Research Title:	Effects of Brackish Water on Mangrove Crab *(Episesarma mederi)* Population in Samet, Chonburi, Thailand
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Abstract

Evaluating the effect of brackish water and various physical factors that are capable of affecting the Mangrove Crab *(Episesarma mederi)* population is the main goal of this current investigation. Using the standard equipment from Extech, the researchers characterized several physico-chemical factors, biological factors, physical factors in the natural habitat of mangrove crab such as water temperature, TDS, dissolved oxygen, electrical conductivity, salinity, transparency, water pH, air temperature, and relative humidity. The number and diameter of the mangrove crab holes were counted and measured. Results showed that there was a significant difference in various physico-chemical factors measured except for water temperature. The population of the experimental organism varied due to different level of salinity. Based on the experimentations, results and gathered data, the researchers concluded that there was significant difference ($p<0.05$) in the physico-chemical factors measured in the natural habitat of mangrove crab *(Episesarma mederi)* and the population of mangrove crabs (*Episesarma mederi*) at Samet, Chonburi, Thailand is impacted by brackish water with varying salinity levels. Furthermore, the researchers recommended that further research will be conducted to evaluate the other parameters in the seawater and more experimental sites in Chonburi will be tested and compared which are necessary for determining the correlation of water quality and mangrove crab population.

Keywords: Physico-chemical factors, mangrove crab, brackish water

INTRODUCTION

Chonburi, Thailand has made tremendous advancements in recent years, surpassing previous expectations in the fields of industry, infrastructure, technology, and economy. However, these advancements including anthropogenic activities have significantly impacted the quality of nearby water, both directly and indirectly. The intertidal zones of Samet, Chonburi, is habitat to various aquatic organisms. One of the most common organisms present there are Mangrove Crab *(Episesarma mederi)*. The life of crabs and all living things present in this aquatic zone depends on the constantly shifting quality of the water brought about by development, high and low tides, and freshwater from nearby rivers. The primary physical and chemical factors influencing the number of mangrove crabs and the size of their holes in soil are waste water and saltwater, both of which are products of human activity. Therefore, it is important to evaluate these polluted water physico-chemical parameters (pH levels, salinity, dissolved oxygen, etc.) because they have a significant effect on the crabs themselves (Marine Ecology: Processes, Systems, and Impacts, 2011).

The major region of the overall landscape of Samet, Chonburi, Thailand are plains and coastal area. Therefore, these geographical features made this area experienced with plethora of natural phenomenon such as storm surges, tidal fluctuations, sedimentation, sea level rise, etc. In general, Samet manages its water resources by collecting all of the household waste water and sending it to the sea, where mangrove forests—a habitat for crabs—serve as a passageway (Simon A. McKee 2004). Water from an industrial business that had been tainted with dangerous chemicals was also dumped into the ocean. As a result, physico-chemical factors are highly vulnerable.

The situations above prompted the researchers to conduct a thorough research entitled "Effects of Brackish Water on Mangrove Crab *(Episesarma mederi)* Population in Samet, Chonburi, Thailand" in which the main goal of this research is to evaluate various physical factors that are capable of affecting the crab's population.

Research Questions:

1. Is there a significant difference in the physico - chemical factors of brackish water in Samet, Chonburi, Thailand?

2. Can brackish water affect the mangrove crab *(Episesarma mederi)* population in Samet, Chonburi, Thailand?

Objectives:

1. To measure and compare the physico - chemical factors in the natural habitat of mangrove crab population in the Samet, Chonburi, Thailand.
2. To ascertain how the mangrove crab (*Episesarma mederi*) population in Samet, Chonburi, Thailand is affected by brackish water.

Hypotheses:

Alternative: There is a significant difference in the physico-chemical factors and mangrove crab *(Episesarma mederi)* population in Samet, Chonburi, Thailand.

Null: There is no significant difference in the physico-chemical factors and mangrove crab *(Episesarma mederi)* population in Samet, Chonburi, Thailand.

Materials:

Materials and equipment used in this science project.

pH, Conductivity, TDS, Salinity, Temperature Meter	Meterstick	Dissolved Oxygen meter
Thermo Hygrometer	Refractometer	Test tubes
Beaker	Medicine Dropper	Secchi Disc

Research Methodology

A. Study Sites

The study site is located at Samet Intertidal zones. Site 2 Latitude 13°20'40.8" N, Longitude 100°56'57.4" E.

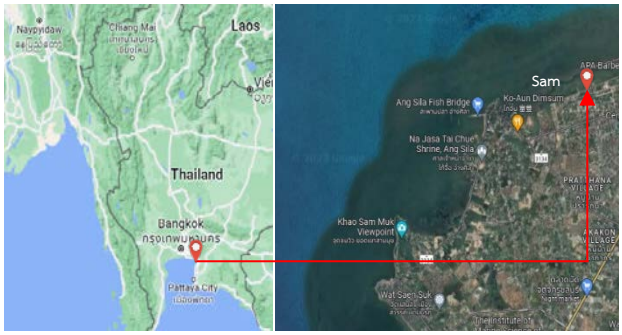

FIGURE 1. The study site at intertidal zones of Samet and Angsila, Chonburi, Thailand.

B. Survey and Preparation of Materials

The researchers went to the Center of Expertise on Eco-tourism for Mangrove Conservation, Chonburi Province Office and asked permission to conduct a field study about the mangrove crab *(E. mederi)*

population in the coastal area of Samet Municipality. After the survey and selection of study site, needed laboratory materials and equipment for testing the water quality in the habitat of mangrove crabs *(E. mederi)* were procured from the science laboratory of Chonradsadornumrung School.

Figure 2. The study site at Angsila, Chonburi, Thailand and the researchers.

C. Field Measurement in the natural habitat of crab

Various physical and chemical parameters were considered in assessing the mangrove crab's *(E. mederi)* habitat such as Water temperature, Total Dissolved Solids (TDS), electrical conductivity, salinity, hydrogen potential (pH), transparency, air temperature, relative humidity, dissolved oxygen, and water color. Secchi disc was used to determine the transparency of the water. Extech standard instruments were used to measure the water temperature, TDS, pH, electrical conductivity, salinity, and dissolved oxygen. Visual comparison was used to evaluate the color of the water. In this test 20ml of the sample and 20ml of distilled water were taken in two separate wide mouthed test tubes. The results were tabulated (as clear, greenish, greyish, brownish, and blackish) by comparing the color of the sample with distilled water. Thermo-hygrometer was used to determine the air temperature and relative humidity of the study site. The hydrosphere protocols from www.globe.gov were used in all the tests needed to evaluate the natural habitat of the experimental organisms.

Figure 3. Assessing various factors in the natural environment of mangrove crabs.

G. Determining Mangrove Crab *(E. mederi)* population

Initially, tool used for determining the mangrove crab population and holes were invented by cutting the center of the polypropylene flute board into a rectangle shape with

the width and the length of 45 and 50 centimeter accordingly. After that, the tool was used to determine crab population by counting the crab hole within the designated area while the researchers were wearing protective pants and boots. The criteria used by the researchers to count the crab holes is that their diameter needed to be larger than 0.5 centimeter or else there is a probability it could turn out to be an air bubble (George A. Fowler, 2002), and the data was recorded accurately. Finally, the recorded data was analyzed using ANOVA and HSD Tukey test in order to indicate which factors have potential impact on mangrove crab *(E. mederi)* population.

Figure 4. Determining mangrove crab population.

Results and Discussion

The figures below show the data encoded on Globe web page from 26 December 2023 to 18 January 2024. Figures 5 to 11 show the data for water temperature, dissolved oxygen, transparency, air temperature, salinity, relative humidity, and water pH that were measured for 4 consecutive times in Samet, Chonburi, Thailand.

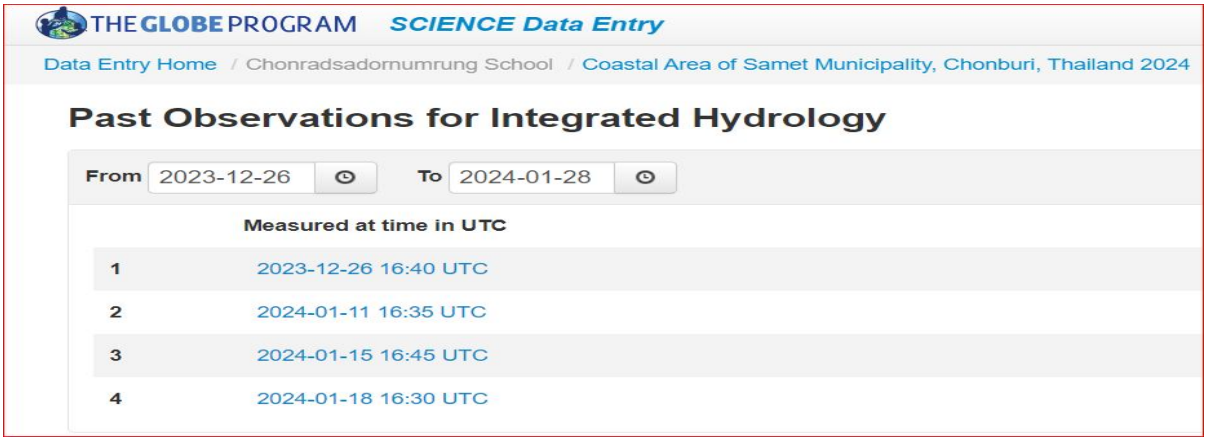

FIGURE 5: Globe Data Entry from Samet, Chonburi that has been entered from December 26, 2023 to January 18, 2024.

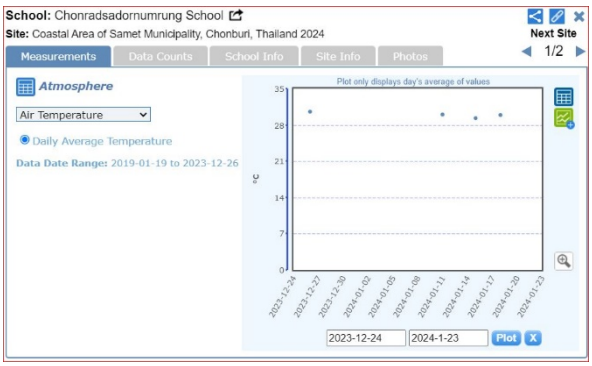

Figure 6. Globe Data Entry for Air Temperature.

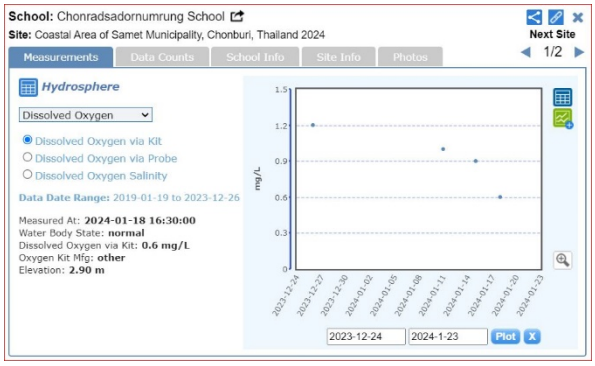

Figure 7. Globe Data Entry for Dissolved Oxygen.

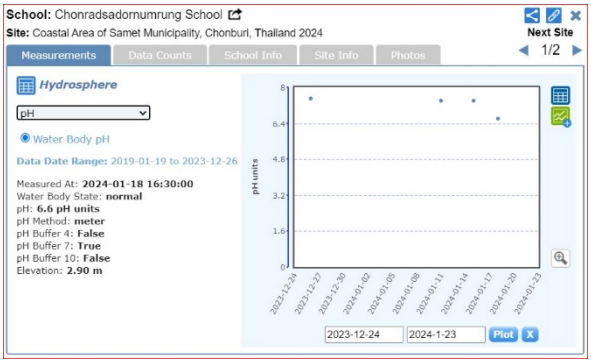

Figure 8. Globe Data Entry for water pH.

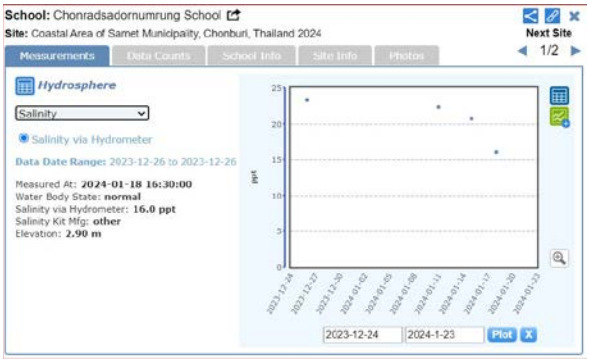

Figure 9. Globe Data Entry for salinity.

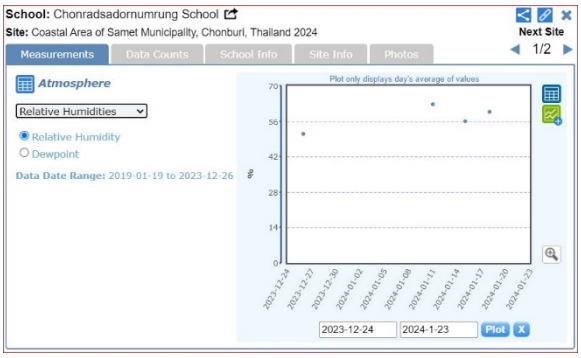

Figure 10. Globe Data Entry for relative humidity.

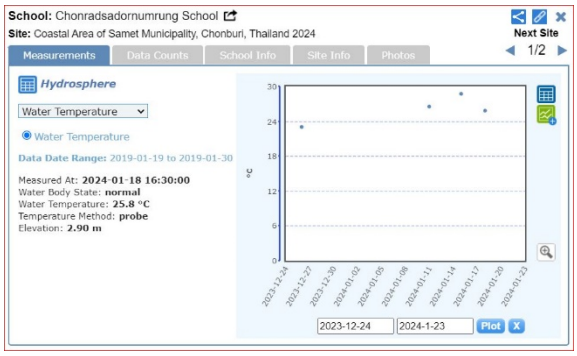

Figure 11. Globe Data Entry for water temperature.

The figures above show the globe data entry for water temperature, dissolved oxygen, transparency, air temperature, salinity, relative humidity, and water pH that were measured for 4 consecutive times in Samet, Chonburi, Thailand.

TABLE 1. The average results of physico-chemical factors measured in the natural habitat of mangrove crabs in Samet, Chonburi, Thailand.

Parameters	26 Dec. 2023 (4:40 PM)	11 Jan. 2024 (4:35 PM)	15 Jan. 2024 (4:45 PM)	18 Jan. 2024 (4:30 PM)
Water Temperature (°C)	23	26.47	28.67	25.8
Dissolved Oxygen (mg/L)	1.19	0.97	0.93	0.60
TDS (ppm)	2864	2883	2893	2779
Electrical Conductivity (µS/cm)	5729	5748	5758	5559
Transparency (m)	0.268	0.235	0.13	0.23
Water pH	7.51	7.44	7.43	6.55
Salinity (%)	23.33	22.33	20.67	16
Water color	Turbid	Turbid	Turbid	Turbid
Relative Humidity (%)	51	62.67	56	59.67
Air Temperature (°C)	27.67	30	29.3	29.87

Table 1 shows the comparison of the average results of physico-chemical factors measured from Samet. These results were gathered after 4 series of experiments that started from 26 December 2023 to 18 January 2024. It can be seen from the table and graph that there was a variation in the parameters measured from the natural habitat of mangrove crabs. One-way ANOVA showed that the p-value corresponding to the F-statistic of one-way ANOVA is higher than 0.05 for water temperature, suggesting that the treatments are not significantly different. For, DO, TDS, Electrical conductivity, water pH, salinity, relative humidity, air temperature, and transparency, the p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that the treatments are significantly different for that level of significance.

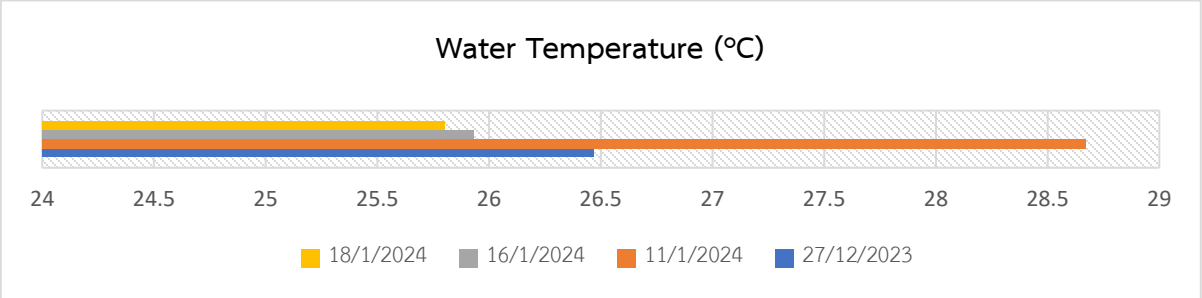

FIGURE 12. Average Water temperature (°C) in Samet.

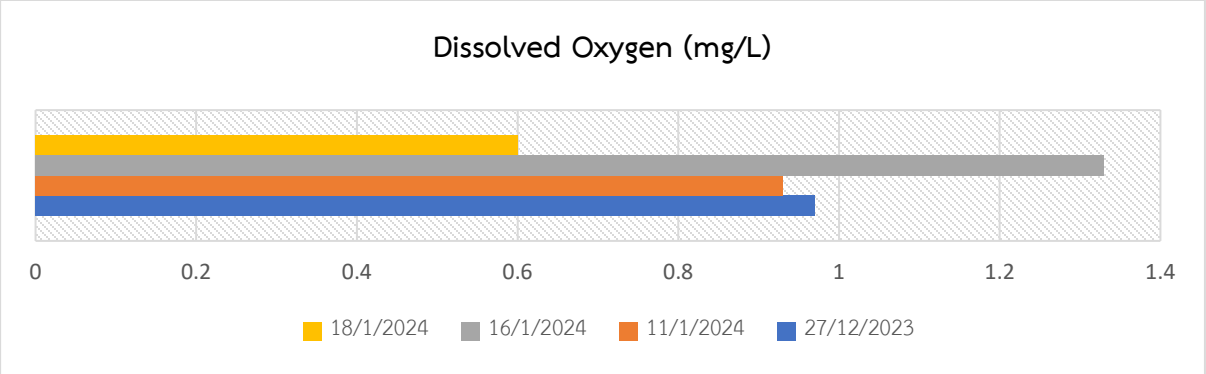

FIGURE 13. Average Dissolved Oxygen (mg/L) in Samet.

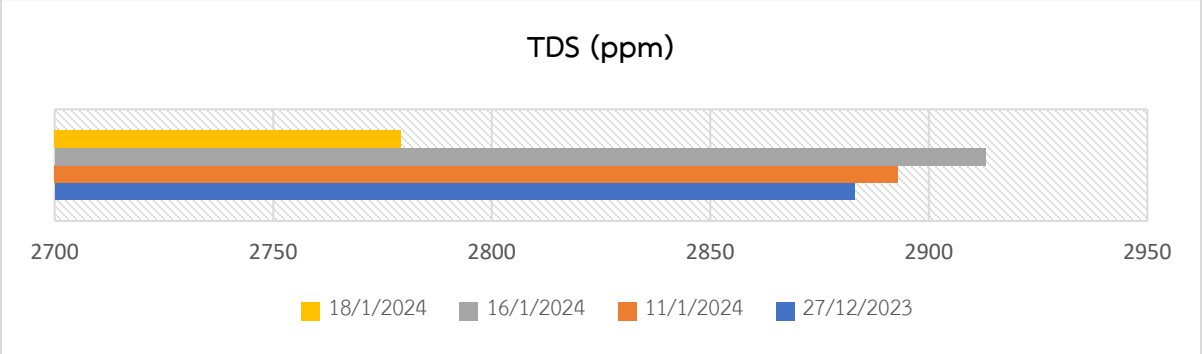

FIGURE 14. Average TDS (ppm) in Samet.

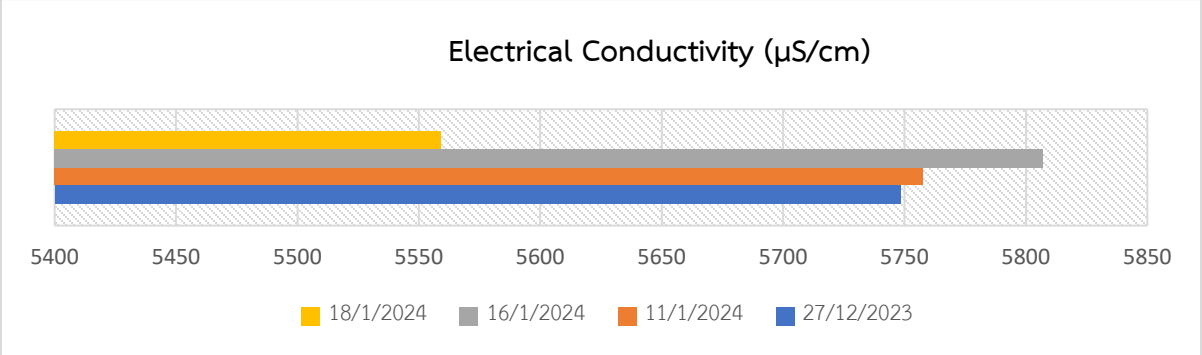

FIGURE 15. Average electrical conductivity (µS/cm) in Samet.

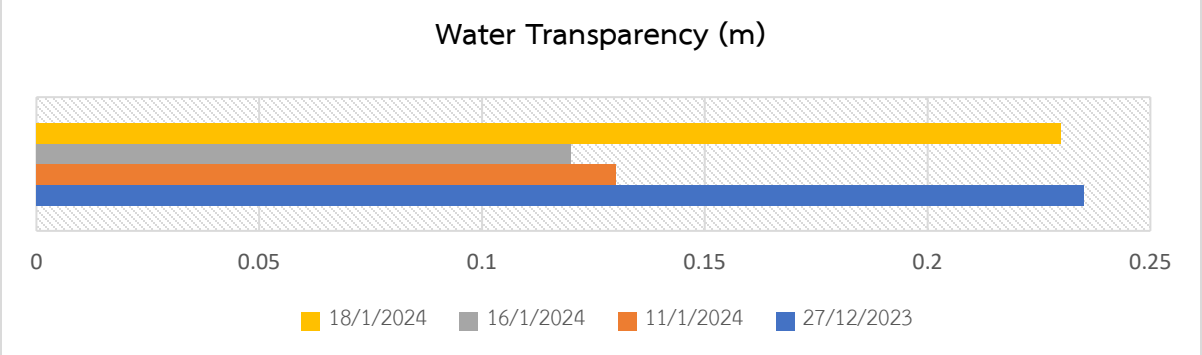

FIGURE 16. Average water transparency (m) in Samet.

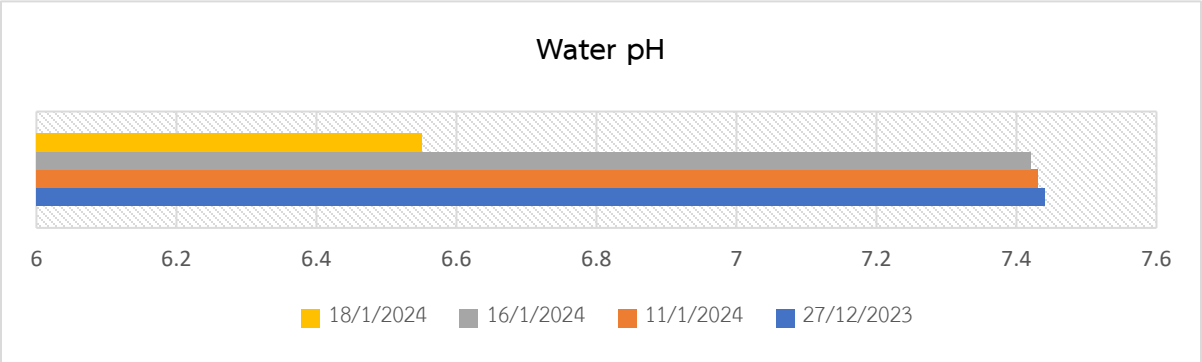

FIGURE 17. Average water pH of the study site.

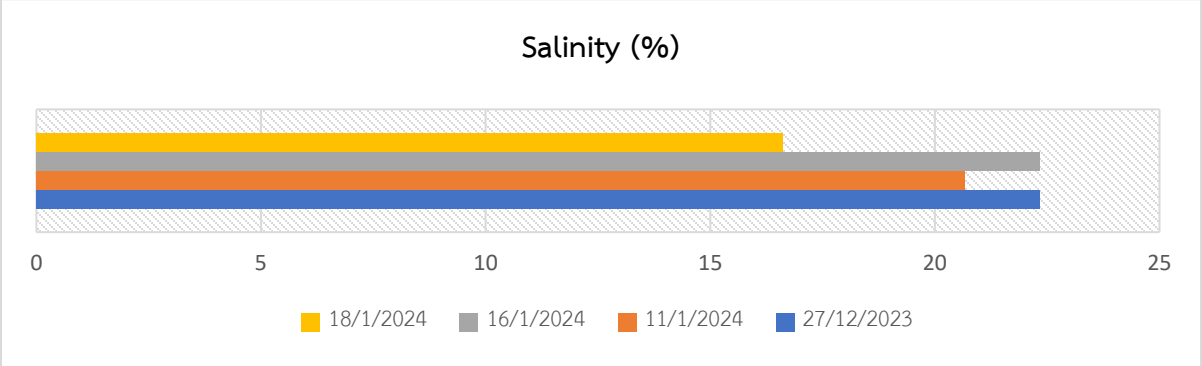

FIGURE 18. Average salinity level (%) in Samet.

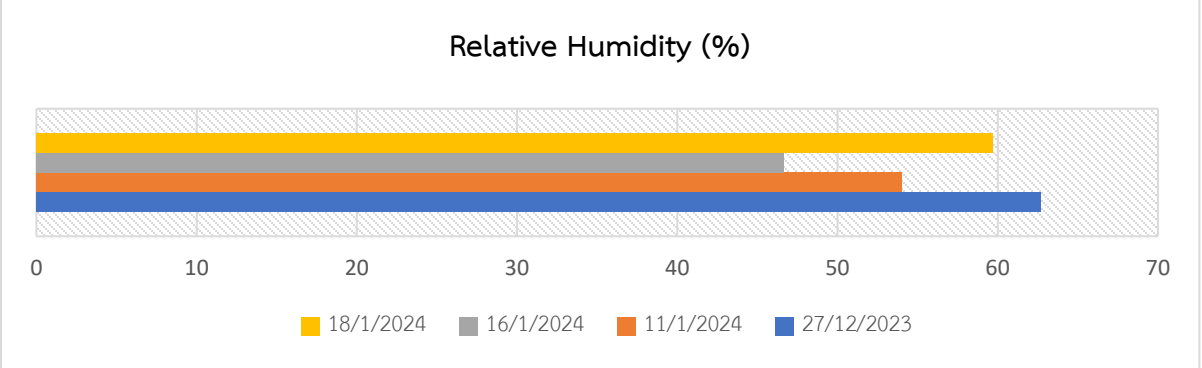

FIGURE 19. Average relative humidity (%) in Samet.

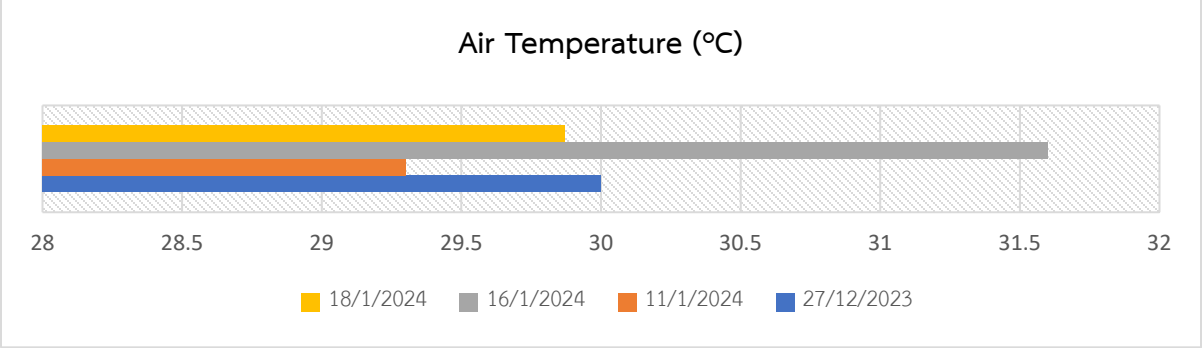

FIGURE 20. Average air temperature (°C) of the study site.

Figure 12 to 20 shows the average results of all factors measured from the natural habitat of mangrove crab in Samet, Chonburi. The average range for water temperature in Samet was 23.0 ºC - 28.67ºC. Average Dissolved oxygen ranges from 0.60 mg/L – 1.19 mg/L. Average TDS ranges from 2779.3 ppm – 2893.0 ppm. Average electrical conductivity ranges from 5559.0 µS/cm – 5757.67 µS/cm. Average water transparency ranges from 0.13 m – 0.268 m. Average water pH ranges from 6.55 – 7.51. Average salinity ranges from 16.63 % – 23.33 %. Average relative humidity ranges from 56.0 % – 62.67 %. Lastly, average air temperature ranges from 27.67ºC – 30.0ºC. As seen from Figure 12-20, there were variations among the physico-chemical factors measured for 4 consecutive times. One-way ANOVA revealed that the p-value corresponding to the F-statistic is lower than 0.05 for DO, TDS, Electrical conductivity, water pH, salinity, relative humidity, air temperature, and water transparency, which means that there was significant difference in various factors measured in Samet except water temperature, where the p-value corresponding to the F-statistic of one-way ANOVA is higher than 0.05, suggesting that there was no significant difference between the water temperature of Samet.

TABLE 1. The average amount and size of mangrove crab's hole in Samet

DATES	RECORDS	
	Number of Mangrove Crab's hole	Mean Size of Mangrove Crab's Hole (cm)
26 December 2023	41	1.54
11 January 2024	98	1.55
15 January 2024	63	2..00
18 January 2024	87	1.08

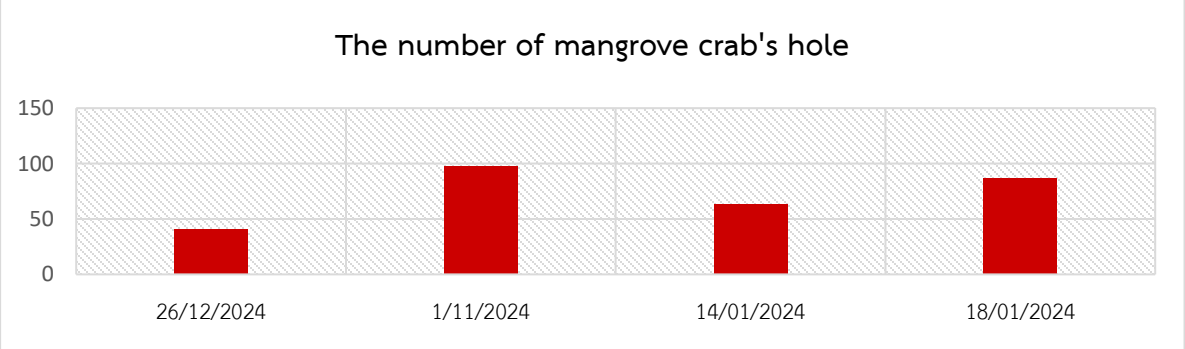

FIGURE 21. Number of mangrove crab's holes in Samet.

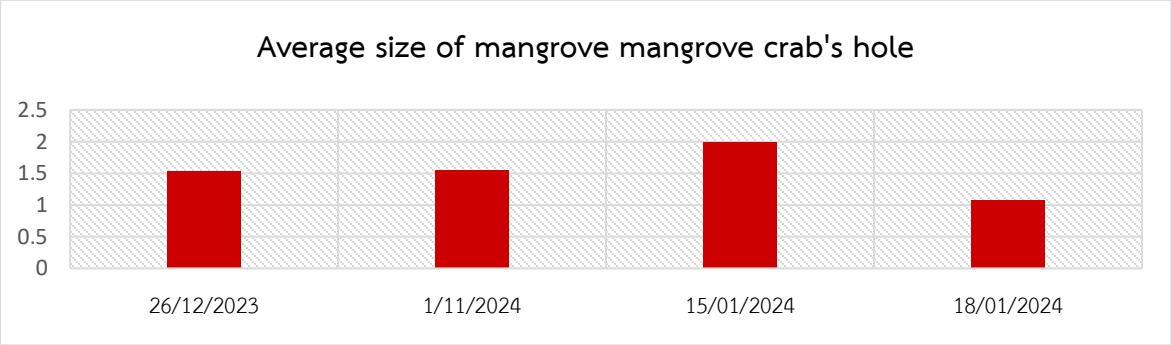

FIGURE 22. Average size of mangrove crab's hole in Samet.

Table 1 and **Figure 21 - 22** shows the number and average size of holes created by mangrove crabs in Samet, Chonburi, Thailand. It can be seen that there were variations in mangrove crab population after 4 testing periods**.** According to the results, the average diameter of mangrove crab holes also diverse. These observations can be correlated to the ever-changing physico-chemical factors of the brackish water which can be seen in figures 12 to 20. Among these factors, salinity level has the significant impact in the population of mangrove crabs. The average salinity ranges from 16.63 % – 23.33 %. This result is interrelated to the study published by Yuan, et. al, 2022 which emphasized that sesarmid crab (*Chiromantes dehaani*) population declined in reclaimed areas due to decreased salinity.

Discussion

The marine water in the study site change much during the study period and the results of analysis of variance (ANOVA) also post-hoc Tukey HSD (Honestly Significant Difference) Test showed that there was significant difference ($p<0.05$) in the physico-chemicals after 4 series of experiments except for water temperature where, $p>0.05$.

The lowest average water temperature recorded from the 4 days was 25.80°C and the maximum average water temperature was 28.67°C. Temperature in tropical surface ocean waters is usually between 27°C and 28°C. Solar radiation, tidal currents, incidence of upwelled waters and atmospheric variations were the reasons for the temperature variations (Kannan and Kannan, 1996; Richardson et al, 2000).

The amount of dissolved oxygen measured from the site is lower compared to the normal level of DO in seawater which ranges from 0.6 mg/L – 1.33 mg/L (Figure 11). According

to various scientific studies, 4 – 9 mg/L of DO is the optimal range that will support a large, diverse fish population (Abdus-Salam et al. 2010). As a general rule, concentrations of DO above 5 mg/L are considered supportive of marine life, while concentrations below this are potentially harmful. At about 3 mg/L, bottom fishes may start to leave the area, and the growth of sensitive species such as mangrove crab larvae is reduced. At 2.5 mg/L, the larvae of less sensitive species of crustaceans may start to die, and the growth of mangrove crab species is more severely limited. Below 2 mg/L, some juvenile fish and crustaceans that cannot leave the area may die, and below 1 mg/L, fish totally avoid the area or begin to die in large numbers (U.S. EPA, 2000). From the data above, it can be inferred that there is a problem when it comes to DO of seawater from the study site.

Although, the optimal DO of mangrove crab is at 5 – 8 mg/L (Eudene P. Odum, Robert L. Linn and Carl D. Hopkins, 1953), but level is lower than the standard value, large quantities of mangrove crab were still thriving in the area.

Average TDS ranges from 2779 ppm – 2913 ppm as seen from (Figure 12). Average electrical conductivity ranges from 5559 µS/cm – 5807 µS/cm as seen from Figure 13. The concentration of TDS measured in ppm or mg/L represents the presence of inorganic salts and small amounts of organic matter in water and EC is the measure of water capacity to conduct electrical current (*Sawyer C., et.al, 1994*). There are many standards that govern TDS and EC in water. For health reason, desirable limit for TDS is between 500 mg/L and 1,000 mg/L and for EC is no more than 1,500 µS/cm (*WHO, 2011*). Other quality standards classify these parameters based on salt content or salinity level (*Todd et.al., 2005*). TDS has also been classified into four types: type I is freshwater with TDS < 1,000 mg/L; type II is brackish water with TDS between 1,000 and 10,000 mg/L; type III is saline water with TDS from 10,000 till 100,000 mg/L; and type IV is brine water with TDS > 100,000 mg/L (Todd et.al.,2005). For electrical conductivity (EC), water is classified into 6 types according to Rhoades J., 1992: type I is non-saline, if EC < 700 µS/cm; type II is slightly saline, if EC rely between 700 and 2,000 µS/cm; type III is moderately saline, if EC higher than 2,000 and less than 10,000 µS/cm; type IV is highly saline with EC value from 10,000 till 25,000 µS/cm; type V is very highly saline, if EC value between 25,000 and 45,000 µS/cm; and type VI is brine water with EC more than 45,000 µS/cm. From this given data from various sources, it can be concluded that the TDS and EC from Samet is higher than the normal range for a typical seawater.

The pH of seawater from the area ranges from 6.55 – 7.44 (Figure 15). Seawater pH has an essential role in the life history and some biological activity of shellfish. While pH does not vary greatly in time and space along open oceans, its high variations in near-shore areas can exceed 1 unit owing to biological activity (Cornwall, et al., 2013). Low pH affects the balance of sodium and chloride in the blood of aquatic animals. When sodium is depleted, hydrogen ions are taken into its cell causing death due to respiratory failure or the loss of regulation in osmotic pressure. Further, a pH level lower than 4.5 is harmful to aquatic environments while higher values can also cause adverse biological effects (Jacob, 2017).

Despite of differences in some data between the experimental and the standard data, it can be considered that the natural habitat of the experimental mangrove crab is not in stable condition because each parameter measured went up and down to the extreme level. Also, the ANOVA and post-hoc Tukey HSD (Honestly Significant Difference) test showed that there were significant differences in the parameters measured in Samet, Chonburi. Along with physico-chemical investigation, the size of mangrove crab holes, number of mangrove crab holes in the area were necessary for the evaluation of the mangrove crab populations.

Summary of Findings, Conclusion, and Recommendations

This chapter presents the summary of findings and conclusion made from the study as well as recommendations given by the researchers.

Summary of Findings

This environmental science research started with the survey done by the researchers at the coastal area of Samet, Chonburi, Thailand. It was followed by the selection of specific study site for the determination of the mangrove crab population. The location was chosen for its potential as a habitat for mangrove crab. Before the field study, the needed laboratory materials and equipment were procured from the science laboratory of Chonradsadornumrung School.

Measurements of physico–chemical factors were done in the selected place at the intertidal zones of Samet, Chonburi. Site Latitude 13°20'40.8" N, Longitude 100°56'57.4" E. The physico-chemical parameters measured *In situ* are: Water temperature, Total Dissolved Solids (TDS), electrical conductivity, hydrogen potential (pH), transparency, dissolved oxygen, salinity, air temperature, and relative humidity.

After the field study, the researchers counted the quantities of the mangrove crab holes and recorded the data regarding its diameter from Samet. The results of field measurement showed that there were changes among the factors measured in the site except for the water temperature. However, the result of ANOVA showed that the p-value corresponding to the F-statistic is lower than 0.05 for DO, TDS, Electrical conductivity, water pH, salinity, Transparency, relative humidity, and air temperature, which means that there was significant difference in various factors measured in study site except for water temperature, where the p-value corresponding to the F-statistic of one-way ANOVA is higher than 0.05, suggesting that there was no significant difference.

Conclusion

Based on the experimentations, results and gathered data, the researchers concluded that there was significant difference ($p<0.05$) in the physico-chemical factors measured in the natural habitat of mangrove crab *(Episesarma mederi)* such as Transparency, Dissolved Oxygen, Total Dissolved Solids, electrical conductivity, water pH, air temperature, salinity, and relative humidity. Furthermore, the population of mangrove crabs (*Episesarma mederi*) at Samet, Chonburi, Thailand is impacted by brackish water with varying salinity levels.

Recommendations

For the improvement of the study, the researchers recommended that further research will be conducted to evaluate the other parameters in the seawater and more experimental sites in Chonburi will be tested and compared which are necessary for determining the correlation of water quality and mangrove crab population.

GLOBE Badges

I am a Collaborator

This environmental research was done successfully because of the collective efforts of various individuals. The researchers were allowed by the administration of the Center of Expertise on Eco-tourism for Mangrove Conservation, Chonburi Province Office to conduct a study in the coastal area of Samet Municipality where many mangrove crabs are thriving. The survey done in the said office had given the team enough ideas pertaining to the factors that need to be studied in the area. During the conduct of the study, the researchers were guided

and given knowledge by their teachers namely Ms. Rawadee Meesuk and Mr. Marvin Servallos. Thorough guidance and invaluable ideas from the above names and institution were indeed significant to completely understand all the scopes of this research. Finally, the researchers of this science project have cooperated to finish the work entirely from the planning stage, experiments, analyzing of data, and packaging of the final research paper.

I Make an Impact

The success of this experiment would greatly benefit the public, the administration of the Center of Expertise on Eco-tourism for Mangrove Conservation, Chonburi Province Office, and government officials because the results of physico-chemical factors measurement in the coastal zone of Samet would give them valuable information about the current condition of Samet seawater where many mangrove crabs are thriving. Most importantly, the methods and results gathered in this study have great impact to the community of Chonradsadornumrung School, especially to the students because it serves as an eye opener for them that young learners like the researchers can have a valuable contribution in studying their surroundings like water quality and how it affects to the population of aquatic organisms.

I am a Data Scientist

The researchers have studied systematically the current condition of the seawater in Samet, Chonburi, Thailand where mangrove crabs are found. All of the data gathered from the field measurement were analyzed using the statistical models like ANOVA (Analysis of Variance) with post-hoc Tukey HSD (Honestly Significant Difference). Through these statistical tools, the researchers were able to determine if there are significant differences or none among the parameters measured in the natural habitat of the experimental organism. The results of the analysis were discussed and presented properly. Moreover, the results of the experiment were linked to the research done by other researchers.

I am a STEM Professional

This environmental research is not possible without the invaluable insights from various STEM Professionals. The researchers were able to formulate research topic and questions by asking their Biology teacher pertaining to possible studies that they can pursue that is relevant to Globe mission and vision. During data gathering and interpretation, the statistician of the school was consulted about the accurate statistical method that can be used in interpreting the data about physico-chemical factors of water in Samet, Chonburi,

Thailand as well as the results of crab population. From the consultation with the school's statistician, the researchers learned that ANOVA (Analysis of Variance) and post-hoc Tukey HSD (Honestly Significant Difference) Test are the most appropriate tool to analyze the collected data. Moreover, the researchers also asked help from the statistician of the school to calculate and interpret the results of the study.

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Appendix 1

ANOVA (Analysis of Variance) for water temperature that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	23.0	26.2	28.6	25.5
	23.0	26.6	28.7	25.9
	23.0	26.6	287.0	26.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	18,115.0358	3	6,038.3453	1.0856	0.4089
error	44,496.7333	8	5,562.0917		
total	62,611.7692	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **higher** than 0.05, suggesting that the treatments are not significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	0.0805	0.8999947	insignificant
A vs C	2.1312	0.4772103	insignificant
A vs D	0.0650	0.8999947	insignificant
B vs C	2.0507	0.5059243	insignificant
B vs D	0.0155	0.8999947	insignificant
C vs D	2.0662	0.5003222	insignificant

Appendix 2

ANOVA (Analysis of Variance) for dissolved oxygen that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	1.33	1.21	1.06	0.72
	1.15	0.92	0.85	0.52
	1.1	0.79	0.89	0.55

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	0.5466	3	0.1822	8.5812	0.0070
error	0.1699	8	0.0212		
total	0.7165	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test

multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	2.6150	0.3198494	insignificant
A vs C	3.0905	0.2069067	insignificant
A vs D	7.0922	0.0045441	** p<0.01
B vs C	0.4755	0.8999947	insignificant
B vs D	4.4772	0.0526610	insignificant
C vs D	4.0018	0.0846672	insignificant

Appendix 3

ANOVA (Analysis of Variance) for total dissolved solids (TDS) that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	2854.0	2883.0	2913.0	2784.0
	2869.0	2883.0	2883.0	2770.0
	2869.0	2883.0	2883.0	2784.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	24,103.00	3	8,034.33	72.9841	3.7455e-06
error	880.6667	8	110.08		
total	24,983.67	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	3.1366	0.1980162	insignificant
A vs C	4.7874	0.0387042	* p<0.05
A vs D	13.9769	0.0010053	** p<0.01
B vs C	1.6508	0.6505739	insignificant
B vs D	17.1135	0.0010053	** p<0.01
C vs D	18.7643	0.0010053	** p<0.01

Appendix 4

ANOVA (Analysis of Variance) for electrical conductivity that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	5739.0	5767.0	5739.0	5568.0
	5739.0	5739.0	5767.0	5568.0
	5709.0	5739.0	5767.0	5541.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	79,123.67	3	26,374.56	98.99	1.15e-06
error	2,131.33	8	266.4167		
total	81,255.00	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	2.0516	0.5056089	insignificant
A vs C	3.0420	0.2166323	insignificant
A vs D	18.0397	0.0010053	** p<0.01
B vs C	0.9904	0.8894661	insignificant
B vs D	20.0913	0.0010053	** p<0.01
C vs D	21.0817	0.0010053	** p<0.01

Appendix 5

ANOVA (Analysis of Variance) for transparency that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	0.29	0.23	0.13	0.23
	0.26	0.24	0.13	0.23
	0.26	0.24	0.13	0.23

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	0.0328	3	0.0109	131.20	3.8441e-07
error	0.0007	8	0.0001		
total	0.0335	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test

multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	6.3246	0.0089595	** p<0.01
A vs C	26.5631	0.0010053	** p<0.01
A vs D	7.5895	0.0029854	** p<0.01
B vs C	20.2386	0.0010053	** p<0.01
B vs D	1.2649	0.7901694	insignificant
C vs D	18.9737	0.0010053	** p<0.01

Appendix 6

ANOVA (Analysis of Variance) for water pH that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment →	A	B	C	D
Input Data →	7.53	7.44	7.44	6.55
	7.48	7.44	7.43	6.55
	7.52	7.44	7.43	6.55

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	1.8786	3	0.6262	3,415.64	9.116e-13
error	0.0015	8	0.0002		
total	1.8801	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	8.9544	0.0010174	** p<0.01
A vs C	9.8072	0.0010053	** p<0.01
A vs D	122.8036	0.0010053	** p<0.01
B vs C	0.8528	0.8999947	insignificant
B vs D	113.8492	0.0010053	** p<0.01
C vs D	112.9964	0.0010053	** p<0.01

Appendix 7

ANOVA (Analysis of Variance) for salinity that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	23.0	23.0	20.0	16.0
	24.0	22.0	22.0	16.0
	23.0	22.0	20.0	16.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	94.916	3	31.6389	63.28	6.47e-06
error	4.0000	8	0.5000		
total	98.916	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	2.4495	0.3694296	insignificant
A vs C	6.5320	0.0074287	** p<0.01
A vs D	17.9629	0.0010053	** p<0.01
B vs C	4.0825	0.0781101	insignificant
B vs D	15.5134	0.0010053	** p<0.01
C vs D	11.4310	0.0010053	** p<0.01

Appendix 8

ANOVA (Analysis of Variance) for relative humidity that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	51.0	64.0	58.0	63.0
	51.0	62.0	56.0	58.0
	51.0	62.0	54.0	58.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	227.3333	3	75.7778	22.18	0.0003
error	27.3333	8	3.4167		
total	254.6667	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test

multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	10.9322	0.0010053	** p<0.01
A vs C	4.6852	0.0428219	* p<0.05
A vs D	8.1210	0.0019374	** p<0.01
B vs C	6.2470	0.0096163	** p<0.01
B vs D	2.8111	0.2683832	insignificant
C vs D	3.4358	0.1482763	insignificant

Appendix 9

ANOVA (Analysis of Variance) for air temperature that was measured for 4 consecutive times in the coastal zone of Samet, Chonburi, Thailand.

Treatment ⟶	A	B	C	D
Input Data ⟶	27.2	29.7	29.0	29.6
	27.9	29.8	29.2	30.4
	27.9	30.5	29.7	30.6

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	11.9025	3	3.9675	20.7904	0.0004
error	1.5267	8	0.1908		
total	13.4292	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is **lower** than 0.05, suggesting that the one or more treatments are significantly different. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	9.2515	0.0010053	** p<0.01
A vs C	6.4760	0.0078123	** p<0.01
A vs D	10.0444	0.0010053	** p<0.01
B vs C	2.7754	0.2772505	insignificant
B vs D	0.7930	0.8999947	insignificant
C vs D	3.5684	0.1301063	insignificant