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Population and Distribution of Hard Clams (*Meretrix* spp.) in the Mudflat Area front of The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Phetchaburi Province, Thailand

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Abstract

This research aims to study abundance and distribution of Hard clams in genus *Meretrix* and some environmental factors in the Mudflat area front of The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Laem Phak Bia Sub-district, Ban Laem District, Phetchaburi Province. Determine 3 survey lines, consisting of 1 survey line in an area that uninfluenced by the domestic wastewater treatment system (survey lines R) and 2 survey lines in an area that were influenced (survey line A and B), on each survey line determine sampling stations at 5 different distances from the coastline, starting from the mangrove shoreline toward the mudflats area. Research was conducted during December 2021 to December 2022. The results showed that Hard clam's population in this coastline have average density at 3.6 ± 4.4 ind./m² with no significant difference ($P < 0.05$) between population in each survey lines and significantly density different ($P < 0.05$) in each distance from the coastline, with highest density at 450 meters distance (7.4 ± 5.8 ind./m²)), following by 650 (5.2 ± 4.0 ind./m²) and 250 meters distance (3.6 ± 3.4 ind./m²), in order, with suspended solids, organic matter and relative proportion of sand, silt, and clay in the sediment as environmental factors that display a significance different ($P < 0.05$) in each distance from the coastline, due to soil properties at 250, 450 and 650 meters distance, which have average suspended solids range from 163.87 to 204.83 mg/l, soil organic matter range from 0.327 to 0.370 percent and ratio of sand, silt and clay content range between 61.49 to 79.32 percent, 15.78 to 33.80 percent and 4.37 to 4.90 percent respectively, with Sandy loam type of soil texture at 250 and 450 meters distance, which are the most suitable for Hard clams growth and survival. Hard clams's density was highest during winter season from December to February, which are the period that Hard clams were gathering in preparation for mating season.

Keywords: Hard clams; Abundance; Environmental factors; Mudflat

1. Introduction

Hard clams (*Meretrix* spp.) are brackish water bivalves with habitat found in the Indo-West Pacific, with widespread distribution from East China Sea to southern Indonesia (Palomares and Pauly, 2020; Poutiers, 1998). In Thailand, multiple variations of Hard clams can be found on open coasts and estuary area (Thuaycharoen and Benjamalai, 1986; Yoosukh and Matsukuma, 2001). In the present, Hard clam's popularity and demand for consumption is more widespread, however as the demand of Hard clams went up, it may cause an excessive harvest that exceed the limit of Hard clam's population recovery and harvesting potential for each individual area. (Thuaycharoen and Benjamalai, 1986; Khowhit, 2016)

The Mudflat area of Laem Phak Bia Sub-district, Ban Laem District, Phetchaburi Province were mudflat area around 1,500 meters wide front of mangrove forest which received an effluent from Phetchaburi domestic wastewater treatment system of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, which is freshwater with nutrient from treated domestic wastewater. The effluent flows though natural mangroves forest area and runoff toward coastline causing a shift in surrounding ecosystem into an area with abundant Hard clams and others aquatic animal (Phonlar, 2014; Sroikham, 2014; Songmuang, 2015; Khowhit, 2016; Khowhit and Chunkao, 2016). Fisheries activity in the area along with change in climate may have an impact on mudflat potential as Hard clam's production sites, therefore, this research aim to study abundance and distribution of *Meretrix* and some environmental factors in the mudflat area front of The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Laem Phak Bia Sub-district, Ban Laem District, Phetchaburi Province in order to find guidelines for management purpose in the future.

2. Methodology

2.1 Determine the sampling sites

Study sites in the mudflat area front of The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Laem Phak Bia Sub-district, Ban Laem District, Phetchaburi Province (Laem Phak Bia Project) include both areas influenced and uninfluenced by effluent from Laem Phak Bia Project domestical wastewater treatment system. Effluent from wastewater treatment system was released on natural mangroves 920 meters in length before runoff toward the mudflats area. Determine 3 survey lines, consist of 1 survey lines in mudflat area uninfluenced by the effluent (survey lines R) and 2 survey lines in mudflat area influenced by the effluent (survey lines A and B) (with 200 meters distance between each survey lines), on each survey lines, determine sampling stations at 50, 250, 450, 650 and 850 meters distance from natural mangrove edges (Figure 1).

2.2 Hard clam's sample collection

Collect Hard clam's samples with 1 square meter quadrat in determined sampling stations area (Figure 1), by using shovel to dig 15 centimeters below soil surface and panning the soil with 2 millimeters aperture sieve. Repeat sample collection 3 times per sampling station during the lowest tide, collect sample for every 2 months from December 2021 to December 2022 for 7 times in total.

2.3 Environmental factors

1) Water quality

Collect seawater samples in same area as Hard clam samples during highest tide (in the same day as the Hard clams sampling) from 30 centimeters above coastal soil for every 2 months from December 2021 to December 2022 for 7 times in total. Perform analysis of water quality for water temperature, dissolved oxygen (DO), pH, electrical conductivity (EC), Salinity and Total Dissolved Solids (TDS) on field, while collecting water samples in 1 liters HDPE bottles. Bring samples to analyses in laboratory as per indicated in Table 1 by using analysis method based on APHA and AWWA standards (American Public Health Association, 2017)

2) Sediment quality

Collect sediment in same area as Hard clam samples, By collecting sediment sample from 15 centimeters below soil surface during Hard clam samples collecting process. Air dry sediment samples then analyse sediments quality in laboratory as per indicated in Table 2 by using analysis method based on International Soil Reference and Information Centre standards (Van Reeuwijk, 2002).

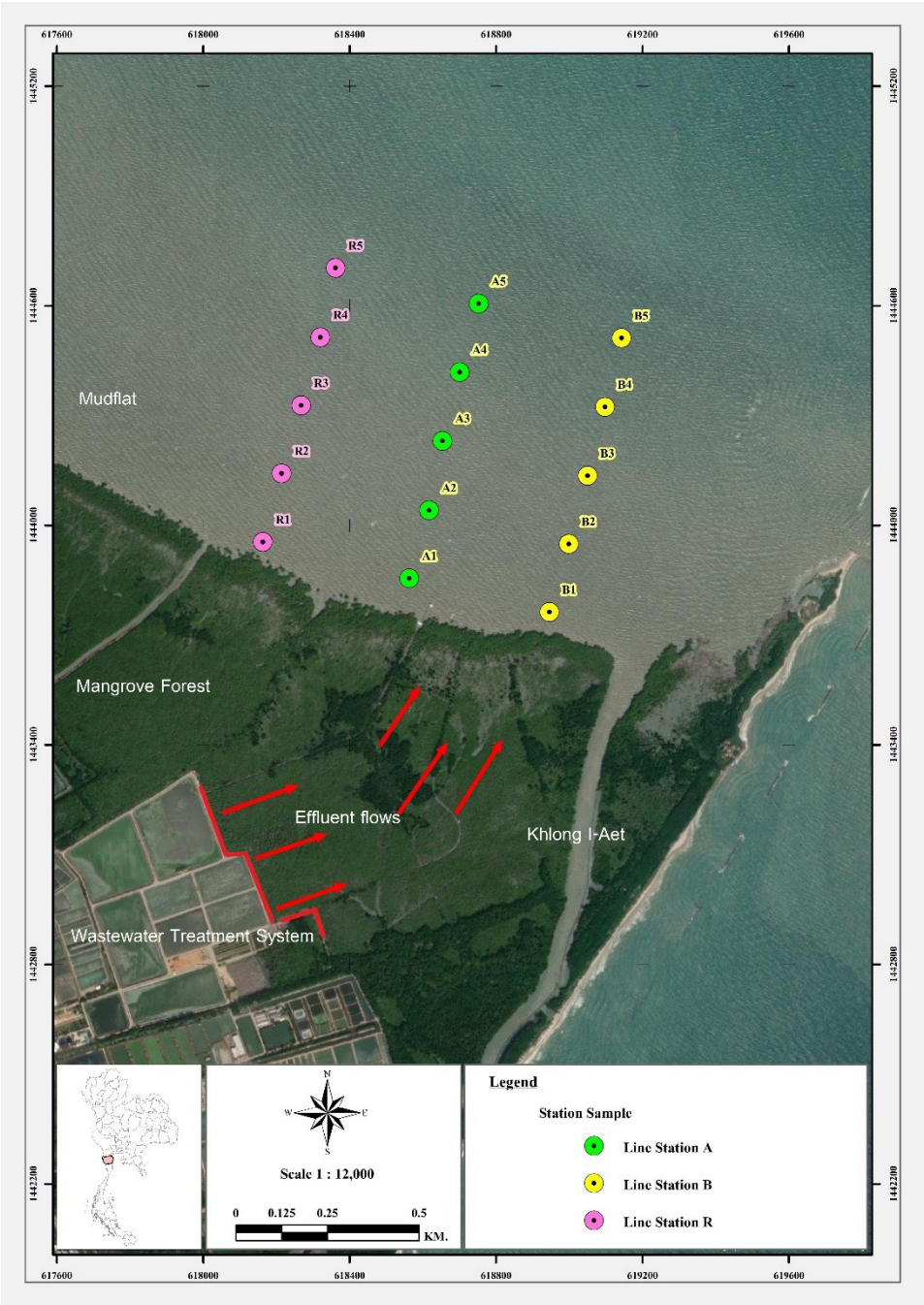


Figure 1. Study sites and sampling stations in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Phetchaburi Province

Table 1. Water quality parameters and methods of analysis in the laboratory

Order	Water quality parameters	Methods
1	Biochemical Oxygen Demand (BOD)	Azide Modification Method
2	Alkalinity	Titration Method
3	Hardness	EDTA Titrimetric Method
4	Suspended Solids (SS)	Gravimetric analysis
5	Total Kjeldahl Nitrogen (TKN)	Kjeldahl Titration
6	Ammonia (NH3)	Colorimetric method
7	Nitrate (NO3-)	Cadmium reduction method
8	Orthophosphate	Ascorbic Acid method
9	Total phosphorus	Sulfuric acid-Nitric acid Digestion

Table 2. Sediment quality parameters and methods of analysis

Order	Sediment quality parameters	Methods
1	Soil texture	Hydrometer Analysis
2	Sediment pH	pH probe
3	Organic Matter	Walkley and Black method

3. Results and Discussion

3.1 General condition of study

The coastal area front of Laem Phak Bia Project natural mangrove has characteristic of mudflat area with continuous slope from mangrove shoreline reaching toward the sea. The area was completely flooded during the highest tide and during the lowest tide mudflat surface will be exposed above the water (Figure 2).

3.2 Water quality

Water quality in the mudflat area front of Laem Phak Bia Project from 3 survey lines (survey line R, A and B) which include 2 survey lines that are influenced by effluent from Laem Phak Bia Project (Survey line A and B) and 1 survey lines that are uninfluenced by effluent (Survey line R) during December 2021 to December 2022 have details as follows

1) Water temperature, Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD)

Seawater quality has an average temperature at 27.6 ± 2.10 °C average Dissolved Oxygen (DO) and BOD at 6.87 ± 0.94 and 1.25 ± 0.94 mg/L, respectively. Water temperatures were in suitable range for living and growth of aquatic organisms (25 - 30 °C range) (Boyd & Lichtkoppler,1979; Musik, 1996) with water temperature that are suitable for juvenile Hard clams in genus *Meretrix* at 12.2 - 35.6 °C range (Zhimin *et al.,* 2010). Dissolved oxygen were in acceptable range according to Marine water quality standard type 1 for conservation of natural resources (Pollution Control Department, 2549) water temperature have showed a slight uptrend during February to June and downtrend during August to December (Figure 3) cause by seasonal temperature change (Boontongmai, 2020) which have highest tide period during the day and therefore receive heat energy from sunlight all day long from February to June which cause slightly higher temperature, while during August to December highest tide were occurred during the night which seawater release it heat back to the atmosphere cause water temperature to slightly lowered, while dissolved oxygen trend change in opposite direction from water temperature due to water capability to dissolve oxygen were lowered when water temperature increased and raised when temperature decreased (Boyd and Lichtkoppler,1979; Na Chiang Mai, 1982).

When compared by the survey lines, there are no statistical significance difference ($p < 0.05$) between temperature, dissolved oxygen and BOD of seawater (Table 3), same with the distance from the coastline which display no significance difference ($p < 0.05$) between temperature, dissolved

During highest tides During lowest tides

Figure 2. General conditions the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project

oxygen and BOD of seawater either (Table 4) due to coastal area were a relatively small enclosure area which were affected in a similar way by the tides while receive comparatively lower amount of effluent, and therefore have less impact on coastal water quality change. (Aksornkoae, 1998; Nukeaw *et al.,* 2022).

2) Potential of Hydrogen (pH), Hardness and Alkalinity

Water quality has an average pH at 8.2 ± 0.18, hardness and alkalinity at 5,557.42 ± 1,029.76 and 118.32 ± 15.75 mg/L, respectively. Seawater has pH in acceptable range according to Marine water quality standard type 1 for conservation of natural resources (Pollution Control Department, 2549) and has alkalinity in suitable range for aquatic animal living (Boyd and Lichtkoppler, 1979). Seawater has similar level of pH all year round, while hardness and alkalinity display uptrend from December to August (Figure 3) due to winter season, especially during January to February, was a period that area receive higher influence from tides when compared to another months, which cause influx of water mass with high salinity, hardness and alkalinity toward the coastal area, while rainy season has more influence from runoff from soil surface toward water reservoir which cause hardness to increase as a result (Duangsawat and Somsri, 1985; Boontongmai, 2020).

When compare pH, hardness and alkalinity value by both the survey line and distance from the coastline, result reveal no significance difference ($p < 0.05$) (Table 3 and Table 4) due to coastal surrounding were set in a small area with 3 survey line in close proximity to each other and receive influence of tides from Gulf of Thailand in the same direction, which are contributing cause for similarity of water quality (Aksornkoae, 1998; Boontongmai, 2020).

3) Salinity, Conductivity and Total Dissolved Solids

Seawater quality has average salinity at 27.83 ± 5.65 psu, conductivity at 44.16 ± 5.20 mS/cm and Total Dissolved Solids at 34.50 ± 4.91 mg/L. Salinity, conductivity and total dissolved solids all have uptrend during December to February, however salinity has downtrend during Aprill to June (Figure 3) due to December to February were period that have highest tides in annual cycle which bring water mass with higher salinity from ocean toward coastal area (Boontongmai, 2020), additionally salt farm activity in nearby area during dry season (Khowhit, 2016) cause coastal water to have increase amount of salinity, conductivity and total dissolved solids due to correlation of these parameter and salinity level of water (Duangsawat and Somsri, 1985; Aksornkoae, 1998).

4) Suspended Solids

Seawater quality has average suspended solids at 194.41 ± 114.79 mg/L which are in suitable range for living of organism (Duangsawat and Somsri, 1985) but also enough to impact filtration capability of bivalve (Tuttle-Raycraft *et al.,* 2017). Suspended solids

have uptrend during August to December and have downtrend in another month while remain relatively stable (Figure 3) due to August to December were a period that Gulf of Thailand receive influence from northeast monsoon causing strong wave and current (Tepparos *et al.,* 2022; Imlamai *et al.,* 2023) especially during December 2022 (Thai Meteorological Department, 2565) which cause coastal sediment to stir up, in conjunction with runoff toward the sea during rainy season, cause amount of suspended solids in water to increase (Duangsawat and Somsri, 1985).

When compare average suspended solids by distance from the coastline, there are significance difference ($p < 0.05$) with highest average suspended solids at 50 meters distance, follows by 250, 450, 650 and 850 meters distance from coastline, in order (Table 4), due to shallow water of coastal area and precipitation of numerous small particle during high tide which have wave and water current stir up sediment toward coastline along with influence on coastal area from effluent from Ban Phanen community, Laem Phak Bia Project and Khlong I-Aet community, which have suspended organic and inorganic matter in water constantly flow down toward the coastline, and therefore cause suspended solids to be higher as mangrove forest area were approached (Boontongmai, 2020; Pholchart, 2023).

5) Total Kjeldahl Nitrogen (TKN), Ammonia and Nitrate

Seawater quality has average Total Kjeldahl Nitrogen (TKN), ammonia and nitrate at 0.18 ± 0.15, 0.06 ± 0.07 and 0.14 ± 0.18 mg/L, respectively. Average amount of ammonia and nitrate were in acceptable range according to Marine water quality standard type 1 for conservation of natural resources (Pollution Control Department, 2549). TKN have uptrend during Aprill to June and downtrend during December to February, while ammonia show downtrend during December to Aprill period due to runoff of substance with nitrogen in composition toward water reservoir during rainy seasons (Duangsawat and Somsri, 1985). At the same time, nitrate that were increased during December to February period and decreased during Aprill to June period were due to amount of dissolved oxygen that increased during October to December period which increase nitrification by during that (Aksornkoae, 1998; Menasveta, 2000, Pholchart, 2023).

6) Total Phosphate and Orthophosphate

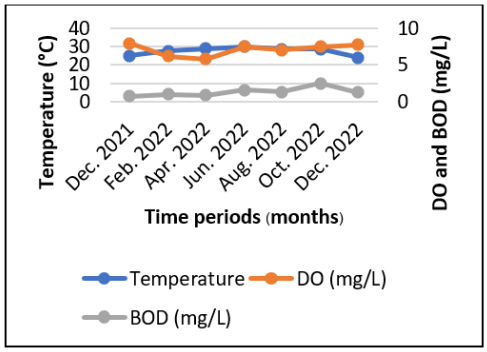
Seawater quality has average total phosphate and average orthophosphate at 0.09 ± 0.08 and 0.04 ± 0.04 mg/L, respectively. The average amount of total phosphate was in acceptable range according to Marine water quality standard type 1 for conservation of natural resources (Pollution Control Department, 2549). Orthophosphate display continuous uptrend during Aprill to December while total phosphate show uptrend during October to December (Figure 3) due to runoff of organic phosphate into water reservoir during rainy season (Duangsawat and Somsri, 1985) and solubilization of phosphate by bacteria into orthophosphate (Pholchart, 2023)

7) Soil quality

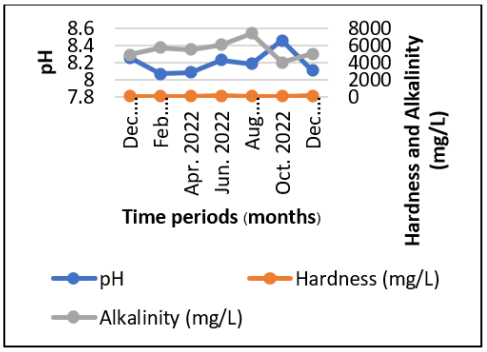
Soil quality in the mudflat area front of Laem Phak Bia Project mangrove forest from 3 survey lines (survey line R, A and B) which include 2 survey lines that are influenced by effluent from Laem Phak Bia Project (Survey line A and B) and 1 survey lines that are uninfluenced by effluent (Survey line R) during December 2021 to December 2022 have details as follows

(1) Potential of Hydrogen (pH)

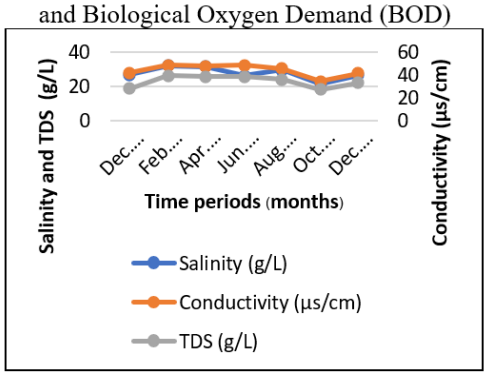
Soil has average pH at 8.69 ± 0.31 with Average pH show downtrend during October to February (Figure 4), which consistent with seawater pH trend that show downtrend during December to February due to decrease in rainfall water during winter which lead to less dilution of seawater (Boontongmai, 2020). When compare by the survey line and by distance from the coastline, there are no significance difference ($p < 0.05$) (Table 5 and Table 6) due to each survey line were in close approximately on the coastal area cause the area to receive influence from tides in same way, and therefore have similar soil composition, nutrient and bacteria capability to break down organic matter in soil, causing sediment to have similar level of pH (Boontongmai, 2020).



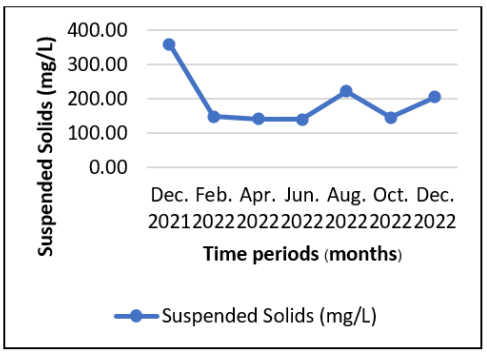
(A) Temperature, Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD)



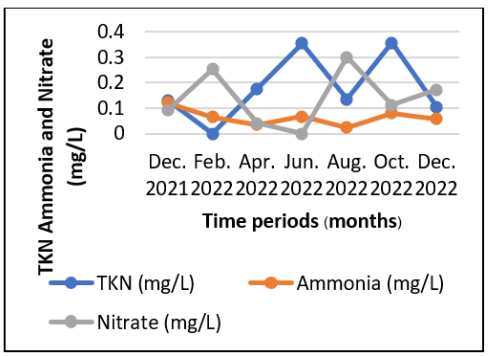
(B) Seawater pH, Hardness and Alkalinity



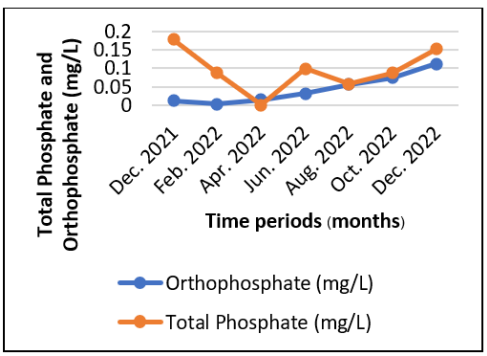
(C) Salinity, Conductivity and Total Dissolved Solids



(D) Suspended Solids



(E) Total Kjeldahl Nitrogen, Ammonia and Nitrate



(F) Total Phosphate and Orthophosphate

Figure 3. Water quality in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project from December 2021 to December 2022

Table 3. Average water quality by the survey lines in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Subdistrict Banlaem Phetchaburi province

Order	Water quality parameters	Survey lines			Average
		R	A	B	
1	Temperature (°C)	27.55 ± 2.16[a]	27.62 ± 2.23[a]	27.64 ± 1.95[a]	27.60 ± 2.01
2	Dissolved Oxygen (mg/L)	7.14 ± 0.83[a]	7.05 ± 0.80[a]	7.13 ± 0.91[a]	7.11 ± 0.84
3	Biological Oxygen Demand (mg/L)	1.32 ± 0.88[a]	1.29 ± 0.90[a]	1.37 ± 1.05[a]	1.32 ± 0.94
4	Seawater pH	8.21 ± 0.23[a]	8.19 ± 0.16[a]	8.21 ± 0.17[a]	8.20 ± 0.18
5	Alkalinity (mg/L)	119.83 ± 15.58[a]	118.37 ± 16.68[a]	116.75 ± 15.25[a]	118.32 ± 15.75
6	Hardness (mg/L)	5488 ± 1020[a]	5560 ± 1142[a]	5623 ± 942[a]	5557 ± 1029
7	Salinity (psu)	28.50 ± 3.98[a]	28.67 ± 3.78[a]	26.34 ± 8.01[a]	27.83 ± 5.65
8	Conductivity (mS/cm)	43.92 ± 5.51[a]	44.15 ± 5.25[a]	44.41 ± 4.96[a]	44.16 ± 5.20
9	Total Dissolved Solids (mg/L)	34.34 ± 5.08[a]	34.46 ± 5.03[a]	34.71 ± 4.74[a]	34.50 ± 4.91
10	Suspended Solids (mg/L)	195.92 ± 122.55[a]	195.34 ± 115.52[a]	191.96 ± 109.23[a]	194.41 ± 114.79
11	Total Kjeldahl Nitrogen (mg/L)	0.203 ± 0.156[a]	0.160 ± 0.141[a]	0.176 ± 0.168[a]	0.180 ± 0.155
12	Ammonia (mg/L)	0.083 ± 0.102[a]	0.049 ± 0.041[a]	0.060 ± 0.048[a]	0.064 ± 0.070
13	Nitrate (mg/L)	0.162 ± 0.186[a]	0.119 ± 0.211[a]	0.133 ± 0.154[a]	0.138 ± 0.185
14	Orthophosphate (mg/L)	0.047 ± 0.045	0.041 ± 0.040[a]	0.042 ± 0.040[a]	0.044 ± 0.042
15	Total Phosphate (mg/L)	0.105 ± 0.070[a]	0.106 ± 0.087[a]	0.121 ± 0.084[a]	0.111 ± 0.080

Table 4. Average water quality by distance from the coastline in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Subdistrict Banlaem Phetchaburi province

Order	Water quality parameters	Distance (meters)					Average
		50	250	450	650	850	
1	Temperature (°C)	27.35 ± 2.18[a]	27.60 ± 2.12[a]	27.66 ± 2.19[a]	27.68 ± 2.18[a]	27.71 ± 2.01[a]	27.60 ± 2.01
2	Dissolved Oxygen (mg/L)	6.90 ± 0.86[a]	7.21 ± 0.92[a]	7.16 ± 0.78[a]	7.13 ± 0.85[a]	7.12 ± 0.83[a]	7.11 ± 0.84
3	Biological Oxygen Demand (mg/L)	1.41 ± 1.13[a]	1.32 ± 0.54[a]	1.27 ± 0.96[a]	1.31 ± 0.99[a]	1.29 ± 1.05[a]	1.32 ± 0.94
4	Seawater pH	8.17 ± 0.26[a]	8.18 ± 0.12[a]	8.22 ± 0.15[a]	8.22 ± 0.18[a]	8.23 ± 0.19[a]	8.20 ± 0.18
5	Alkalinity (mg/L)	122.81 ± 19.31[a]	116.15 ± 15.82[a]	117.76 ± 14.40[a]	117.52 ± 14.70[a]	117.33 ± 14.66[a]	118.32 ± 15.75
6	Hardness (mg/L)	5550 ± 1161[a]	5569 ± 1051[a]	5564 ± 1037[a]	5495 ± 977[a]	5608 ± 1010[a]	5557 ± 1029
7	Salinity (psu)	28.07 ± 4.32[a]	28.50 ± 4.00[a]	27.41 ± 6.63[a]	27.56 ± 6.60[a]	27.61 ± 6.56[a]	27.83 ± 5.65
8	Conductivity (mS/cm)	43.43 ± 5.87[a]	43.96 ± 5.56[a]	44.31 ± 5.12[a]	44.50 ± 4.96[a]	44.59 ± 4.84[a]	44.16 ± 5.20
9	Total Dissolved Solids (mg/L)	33.95 ± 5.44[a]	34.36 ± 5.12[a]	34.66 ± 4.80[a]	34.65 ± 4.90[a]	34.88 ± 4.67[a]	34.50 ± 4.91
10	Suspended Solids (mg/L)	270.41 ± 194.95[a]	204.83 ± 103.80[ab]	174.40 ± 66.62[b]	163.87 ± 59.13[b]	158.54 ± 53.59[b]	194.41 ± 114.79[b]
11	Total Kjeldahl Nitrogen (mg/L)	0.208 ± 0.187[a]	0.203 ± 0.137[a]	0.165 ± 0.174[a]	0.149 ± 0.142[a]	0.173 ± 0.135[a]	0.180 ± 0.155
12	Ammonia (mg/L)	0.104 ± 0.118[a]	0.055 ± 0.041[a]	0.042 ± 0.041[a]	0.060 ± 0.059[a]	0.058 ± 0.051[a]	0.064 ± 0.070
13	Nitrate (mg/L)	0.165 ± 0.154[a]	0.086 ± 0.153[a]	0.143 ± 0.186[a]	0.169 ± 0.217[a]	0.127 ± 0.208[a]	0.138 ± 0.185
14	Orthophosphate (mg/L)	0.050 ± 0.051[a]	0.049 ± 0.047[a]	0.038 ± 0.040[a]	0.040 ± 0.036[a]	0.041 ± 0.034[a]	0.044 ± 0.042
15	Total Phosphate (mg/L)	0.125 ± 0.123[a]	0.104 ± 0.087[a]	0.078 ± 0.064[a]	0.083 ± 0.068[a]	0.084 ± 0.057[a]	0.095 ± 0.083

Note: Means in a same row followed by the different letters are significantly different by LSD ($P < 0.05$)

(2) Organic matter

Soil has 0.39 ± 0.24% average organic matter with organic matter level remains similar in each month, however, there are uptrend from June to August (Figure 4) which are in rainy season that has frequent runoff along with influence from southwest monsoon which lead to higher amount of sediment flow towards the coastal area (Imlamai *et al.,* 2023), and higher sedimentation of organic matter in this period.

When compare average organic matter by the survey line, there are significance difference ($p < 0.05$), with higher average organic matter in survey line R more than survey line B and A, respectively (Table 5), due to survey line R receive influence from effluent from Ban Phanen community and Laem Phak Bia Project effluent, while survey line B which receive influence from Khlong I-Aet community and northern agricultural area effluent that cause higher deposit in the area (Boontongmai, 2020). When compare organic matter by distance from coastline, there are significance difference ($p < 0.05$), with highest organic matter at 50, 450, 850, 250 and 650 meters distance, in order (Table 6), which are due to high amounts of organic matter deposition in mangrove forest and nearby area, along with dilution which decreased amount of organic matter found (Jitthaisong, 2012) and cause average organic matter at 50 meters distance from coastline to be distinctively higher than another area.

(3) Soil texture

Soil in the mudflat area has Sandy loam type of soil texture, with proportion of Sand particle, Silt particle and Clay particle at 68.22 ± 22.16%, 26.38 ± 20.84% and 7.22 ± 2.56%, respectively. When compare soil texture by survey months, it was found that Sand particle have uptrend during February to June and decrease during August to December (Figure 4) due to higher influence of seawater during dry season that carry large precipitate inward which increase amount of Sand particles, while during rainy season from May to November there are increase accumulation of Silt and Clay particles which have small particles size, due to runoff toward water reservoir that flow out and precipitated in the coastal area (Boontongmai, 2020).

Soil texture compared by distance from the coastline have significance difference ($p < 0.05$), with proportion of Sand, Silt and Clay that cause soil texture at 50 meters distance to be Loam, at 250 and 450 meters distance to be Sandy loam, and cause soil texture at 650 and 850 meters distance to be Loamy sand, with increase proportion of Sand as distance from coastline increase, which were in line with result from year 2012 to 2013 study by Khowhit (2016), due to sand particle get carried toward coastal area by high tide, along with sedimentation from mangrove forest and effluent from Laem Phak Bia Project, Ban Phanen and Khlong I-Aet community, which cause accumulation of Clay particles which have small particle size in the coastal area (Boontongmai, 2020).

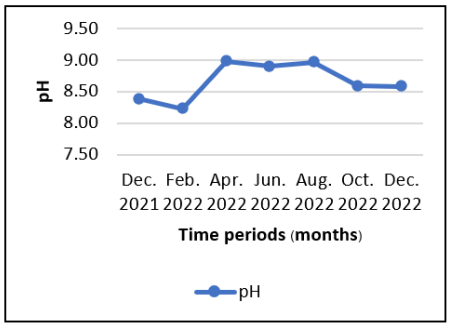
8) Density and distribution of Hard clam's population

Hard clams (*Meretrix* spp.) in mudflat area front of Laem Phak Bia Project have average density 3.6 ± 4.4 ind./m², which increase when compared to the past during May 2012 to Aprill 2013 which have average density 16 ind./m2 (Khowhit and Chunkao, 2016). In present, there are highest number of Hard clams during December 2021 with average density 6.2 ± 7.5 ind./m², follows by February 2022 and December 2022, in order, with average density at 4.4 ± 5.0 and 4.0 ± 3.6 ind./m², respectively, and there are lowest number of Hard clams during Aprill 2022 with average density 2.2 ± 2.9 16 ind./m² (Figure 5), which were in line with Hard clams study in mudflat front of Laem Phak Bia Project during May 2012 to Aprill 2013, which highest number of Hard clams during winter seasons, especially during December 2012 (density 2.7 ind./m²) (Khowhit and Chunkao, 2016), which are period that Hard clams were gathering in preparation for mating from February to Aprill, therefore, Hard clams population can be found in large quantity during this period (Khowhit, 2016; Khowhit and Chunkao, 2016).

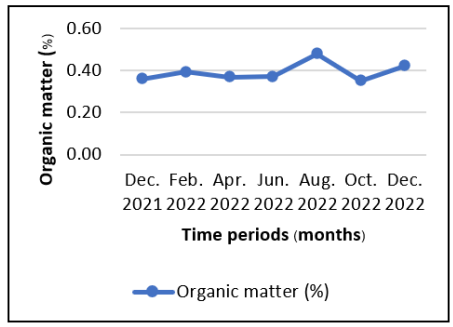
When compare average Hard clam density by survey line, result reveal no significance difference ($p < 0.05$) (Table 7), however, the result were in contradict with Khowhit and Chunkao finding (2016),

which have highest Hard clam density in area near Khlong I-Aet, which was on eastern direction of the study site, and were in close approximate to survey line B, and then as distance increase gradually toward western direction, the area were in approximate to survey line A and R, respectively, due to soil property, wave, current and water quality gradual change over years.

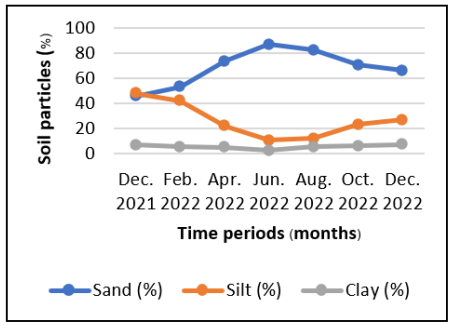
When compare by the distance from coastline, result display significance difference ($p < 0.05$), with highest density at 450 meters distance, which have average density 7.4 ± 5.8 ind./m² (41.25% of total Hard clam that were found in this study), follows by, 650 and 250 meters distance, which have average density 5.2 ± 4.0 and 3.6 ± 3.4 ind./m² (28.85% and 19.88% of total Hard clam), respectively (Table 8), due to soil at 450 and 250 meters distance have Sandy loam type of soil texture that are suitable for Hard clams living, which were in line with Hard clams study in Laem Phak Bia mudflat during May 2012 to Aprill 2013, which found highest Hard clams (*Meretrix* casta) at 300 meter distance from coastline due to Sandy loam type of soil texture and higher organic matter in soil when compare to another distance from coastline (Khowhit and Chunkao, 2016).



(A) Soil pH



(B) Organic matter



(C) Soil texture

Figure 4. Soil quality in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project from December 2021 to December 2022

Table 5. Average soil quality by the survey lines in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Subdistrict Banlaem Phetchaburi province

Order	Soil quality parameter	Survey lines			Average
		R	A	B	
1	Soil pH	8.67 ± 0.26	8.66 ± 0.33	8.64 ± 0.34	8.66 ± 0.31
2	Organic matter (%)	0.467 ± 0.333[a]	0.314 ± 0.150[b]	0.402 ± 0.175[ab]	0.391 ± 0.239
3	Soil texture	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
4	Percentages of Sand (%)	65.16 ± 22.47	69.16 ± 21.57	70.34 ± 22.73	68.22 ± 22.16
5	Percentages of Silt (%)	29.47 ± 20.63	25.91 ± 20.57	23.75 ± 21.50	26.38 ± 20.84
6	Percentages of Clay (%)	5.37 ± 3.07	4.96 ± 2.79	5.91 ± 2.71	5.41 ± 2.86

Note: Means in a same row followed by the different letters are significantly different by LSD ($P < 0.05$)

Table 6. Average soil quality by distance from the coastline in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Subdistrict Banlaem Phetchaburi province

Order	Soil quality parameter	Distance (meters)					Average
		50	250	450	650	850	
1	Soil pH	8.54 ± 0.37	8.67 ± 0.28	8.69 ± 0.29	8.70 ± 0.28	8.69 ± 0.32	8.66 ± 0.31
2	Organic matter (%)	0.547 ± 0.252^{a}	0.342 ± 0.141^{b}	0.370 ± 0.161^{b}	0.327 ± 0.142^{b}	0.369 ± 0.365^{b}	0.391 ± 0.239
3	Soil texture	Loam	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand	Sandy Loam
4	Percentages of Sand (%)	43.42 ± 20.28^{a}	61.49 ± 21.61^{b}	74.09 ± 16.26^{c}	79.32 ± 14.68^{c}	82.77 ± 10.64^{c}	68.22 ± 22.16
5	Percentages of Silt (%)	48.09 ± 19.73^{a}	33.80 ± 21.31^{b}	21.54 ± 15.29^{c}	15.78 ± 13.96^{c}	12.68 ± 9.63^{c}	26.38 ± 20.84
6	Percentages of Clay (%)	8.49 ± 2.40^{a}	4.71 ± 1.86^{b}	4.37 ± 2.46^{b}	4.90 ± 2.87^{b}	4.60 ± 2.56^{b}	5.41 ± 2.86

Note: Means in a same row followed by the different letters are significantly different by LSD ($P < 0.05$)

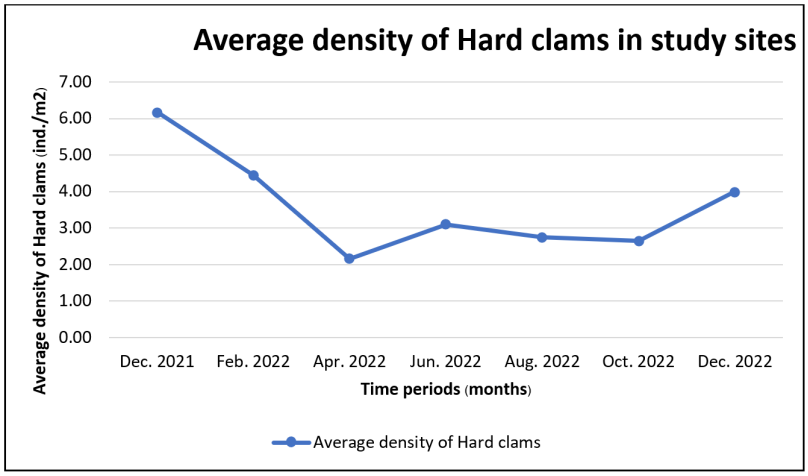


Figure 5. Average density of hard clams in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project from December 2021 to December 2022

Table 7. Average density and distribution of hard clams in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project from December 2021 to December 2022 by the survey lines

Hard clams	Survey lines			
	R	A	B	Average
Average density (ind./m^2)	4.5 ± 5.3	3.5 ± 4.4	2.8 ± 3.1	3.61 ± 4.4
Distribution (percentage)	41.25	32.72	26.03	

Table 8. Average density and distribution of hard clams in the mudflat area front of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project from December 2021 to December 2022 by distance from the coastline

Hard clams	Distance (meters)					
	50	250	450	650	850	Average
Average density (ind./m^2)	0.1 ± 0.2^{a}	3.6 ± 3.4^{bc}	7.4 ± 5.8^{d}	5.2 ± 4.0^{c}	1.7 ± 1.6^{ab}	3.6 ± 4.4
Distribution (percentage)	0.62	19.88	41.25	28.85	9.41	

Note: Means in a same row followed by the different letters are significantly different by LSD ($P < 0.05$)

4. Conclusion

Abundance and distribution of Hard clam in genus *Meretrix* in mudflat area front of The King's Royally Initiated Laem Phak Bia Environmental Research and Development Project, Laem Phak Bia Sub-district, Ban Laem District, Phetchaburi Province, mangrove forest from December 2021 to December 2022 have average density 3.6 ± 4.4 ind./m². Hard clam in mudflat have similar distribution along horizontal axis of the coastline, however distribution along distance from the coastline were different with highest density at 450 to 650 meters distance from mangrove shoreline, which account for 41.25% and 28.85% of total Hard clam that were found in this study, respectively, and lowest density at 50 meters distance, which account for 0.62% of total Hard clam that were found in this study. Hard clams have highest density during December 2021 and February 2022, which account for 24.51% and 17.39% of total Hard clam that were found in this study, respectively, and lowest density during April 2022 which account for 8.70% of total Hard clam that were found in this study. Environmental factors that have influence on density and distribution of Hard clam in genus *Meretrix* were suspended solids and mainly the soil texture type which are Sandy loam that suitable for Hard clam living. Highest number of Hard clams were found during pre-mating season which is during winter season that Hard clams gather in preparation for mating during rainy season.

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