The study of physical factors affecting habitats suitability for increasing growth of mussels

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Abstract

First, I set the study area around the Gulf of Thailand. All mussels that were collected belong to the species *Perna Viridis*. I found that the mussels in S3 area have the highest growth. From the study of biological factors, I found that the increase in number of barnacles decreases the growth of mussels. From the study of physical factors, I found that the growth of mussels increases with water flowrate. After that I studied the relationship between biological and physical factors and found that flowrate is inversely proportional to the number of barnacles and directly proportional to dissolved oxygen, both with statistical significance. I found that in every 7 square meters area, there are total number of 14 mussel poles, which I defined as Formation A. I found that mussel poles are affecting the flowrate. Therefore, I would like to create appropriate habitats for mussels by applying 3 new formation of mussel poles defined as Formation B, C, and D. I then tested them to see how it will affect the flowrate and found that Formation D makes water flow the fastest. When I increased the length into 3 farms, it still makes the water flow the fastest. After testing in laboratory, I tested these 4 formations in the real farm. I found that, in the real farm, formation D makes water flow the fastest and the growth of mussels is also the best. Calculation of the revenue revealed that it can make 6,280.66 USD.

In conclusion, an appropriate way of formatting the habitat of mussels will beneficially affect the flowrate and resulting in increase of mussel productivity. With Formation D that I had created, the productivity of mussel can be increased by 28 percent compared to the original way.

Key words: Mussels, Physical factors, Flowrate and formation of mussel poles

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Researcher

Introduction

"Mussels" is a species of cockles in the phylum Mollusca, Class Bivalvia. It has a common name of Green Mussel. There are 3 species of mussels: *Perna viridis, Perna perna* and *Perna canaliculus* (Rajagopal, 2005). Mussel is a sessile animal, sticking to a fixed habitat. As a result, most of its foods are plant planktons and small animals floating in the water. The most important organ of mussel is siphon which filtrates food flowing in the water into coelom. Mussel is considered a great natural water filter machine (Emilie, 2003).

Mussel is an economic animal that have been cultivated for a long time. Mussels live by sticking along rocks in the coastal area. They are found spreading along the coasts of many countries, such as Philippines, China, India, Singapore, Indonesia, and Thailand. In Thailand, we can typically find mussel in the provinces with coast, both on the Gulf of Thailand and Andaman Sea. Farmers choose to farm mussels because it is easy to raise, has high growth rate, is popular as a food, and it is a business that with low cost and labor (Thailand Department of Fisheries, 2007). Mussel brings a lot of income into the country of up to 13 – 22 million USD in each year (Thailand Department of Fisheries, 2013). There are many methods of mussels farming. The most popular method is to use the poles, because farmers can easily harvest the mussels and this method can also protect mussels form its natural predator (Asokan, 2008). This method is suitable for shallow depths of 4-6 meters in the mud or sand (Masen, 2017). Apart from the factors related to habitats, mussels farming must also take into account the physical factors as well (Sirichai, 2009).

Physical factors of sea water that affect the growth of mussels are 1) temperature: the suitable temperature for mussel is between 20 – 30 °C (Manoj, 2003). 2) salinity: the suitable salinity for mussel is between 20 – 25 ppt. (Sukhum, 2004). 3) dissolved oxygen: if there is more dissolved oxygen in the water, the growth of mussels will increase. It should also not be less than 2.4 mg/L (Suntree, 2011). 4) turbidity: if the turbidity is high, the growth of mussels will decrease, and turbidity should not exceed 80 NTU (Mackie, 2010). 5) flow rate: if there is less flowrate, the growth of mussels will decrease. (Nishizaki, 2017)

From the habitat factors which is the formatting of mussel pole, and the relationship of physical factors that affect mussel growth, I am interested in studying the ecology of mussels and factors that affects the habitat of mussels to create a suitable habitat to increase the growth and productivity of mussels for farmers.

Research Question

1. Which physical factors affects the suitability of mussel habitat?
2. Can suitable habitat of mussel increase the growth and productivity of mussel?

Objective

1. To study the ecology of mussel in the Gulf of Thailand.
2. To study the biological and physical factors affecting the suitability of mussel habitat
3. To create a suitable habitat for the mussel.

Hypothesis

1. If the biological and physical factors affect the habitat of mussel, then different biological and physical factors will affect the suitability of mussel habitat differently with statistical significance.
2. If the habitat affects the growth of mussel, then different habitats will affect the growth of mussel differently with statistical significance.

Method

1. Study area and population

Researcher has chosen the Gulf of Thailand area by Multi-Stage Sampling. First, specific sampling was conducted to choose a region with convenience of sampling as a criteria, which is the central region of Thailand. Then another specific sampling was conducted to choose provinces with the most production of mussels, which is Samut Sakhon (Thailand Department of Fisheries, 2013).

2. Tools and equipment

1. Camera
2. Boxes to collect animal sample
3. Vernier
4. Bottles to collect water sample
5. Container for drawing water
6. Secchi Disk
7. Flowrate probe
8. Thermometer
9. Plastic measuring cylinder
10. Hydrometer

3. Method

Study 1 The study of the ecology of mussel in the Gulf of Thailand

Researcher interviewed 5 farmers in Samut Sakhon about the distribution of mussels. Study area was divided into 3 areas. In each area, samples of mussel were collected using simple sampling method. The photo of external structure of mussel was taken to study the morphology. After that, the samples of mussel were compared with taxonomic key to identify species. Lengths of the mussels was measured to study the growth by collecting data every week for 6 months, 20 times and obtained total of 600 sets of data.

Study 2 The study of the biological and physical factors affecting the suitability of mussel habitat

Data collected on the growth of mussel were used to calculate the growth rate. Then the data on mussel samples living together with other animals were used to measure the size of those other animals to study their effects to the mussel growth. The data were collected for 6 months and obtained total of 600 sets of data. Next, researcher studied 5 physical factors, including temperature, salinity, dissolved oxygen, turbidity and flowrate of water. The depth of study was set to be 1-meter from the water surface at the Gulf of Thailand in Samut Sakhon which was studied for 6 months. After that, average value of each physical factors was taken to compare the difference in each area. Then the biological and physical factors were correlated. Relationship among physical factors with statistically significant difference in each area were determined using correlation analysis. And all of the factors were correlated with the growth of the mussel.

Study 3 The construction of a suitable habitat for increasing the growth of mussel

Researcher interviewed farmers and investigated the study sites to find the formation pattern of mussel poles that farmers are currently using. Then researcher reviewed literature and applied 3 new formations of mussel poles. Experiments were done in a tube that can simulate water flow and record the flowrate in each formation to determine the flowrate difference by comparing averages. After that, the number of mussel poles were extended from 1 farm to 3 farms and same experiments were conducted. These 4 formations of mussel poles were used in real farm to collect the flowrate and growth of mussel data.

Result

Study 1 The study of the ecology of mussel in the Gulf of Thailand

Part 1.1 the study of distribution of mussel

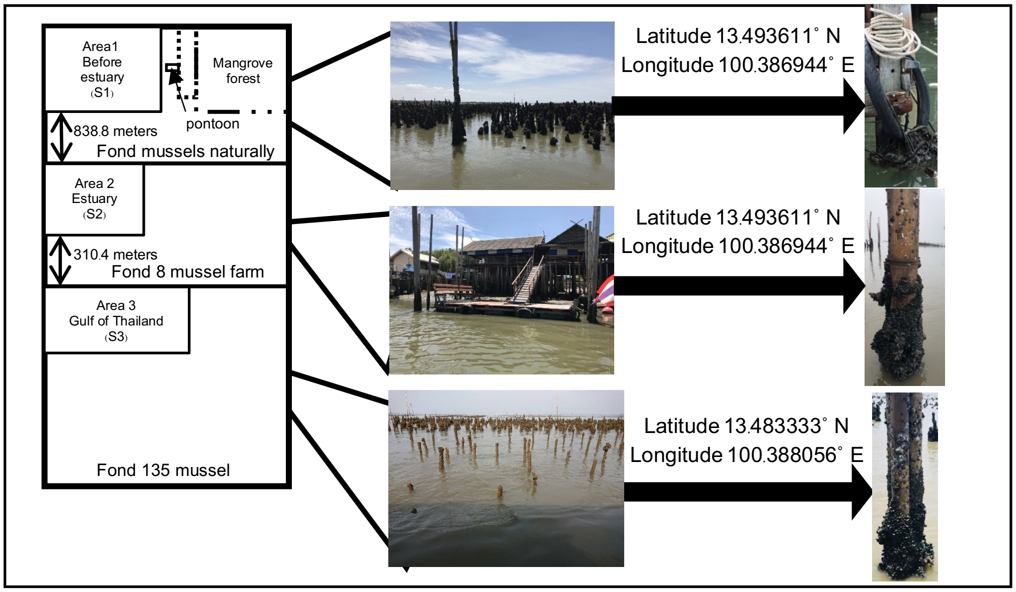


Figure 1 The distribution of mussels in Gulf of Thailand in Samut Sakhon

From figure 1, I found that there are 2 types of mussel distribution. The first one is natural distribution found in the area before estuary area, defined as S1 area. The second one is the distribution of mussels in the farms, which consists of 143 farms and can be divided into 2 areas. The estuary area was defined as S2, with total of 8 farms, and the Gulf of Thailand area was defined as S3, with total of 135 farms. Then 1 farm and 1 pole was chosen in each area to be the study group.

Part 1.2 Morphology and species of mussels in the Gulf of Thailand

From figure 2, mussels have hard smooth shell. The top is called dorsal. The bottom is called ventral, which has bysuss. The anterior side has an umbo and the posterior side is curved. Study group from morphology study was identified using taxonomic key (Rajagopal, 2005).

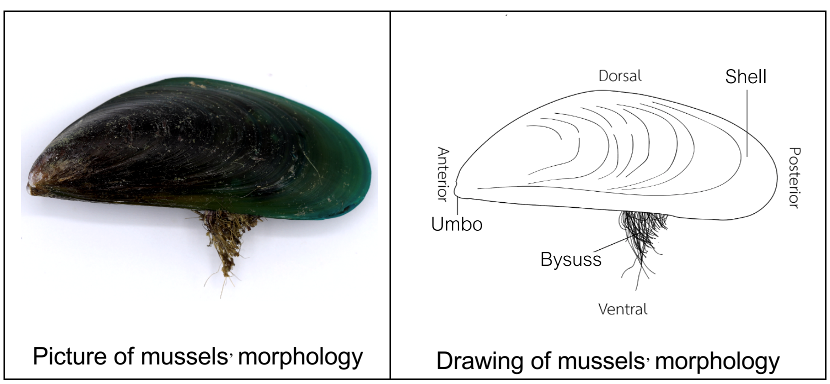
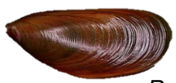


Figure 2 The external morphology of mussels in the Gulf of Thailand

Table 1 The number and species of mussel in the Gulf of Thailand

Taxonomy/structure		Number and the sample's picture		
		S1 area	S2 area	S3 area
 *Perna Viridis*	- Shell is green, black and smooth - Area between two shells is browner than other places	 200	 200	 200
 *Perna perna*	- Shell is brown - Color and shape of shell can change depending on environment	Not found	Not found	Not found
 *Perna canaliculus*	- Shell is light-brown and green	Not found	Not found	Not found

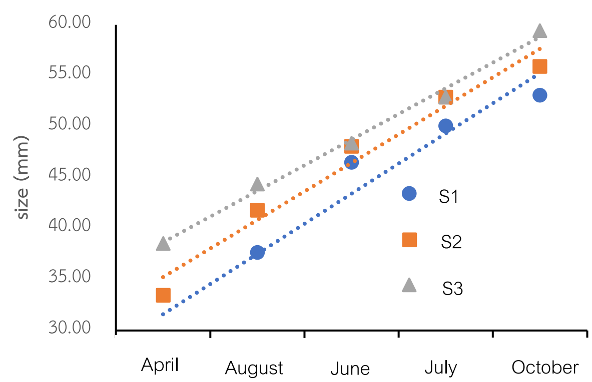
From table 1, 200 samples of mussels in each area were compared with the taxonomic key and found that all 600 mussels in all 3 areas are *Perna Viridis*

Part 1.3 The growth of mussels

Table 2 The size of mussels in all 3 area since April to October

month	The size of mussels (mm)			
	S1	S2	S3	Average
April	29.75	33.49	38.53	33.92
August	37.65	41.80	44.39	41.28
June	46.54	48.09	48.38	47.67
July	50.10	52.90	52.93	51.97
October	53.12	55.96	59.46	56.18
Average (mm)	43.43	46.45	48.74	46.20*

* statistically significant at the 0.05 level



Graph1 The size of mussels in all 3 area since April to October

The data of mussels in all 3 areas show that the size of mussels in all 3 areas are different with statistical significance. The mussels in S3 has the largest average size of 48.74 mm. S1 area has the least average size of mussels of 43.43 mm. After that, sizes of mussels *Perna Viridis* were used to calculate the growth rates of mussels.

Table 3 growth rate of mussel in all 3 studies areas since April to October

Month	Growth rate of mussel (mm)			
	S1	S2	S3	Average
April	0.00	0.00	0.00	0.00
August	7.90	8.32	5.86	7.36
June	8.89	6.29	3.99	6.39
July	3.55	4.80	4.55	4.30
October	3.02	3.07	6.53	4.21
Average (mm)	4.67	4.50	4.19	4.45

* statistically significant at the 0.05 level

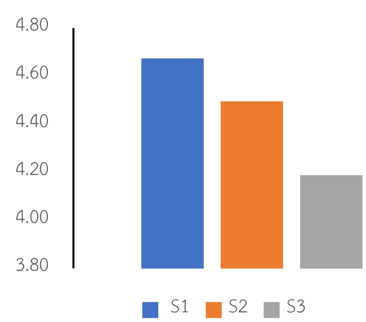


Chart 1 growth rate of in all 3 study areas since April to October

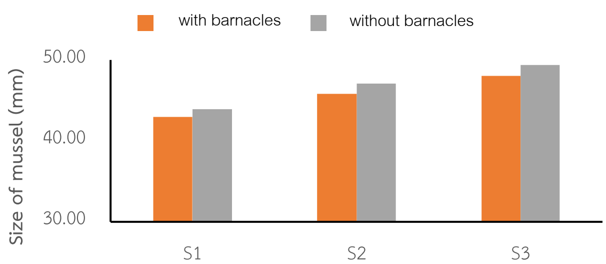
Form table 3, growth rates of mussels in all 3 areas are not different with statistical significance. Mussels in S1 area has the highest growth rate of 4.67 mm. Next-highest is the S2 area which is 4.50 mm. The least growth rate is in S3 area which is 4.19 mm.

Study 2 The study of the biological and physical factors affecting the suitability of mussel habitat

Part 2.1 Biological factors that affects the mussel habitat suitability

Table 4 the size of mussels with barnacles and without barnacles

Month	Size of mussels with barnacles and without (mm)					
	S1 Before estuary		S2 Estuary		S3 Gulf of Thailand	
	With	With out	With	With out	With	With out
April	29.29	30.20	33.00	33.97	37.84	39.21
August	36.86	38.37	41.01	42.43	43.75	44.75
June	46.06	47.02	47.53	48.69	47.84	48.92
July	49.94	50.25	52.78	53.01	51.81	54.05
October	52.56	53.67	54.64	57.29	58.93	59.98
Average (mm)	42.94	43.90	45.79	47.08	48.03	49.38



From table 4, mussels without barnacles will have better growth than the mussels with barnacles in all study area, as shown in chart 2.

Chart 2 the size of mussels with barnacles and without barnacles

Table 5 the number of barnacles that are living with mussel

Month	Number of barnacles that are living with mussel			
	S1 Before estuary	S2 Estuary	S3 Gulf of Thailand	Average
April	5	9	6	6.67
August	8	6	5	6.33
June	12	6	6	8.00
July	9	4	5	6.00
October	6	6	6	6.00
Average	8	6.2	5.6	6.60

From Table 5, S1 area has the highest average number of barnacles of 8. Next-highest is in S2, which is 6.2, and in S3 area there are the least average number of barnacles, which is 5.6.

Table 6 Correlation between the number of barnacles and the growth of mussel

Factor	Correlation
The number of barnacles And the size of mussels	-.252*

* statistically significant at the 0.05 level

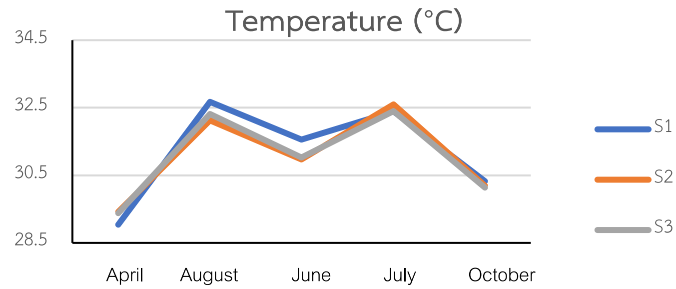
Form Table 6, the number of barnacles and the growth of mussels has the relationship in inverse direction.

Part 2.2 Physical factors that affects the mussel habitat suitability

Table 7 temperature (°C) in Gulf of Thailand

Month	Temperature (°C)			
	S1	S2	S3	Average
April	29.0	29.4	29.4	29.7
August	32.7	32.1	32.3	32.5
June	31.6	31.0	31.0	31.3
July	32.4	32.6	32.4	32.7
October	30.3	30.2	30.1	30.4
Average (°C)	31.2	31.1	31.1	31.3

* statistically significant at the 0.05 level



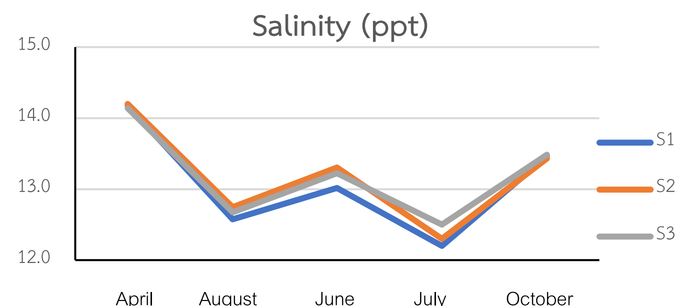
Graph 2 Temperature (°C) in the Gulf of Thailand

From table 7, the average temperature in S1 is 31.2°C, S2 is 31.1°C, and S3 is 31.1°C with no statistically significant difference in each area.

Table 8 salinity (ppt) in the Gulf of Thailand

Month	Salinity (ppt)			
	S1	S2	S3	Average
April	14.2	14.2	14.1	14.0
August	12.6	12.8	12.7	12.6
June	13.0	13.3	13.2	13.1
July	12.2	12.3	12.5	12.3
October	13.5	13.4	13.5	13.4
Average (ppt)	13.1	13.2	13.2	13.1

* statistically significant at the 0.05 level



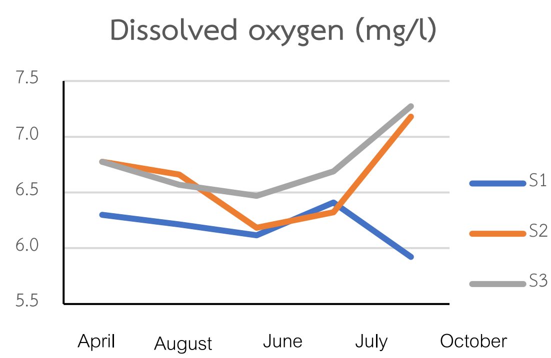
Graph 3 salinity (ppt) in the Gulf of Thailand

From table 8, the average salinity in S1 is 13.1 ppt, S2 is 13.2 ppt, and S3 is 13.1 ppt with no statistically significant difference in each area.

Table 9 dissolved oxygen (mg/l) in the Gulf of Thailand

Month	Dissolved oxygen (mg/l)			
	S1	S2	S3	Average
April	6.3	6.8	6.8	6.4
August	6.2	6.7	6.6	6.3
June	6.1	6.2	6.5	6.2
July	6.4	6.3	6.7	6.4
October	5.9	7.2	7.3	6.5
Average (mg/l)	6.3	6.8	6.8	6.4*

* statistically significant at the 0.05 level



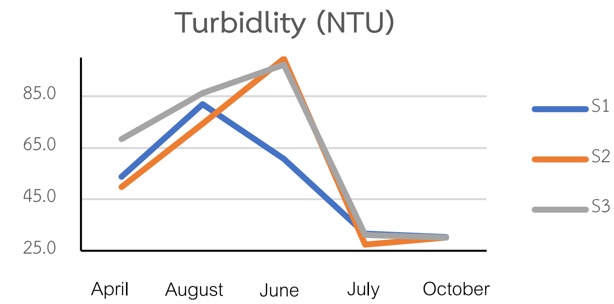
Graph 4 dissolved oxygen (mg/l) in the Gulf of Thailand

From table 9, the average dissolved oxygen in S1 is 6.3 mg/l ppt, S2 is 13.2 ppt and S3 is 13.1 ppt with statistically significant difference in each area.

Table 10 Turbidity (NTU) in the Gulf of Thailand

Month	Turbidity (NTU)			
	S1	S2	S3	Average
April	53.6	49.7	68.3	58.5
August	81.9	74.3	86.3	76.7
June	60.8	99.6	97.2	83.2
July	31.7	27.4	31.1	27.1
October	30.3	30.2	30.1	44.6
Average (mg/l)	51.7	56.2	62.6	58.0*

* statistically significant at the 0.05 level



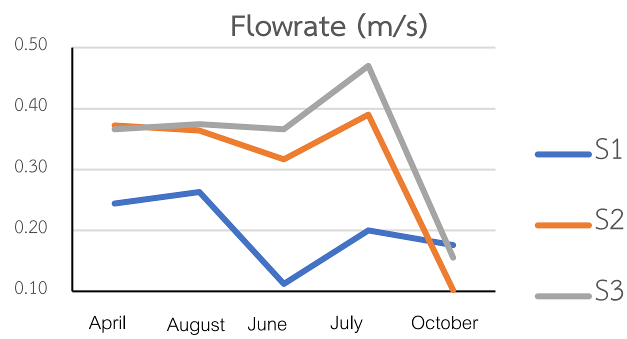
Graph 5 Turbidity (NTU) in the Gulf of Thailand

From table 10, the average turbidity in S1 is 51.7 NTU ppt, S2 is 56.2 NTU, and S3 is 62.6 with statistically significant difference in each area.

Table 11 Flowrate (m/s) in the Gulf of Thailand

Month	Flowrate (m/s)			
	S1	S2	S3	Average
April	0.24	0.37	0.37	0.33
August	0.26	0.36	0.37	0.33
June	0.11	0.32	0.37	0.26
July	0.20	0.39	0.47	0.35
October	0.18	0.10	0.16	0.14
Average (m/s)	0.20	0.31	0.35	0.28*

* statistically significant at the 0.05 level



From table 11, the average flowrate in S1 is 0.20 m/s, S2 is 0.31 m/s, and S3 is 0.35 m/s with statistically significant difference in each area.

Table 12 Correlation between physical factor and the growth of mussels

Factors	Correlation				
	Temperature	Salinity	DO	Turbidity	Flowrate
Size of mussels	-.528	.882	.955	.959	1.000**

** statistically significant at the 0.01 level

From Table 12, study of the correlation between physical factors and the growth of mussels show that flowrate has correlation with mussels with statistical significance.

Table 11 Correlation between flowrate and others physical factors

Factors	Correlation	
	DO	Turbidlity
Flowrate	1.000**	.962

** statistically significant at the 0.01 level

From Table 11, flowrate has correlation with dissolved oxygen in direct variation with statistical significance

Table 12 Correlation between biological and physical factors

Factors	Correlation				
	Temperature	Salinity	DO	Turbidity	Flowrate
Number of barnacles	-.083	.216	-.044	-.134	-6.88**

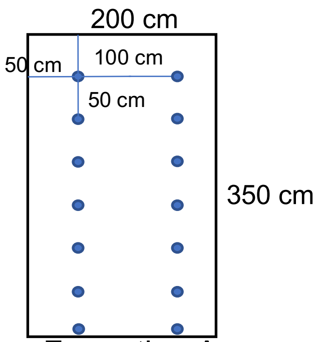
** statistically significant at the 0.01 level

From table 12, flowrate has correlation with the number of barnacles in inverse direction with statistically significant

Study 3 The creating of the appropriate habitat for mussel

From the study, if the flowrate increase, the growth of mussel will increase too. In Thailand, farmers farm mussels by using the pole method. Therefore, I studied about the formatting of mussel poles.

Part 3.1 The habitat of mussel which are created by the farmers



Formation A

From figure 3, in 70 square meters of S2 and S3 areas, there are total of 14 mussel poles, each with distance of 50 cm and distance between row of 100 cm. Researcher defined this as Formation A. Then researcher reviewed literature and applied this into new formation.

Figure 3 The habitat of mussel which are created by the farmers

Table 13 Flowrate of water before and after passing the area with and without mussels' poles

D/M/Y	Flowrate (m/s)									
	S1		S2				S3			
	Without poles		Without poles		With poles		Without poles		With poles	
	Before	After	Before	After	Before	After	Before	After	Before	After
5/1/2562	0.07	0.07	0.06	0.02	0.05	0.05	0.07	0.03	0.06	0.05
12/1/2562	0.06	0.07	0.05	0.03	0.06	0.06	0.07	0.02	0.08	0.05
19/1/2562	0.05	0.06	0.05	0.03	0.06	0.05	0.07	0.03	0.08	0.05
26/1/2562	0.07	0.05	0.05	0.02	0.05	0.05	0.06	0.03	0.07	0.04
2/2/2562	0.08	0.06	0.07	0.03	0.06	0.04	0.06	0.02	0.07	0.04
Average	0.07	0.06	0.06*	0.03*	0.06	0.05	0.07*	0.03*	0.07*	0.05*

* statistically significant at the 0.05 level

From Table 13, the flowrate in S1 area before passing the area without poles is 0.07 m/s and after passing is 0.06 m/s, with no statistically significant difference.

The flowrate in S2 area before passing the area with poles is 0.06 m/s and after passing is 0.03 m/s with statistically significant difference. The flowrate before passing the area without poles is 0.06 m/s and after passing is 0.05 m/s with no statistically significant difference.

The flowrate in S3 area before passing the area with poles is 0.07 m/s and after passing is 0.03 m/s with statistically significant difference. The flowrate before passing the area without poles is 0.07 m/s and after passing is 0.05 m/s with no statistically significant difference.

Part 3.2 The creating of habitat which is appropriate for framing mussel

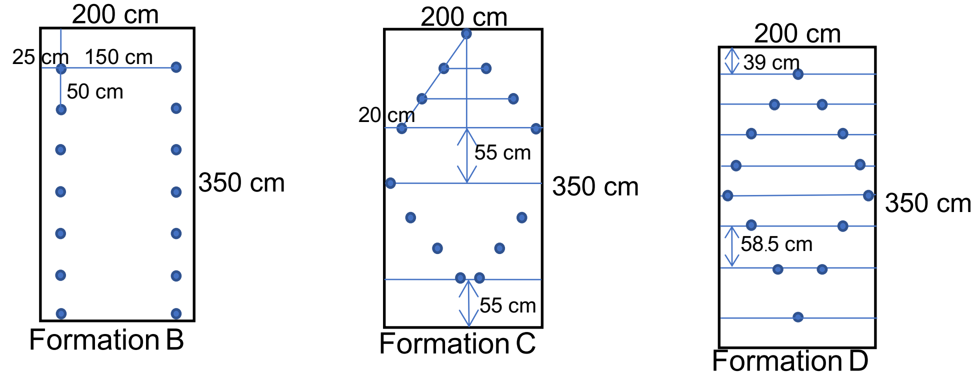


Figure 4 Formation of mussel poles B, C and D

From Figure 4, Formation B has the distance between poles of 50 cm and between rows of 50 cm and 150 cm. Formation C has the oblique distance at 45˚ between poles of 50 cm, between rows of 40 cm and after row 4 it increases to 40 cm. This is according to V-shape formation (Lissaman, 1970). Formation D has 8 rows, the first 6 rows have the distance between rows of 39 cm, but the last 2 rows have the distance between rows of 58.5 cm. This is according to teardrop formation (Nancy, 2015). Then these 4 formations were tested for the flowrate in a tube that can simulate water flow and the results are as follow.

Table 14 Flowrate of water when passing each formation of mussel poles model

Formation	Flowrate (m/s)		
	Before	After	Difference
A	0.26	0.18	0.08
B	0.22	0.22	0.00
C	0.26	0.21	0.05
D	0.24	0.25	-0.01

Form Table 14, formation D has the difference between before and after passing the mussel poles the least at -0.01 m/s, then formation B at 0.00 m/s, then formation C at 0.05 m/s. Finally, formation A at 0.08 m/s.

Table 15 Flowrate of water when passing each formation of mussel poles farm model

Formation	Flowrate (m/s)		
	Before	After	Difference
AAA	0.64	0.13	0.51*
BBB	0.65	0.16	0.49*
CCC	0.65	0.18	0.47*
DDD	0.64	0.27	0.37*

* statistically significant at the 0.05 level

Form Table 15, formation DDD has the difference between before and after passing the mussel poles the least at 0.51 m/s, then formation BBB at 0.49 m/s, then formation CCC at 0.47 m/s. Finally, formation A at 0.37 m/s. Each area is different with statistical significance.

Part 3.3 The experimentation of appropriate habitat for mussels in each formation

Table 16 Flowrate of water when passing each formation of mussel habitats

Month	Flowrate (m/s)											
	formation A			Formation B			Formation C			Formation D		
	Before	After	Difference	Before	After	Difference	Before	After	Difference	Before	After	Difference
December	0.25	0.16	0.09	0.20	0.15	0.05	0.21	0.16	0.05	0.19	0.19	0.00
January	0.17	0.12	0.05	0.18	0.14	0.04	0.19	0.14	0.05	0.19	0.20	-0.01
February	0.20	0.15	0.05	0.19	0.16	0.03	0.20	0.15	0.05	0.20	0.20	0.00
Average	0.20	0.14	0.06*	0.19	0.15	0.04*	0.20	0.15	0.05*	0.19	0.20	0.00

* statistically significant at the 0.05 level

From table 16, considering the flowrate before and after passing each formation of mussel poles, formation A has the average flowrate before passing the poles of 0.20 m/s and after at 0.14 m/s. Formation B has the average flowrate before passing the poles of 0.19 m/s and after at 0.15 m/s. Formation C has the average flowrate before passing the poles of 0.20 m/s and after at 0.15 m/s. And formation D C has the average flowrate before passing the poles of 0.19 m/s and after at 0.20 m/s.

When consider the difference in flowrate before and after passing the habitat of mussel, formation A has the largest difference at 0.06 m/s. Then formation C at 0.05 m/s. Next is formation B at 0.04 m/s. Finally, formation D has the least difference of flowrate at 0.01 m/s.

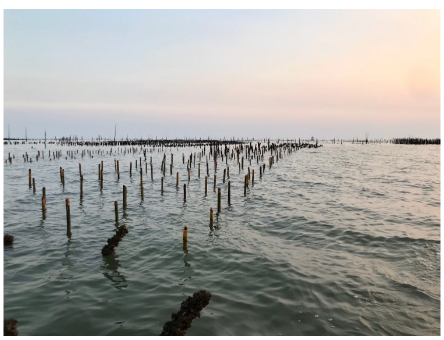


Figure 5 The habitat of mussel in different formation in real farm at Samut Sakhorn

Table 17 The growth of mussel on each formation in real farm at Samut Sakhorn

Month	Size of mussel (mm)			
	Formation A	Formation B	Formation C	Formation D
December	29.28	33.92	30.47	34.53
January	35.43	38.20	37.34	40.24
February	43.12	47.67	45.05	48.47
Average	35.94	39.93	37.62	41.08*

* statistically significant at the 0.05 level

From table 17, comparing the average size of mussel, mussel in formation D is the biggest at 41.08 mm. Then formation B at 39.93 mm. Next is formation C at 37.62 mm. Finally, formation A is the smallest at 35.94 mm.

Table 18 the average of weight per pole (kg) number of mussels in each pole and the weight per each mussel (g) in 1 farm

Formation	weight per each mussel (g)	number of mussels in each pole	weight per pole (kg)
A	32.57*	292.89*	9.54*
B	32.84*	300.54*	9.87*
C	33.86*	308.62*	10.45*
D	34.12*	358.45*	12.23*

* statistically significant at the 0.05 level

From table 18, comparing weight per each mussel, formation D is the heaviest at 34.12 g. Then formation C at 33.86 g. Next is formation B at 32.84 g. Finally, formation A is the least at 32.57 g.

When consider number of mussels in each pole, formation D has the highest number at 358.45. Then Formation C at 308.62. Next is formation B at 300.54. Finally, formation A is the least at 292.89.

When consider weight per pole, Formation D is the heaviest at 12.23 kg. Then Formation C at 10.45. kg Next is formation B at 9.87 kg. Finally, formation A is the least at 9.54 kg.

Table 19 The revenue of harvesting the mussels in 1,600 square meters

Formation	Weight per farm (kg)	Revenue per farm (USD)	Revenue per 1,600 square meters (USD)
A	133.56	296.99	22,274.14
B	138.18	307.26	23,044.63
C	146.30	325.32	24,398.82
D	171.22	380.73	28,554.80

Form table 19, comparing the weight per farm, formation D is the highest at 171.22 kg. Then formation C at 146.30 kg. Next is formation B at 138.18 kg. Finally, formation A is the least at 133.56 kg.

When consider the revenue per farm formation D has the highest number at 380.73 USD. Then formation C at 325.32 USD. Next is formation B at 307.26 USD. Finally, formation A has the least at 296.99 USD.

When consider the revenue per 1,600 square meters formation D has the most at 28,554.80 USD. Then formation C at 24,398.82 USD. Next is formation B at 23,044.63 USD. Finally, formation A has the least at 22,274.14 USD.

When comparing the farm with the most and the least revenue, formation D can increase the revenue by 6,280.66 USD or 28 percent.

Conclusion and Discussion

Study 1

After studying ecology of mussels in the Gulf of Thailand and setting the study site in estuary of Samut Sakhorn at the latitude of 13.493611˚N and the longitude at 100.386944˚E, I found that there are 2 types of mussel distribution. The first one is distribution in nature which I defined as S1. The second one is distribution in farm which I defined as S2 and S3, making up total of 143 farms. Then morphology and species of mussels were studied. The outside shell of mussel is smooth and has dark green color. The connection point between the shell is brown. I found an organism living with mussels, which is barnacle. All mussels that were collected belong to the same species, which is *Perna Viridis*. The growth in S3 area is the highest with statistical significance. In S1 area the growth rate is the highest, but with no statistical significance.

Study 2

After studying the factors that affects the mussel habitat suitability, and studying the biological factors, I found that barnacles affect the growth of mussel by competing with the mussel in consuming food. After studying the physical factors, I found that temperature and salinity in each area is not different with statistical significance. But dissolved oxygen, turbidity, and flowrate in each area are different with statistical significance. Then I studied the relationship by using correlation analysis and found that flowrate is correlated to the growth of mussels in direct variation with statistical significance. After studying the correlation between biological and physical factor, I found that flowrate is correlated with the number of barnacles in inverse variation with statistical significance. After studying about correlation among physical factors with statistically significant difference in each area, I found that flowrate is correlated with dissolved oxygen with statistical significance.

Study 3

After studying the flowrate of water before and after passing through the habitat of mussels, I found that the flowrate of water passing the mussel poles, which is the habitat of mussels, will decrease more than the area without mussel habitat. After investigating the way that farmers create the habitat of mussels, I found that in the 7 square meters there are the total of 14 poles. After that I studied about the formation of mussel poles that will not affect the flowrate and got 4 new formation patterns of mussel poles. Then I conducted the experiment in the tube that can simulate water flow with all 4 formations and found that formation D, which is the tear-drop shape according to Nancy, 2015, has the least effect on flowrate. After adding the number of mussel poles form 1 farm to 3 farms, I found that formation D is still the formation that affect flowrate the least. Formation D is also the formation that has the least effect on flowrate and has the highest growth of mussels when tested in the real farm. After harvesting the mussels, I found that formation D has the highest average weight, number of mussels per poles, and weight per mussel. When calculated the revenue, this formation increases the revenue by 6,280.66 USD or 28 percent.

In conclusion, to create a suitable habitat for the growth of mussels, formation D should be used for farming mussels as it affects the flowrate the least. Test of formation D in real farm also results in increase of mussel growth with statistical significance.

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GLOBE Badges

Be a Data Scientist

This report has included in-depth analysis of physical factors which are temperature, salinity, turbidity and flowrate by using GLOBE Protocol for measuring and has sent data to GLOBE Data Entry, biological factor which is number of barnacles and growth of mussel. Moreover, I have collected data from other sources form interviewing local farmers and investigating real mussel farm. All of the data were collected for 6 months 20 times and the total of 36,000 data to get enough data for analyzing. Next, I compared the average of the data to find the trend of the relationship between physical factors and the growth of mussel. After that, I studied the relationship of the data by using Correlation. Then I applied them to increase the growth of mussel and revenue for farmer who are farming mussel.

Be an Engineer

I have used the engineering knowledge about design formatting the mussel poles. Form observing, different formation of mussel poles affect flowrate differently. So, I used this information to create new formation of mussel poles. If the water flows faster, the mussels will grow better. Therefore, I tried to create new formation which can make water flow faster which has the same area and number of poles as the original way of formatting mussel poles. If the mussels grow better, it will fitter the water and help the global environment.

Make an Impact

Nowadays, the mussels are smaller and making the farmers have less revenue. This make me wanted to find a way that can increase the growth of mussels and using the same cost. If this research can increase the size of mussels and make famers receive more revenue, the economy would be better. Moreover, the mussels have the ability which can filter water. Therefore, the water in area that have mussel farm would be better. When I did a experiment in real farm, I found that the new formation of mussel poles which I has created can increase the revenue for farmers by 6,280.66 USD or 28 percent when compared to the original way of formatting mussel poles.