds. However, the average width of clams in this study ranged in 16-26mm with the average of 19.67 ± 1.66 mm. According to Sang et al. [15], the width of venus clams was 62 mm and the size at first sexual maturity was 35.83 mm. And if the first spawn join size was taken as the mining limit, it shows that all the clams observed during this time wassmall in size and not allowed to be caught. Therefore, to protect the clam resources in this area, it is necessary to limit the exploitation time for this resource to recover.

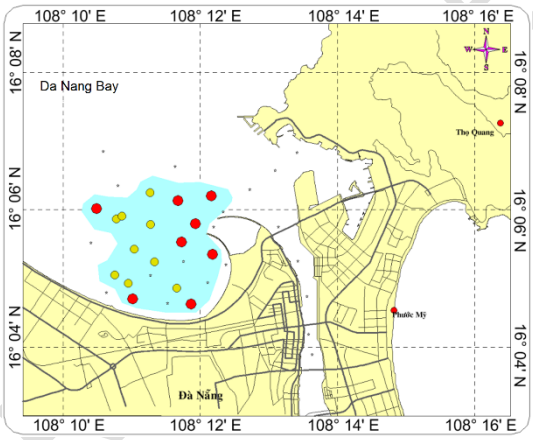

Fig. 5. Distribution of Venus clams in Da Nang Estuaries (left: density and right:)

4. CONCLUSION

In conclusion, the water environment nearby the bottom of the Da Nang estuary area was suitable for the development and distribution of venus clams. However, in the rainy season, the influence of river discharge has limited the distribution of the clams in the river area. The sedimentary environment also was ecologically optimum for the clams to grow, the bottom ground was mainly sand-mud and more than 50% of surveyed stations having organic sources suitable for clams. No clams were detected in the sandy or muddy bottom. The clams are more observed in areas with sandy/silty sediment. On the other hand, this study also partitioned the distribution of chips as well as evaluate their stock. However, because the clam size observed during this period was smaller than the first mature size, it is necessary to issue regulations on exploited period and fishing size for clams to protect these living resources.

In summary, the water environment near the bottom of Da Nang estuary was suitable for the growth and distribution of clams. However, in the rainy season, the influence of river water

flow limited the distribution of clams in the river area. The sediment was also ecologically optimal for clams to grow, the bottom was mainly sand-mud and more than 50% of the survey stations have organic sources suitable for clams. No clams were detected on sandy or muddy bottoms. Clams were observed more in areas with sand/mud deposits. On the other hand, this study also partitions chip distribution as well as evaluates their source. However, because the size of clams observed during this period is smaller than that of the first adult clam, it is necessary to promulgate regulations on harvesting time and clam size to protect this biological resource.

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee

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