Research Title: Biochemical Defenses of Mangroves against Varying Physicochemical Factors of Seawater in Bang Sai District, Chonburi, Thailand

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Abstract

Determining the biochemical compounds used by Red mangrove (*Rhizophora mangle*) and Tall-stilt mangrove (*Rhizophora apiculata*) against various physicochemical factors in the seawater is the main goal of this current investigation. Using the standard equipment from Extech, the researchers characterized several physico-chemical factors of the seawater in Bang Sai, Chonburi such as water temperature, TDS, dissolved oxygen, electrical conductivity, salinity, transparency, water pH, air temperature, and relative humidity. Based on the experimentations, results and gathered data, the researchers discovered that there was a significant difference ($p<0.05$) in all of the physico-chemical factors measured in the natural habitat of mangroves in Bang Sai, Chonburi, Thailand such as water temperature, transparency, dissolved oxygen, total dissolved solids, electrical conductivity, water pH, air temperature, salinity, and relative humidity. Moreover, the selected mangroves contain diverse biochemical compounds that protect them from varying physico-chemical conditions in their habitat. For the improvement of the study, the researchers recommended conducting further research to evaluate the other parameters in the seawater and expanding the investigations to more locations in Bang Sai, Chonburi for the current physico-chemical factors that could affect the survival of various mangrove species in the intertidal zones.

Keywords: Biochemical defenses, Physico-chemical factors, mangrove

INTRODUCTION

The coastal area of Bangsai District, Chonburi, Thailand contains diverse species of mangroves that thrives well from the past to its present condition. Despite the drastic changes due to economic activities in the place, the mangrove plants manifested resilience and adaptability to their ever-changing environment. Plains and littoral areas constitute the majority of the district's overall landscape. As a result of these geographical qualities, this area has experienced a variety of natural phenomena such as storm surges, tidal variations, sedimentation, sea level rise, and so on. Anthropogenic activities such as urbanization, residential sewage, and other economic activity in the catchment area cause variations in the physicochemical parameters of saltwater, resulting in a worsening of water quality (Verma et.al, 2012). Water quality indicates the relation of all hydrological properties including physical, chemical and biological properties of the water body. Hence, water quality assessment involves analysis of physico- chemical, biological and microbiological parameters that reflects the biotic and abiotic status of ecosystem (Smitha, 2013).

With the constant change in their habitat, the mangrove plants have to produce substances that are essential for their survival (Briskin, 2000). As stated in the book of Guevara, et.al., 2005; plants produce a great number of compounds of various chemical structures known as secondary metabolites which plants utilize to counteract the adverse effects of various factors around them. These are constituents present in smaller quantities in the plant but are of high value compared to the primary metabolites. Secondary compounds, often unique to a particular species, include the alkaloids, the steroids, flavonoids, tannins, and others. These compounds are highly significant because they act as anti-feedants, sex attractants, or antibiotics. Currently, the area experienced drastic change due to urbanization and other human activities like building new bridges and improper waste disposal. This could lead to imbalance of the ecosystem and generate pollutants that can affect the physicochemical and biological quality of the area.

The situations stated above prompted the researchers to conduct a study entitled "Biochemical Defenses of Mangroves against Varying Physicochemical Factors of Seawater in Bang Sai District, Chonburi, Thailand". This study aimed to characterize the physico-chemical factors surrounding the mangroves in the area as well as evaluate the secondary compounds produced by the plants that helps them to survive continuously.

Research Questions:

1. Is there a significant difference in the physico-chemical factors of seawater where selected mangroves are thriving in Bangsai, Chonburi coastal area?
2. What are the biochemical defenses of the selected mangroves against varying physico-chemical factors of seawater?

Objectives:

1. To characterize the physico - chemical factors surrounding the mangroves in Bangsai District, Chonburi, Thailand.
2. To screen the secondary metabolites of the selected mangroves.

Hypotheses:

Alternative: There is a significant difference in the physico-chemical factors in the seawater of Bangsai, Chonburi, Thailand and the selected mangroves possess various biochemical defenses against varying physico-chemical factors of seawater.

Null: There is no significant difference in the physico-chemical factors in the seawater of Bangsai, Chonburi, Thailand and the selected mangroves do not possess various biochemical defenses against varying physico-chemical factors of seawater.

Materials:

Secchi disc	Beakers	Filter papers
pH, Conductivity, TDS, Salinity, Temperature Meter	Meterstick	Chemicals for Phytochemical Screening
Dissolved Oxygen meter	Thermo Hygrometer	Microscopes
	Test tubes	Erlenmeyer flask

Research Methodology

A. Study Site

The study site is located at Bang Sai Park, Chonburi, Thailand. Latitude 13°23'02"N, Longitude 100°59'00"E.

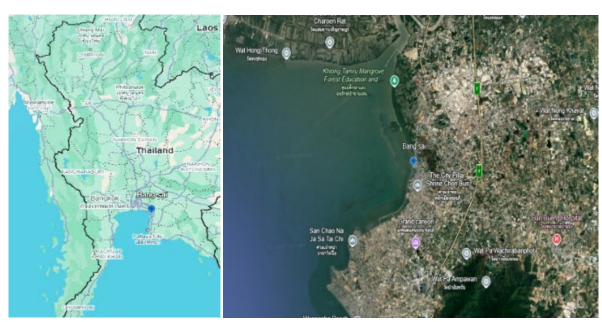

FIGURE 1. The study site at intertidal zones of Bang Sai, Chonburi, Thailand.

B. Survey and Preparation of Materials

The researchers went to the coastal zone of Bang Sai district to conduct a survey pertaining to the current condition of the coastal area. After the survey and selection of study site, needed laboratory materials and equipment for testing the water quality were procured from the science laboratory of Chonradsadornumrung School.

FIGURE 2. The study site at Bang Sai, Chonburi, Thailand.

C. Evaluation of Physio-chemical Factors of Seawater

In situ measurement was done to characterize various parameters in the seawater of Bang Sai District, Chonburi, Thailand such as water temperature, dissolved oxygen, total dissolved solids (TDS), electrical conductivity, transparency, water pH, salinity, relative humidity, also the air temperature and water color of the study site were included. To determine the water parameters, the following steps were carried out: 500 mL of brackish water was collected in a beaker for measuring water parameters, the salinity was measured using Optik handheld refractometers. Secchi disk was used to measure the transparency of water. Extech measuring equipment were also used to examine the dissolved oxygen, TDS, electrical conductivity, water temperature and water pH. 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 or turbid) 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 physico-chemical parameters of the seawater.

FIGURE 3. Assessing the physico-chemical factors of seawater.

D. Collection of Selected Mangroves

The researchers gathered the leaves of Red mangrove (*Rhizophora mangle*) and Tall-stilt mangrove (*Rhizophora apiculata*) from the study site after the physico-chemical characterization. Using the digital balance, 200g of the collected samples were weighed and placed in the separate Erlenmeyer flasks. The plants collected were then soaked in ethyl alcohol for 24 hours. The ethanolic extracts were then used in phytochemical screening to determine the secondary metabolites of the plants.

FIGURE 4. Collecting the leaves of mangrove plants.

E. Phytochemical Screening

Phytochemical screening procedures from the book of Guevarra et.al., 2005 were applied to evaluate the presence of the secondary compounds responsible for the survival of mangrove plants like Alkaloids, Saponins, Tannins, Phenolic Compounds, Flavonoids, and Leucoanthocyanins.

FIGURE 5. Phytochemical screening of the biochemical compounds of mangrove plants.

Results and Discussions

The figures below and on the following page show the data encoded on the Globe website from December 2024 to January 2025. Figures 5 through 12 depict the Globe data entry for air temperature, relative humidity, water temperature, dissolved oxygen, and water pH measured in the seawater of Bang Sai, Chonburi, Thailand.

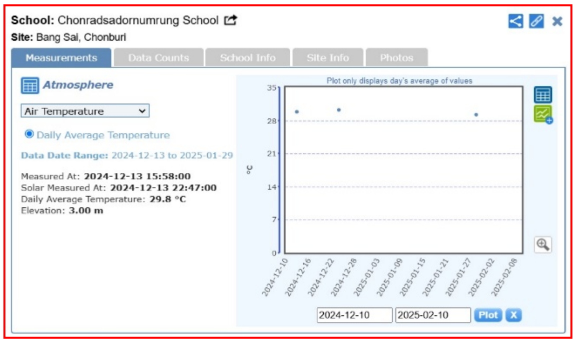

Figure 6. Globe Data Entry for air temperature.

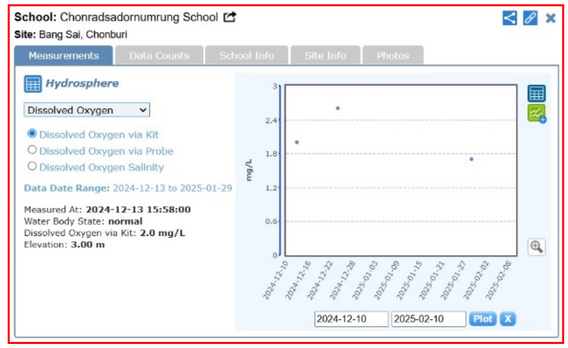

Figure 7. Globe Data Entry for dissolved oxygen.

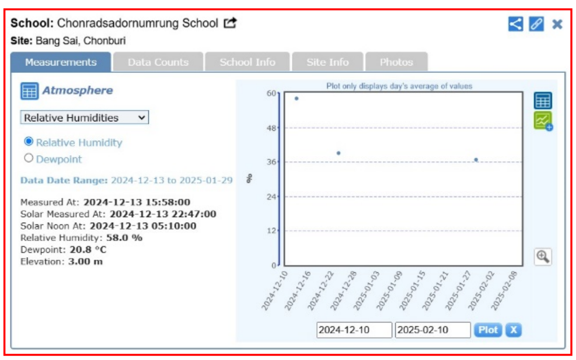

Figure 8. Globe Data Entry for relative humidity.

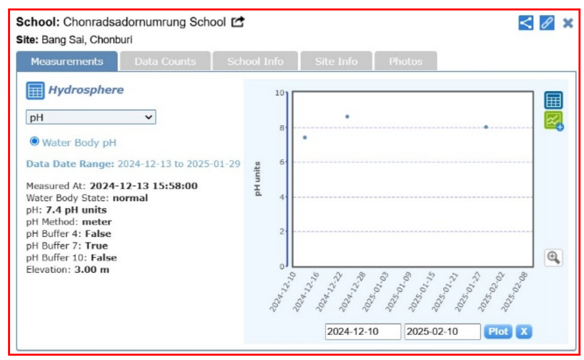

Figure 9. Globe Data Entry for water pH.

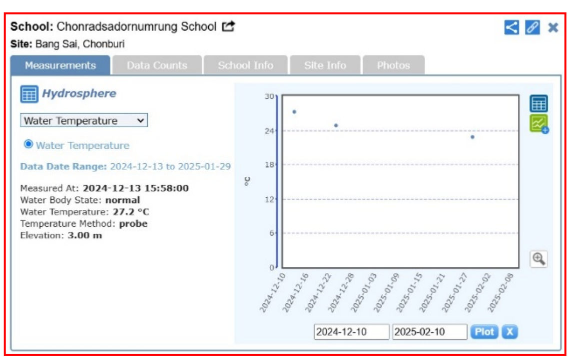

Figure 10. Globe Data Entry for water temperature.

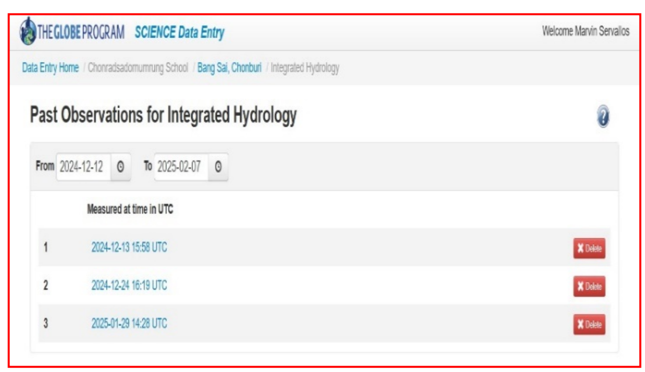

Figure 11. Globe Data Entry for integrated hydrology.

TABLE 1. The average results of physico-chemical factors measured from Bang Sai, Chonburi, Thailand.

	13 Dec. 2024 (4:00 PM)	24 Dec. 2024 (4:20 PM)	29 Jan. 2025 (2:30 PM)
Water Temperature (°C)	27.16	24.76	22.80
Dissolved Oxygen (mg/L)	2.04	2.63	1.75
TDS (ppm)	3248	3212	3056
Electrical Conductivity (µS/cm)	6424	6412	6201
Transparency (m)	0.20	0.25	0.13
Water pH	7.42	8.58	8.00
Salinity (%)	34.30	34.00	35.33
Water color	Turbid	Turbid	Turbid
Relative Humidity (%)	58.00	39.00	36.66
Air Temperature (°C)	29.80	30.20	29.20

Table 1 shows the comparison of the average results of physico-chemical factors measured from Bang Sai. These results were gathered after 3 series of experiments that started from December 2024 to January 2025. It can be seen from the table and graph that there was a variation in the parameters measured from Bang Sai. Though some factors are in higher amount such as TDS and electrical conductivity, plants have secondary compounds that protect them in their natural habitat from any abiotic stress that poses threat to them (Schafer et al., 2009).

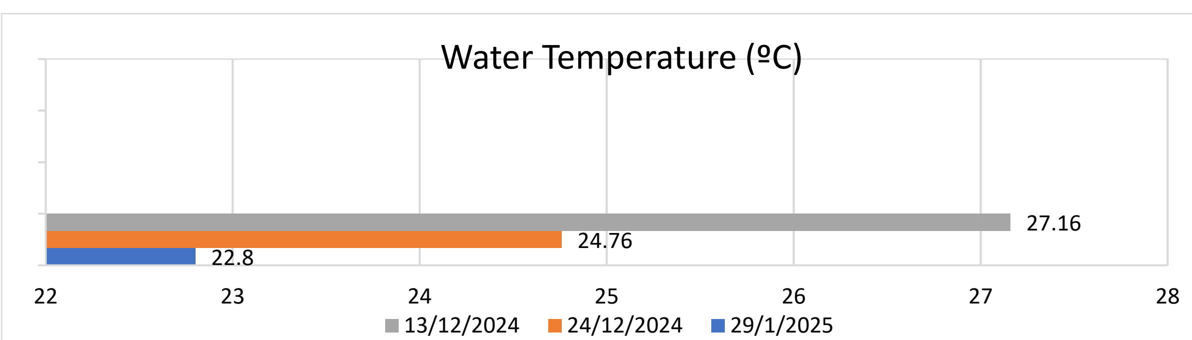

FIGURE 12. Average Water temperature (°C) in Bang Sai.

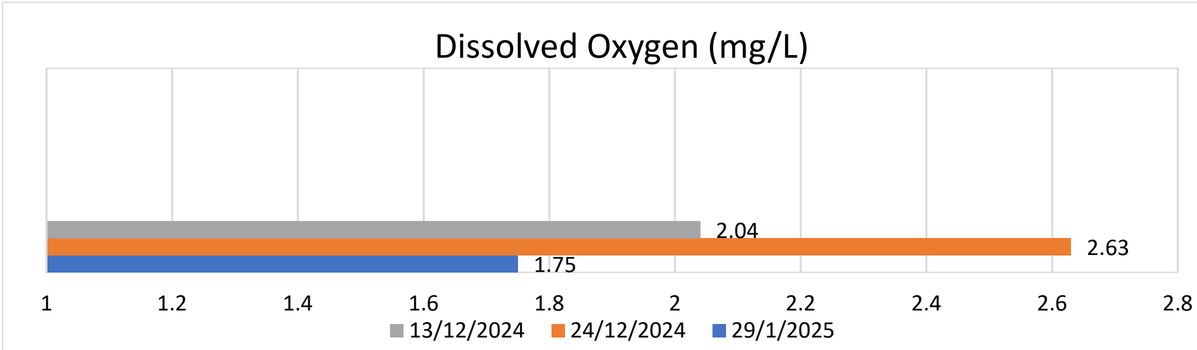

FIGURE 13. Average Dissolved Oxygen (mg/L) in Bang Sai.

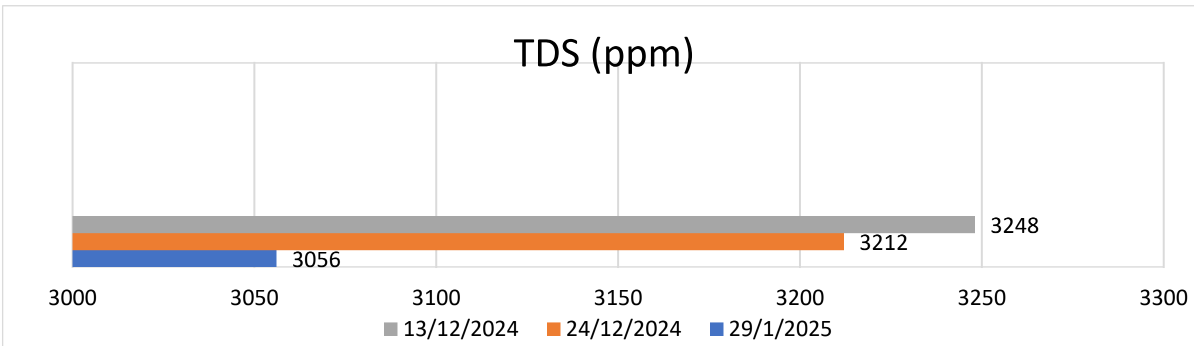

FIGURE 14. Average TDS (ppm) in Bang Sai.

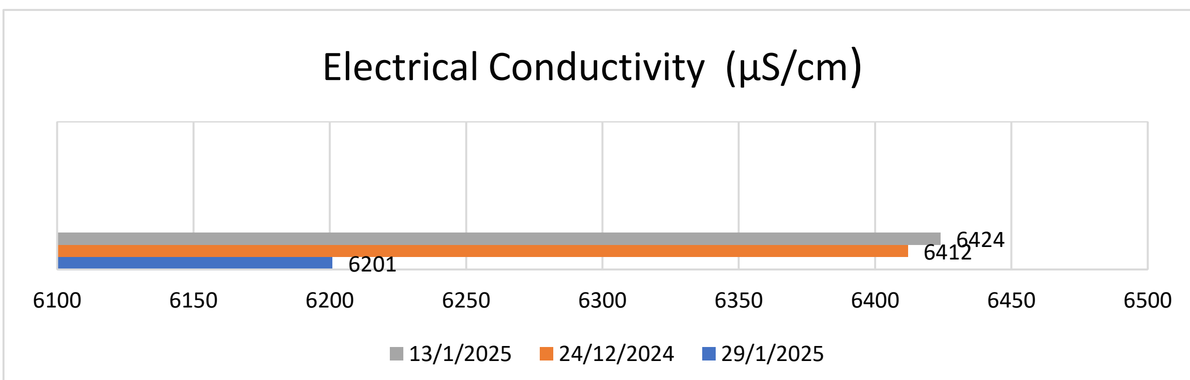

FIGURE 15. Average electrical conductivity (µS/cm) in Bang Sai.

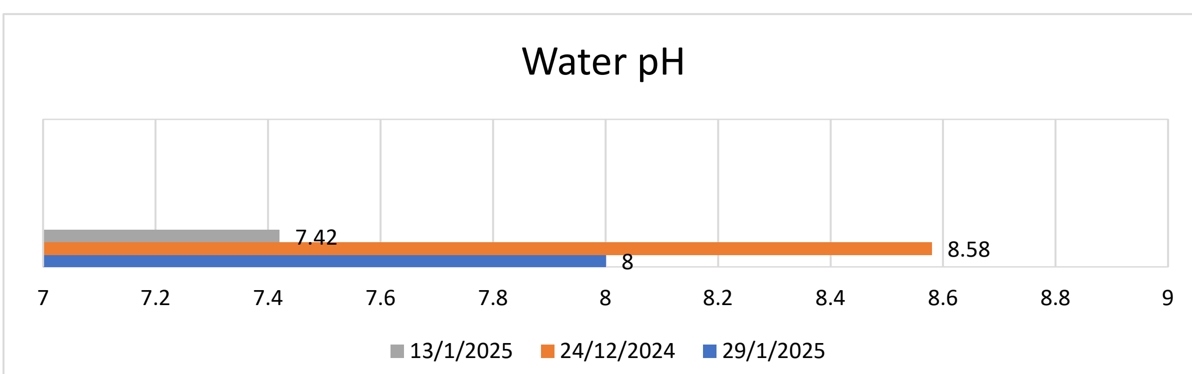

FIGURE 16. Average water pH in Bang Sai.

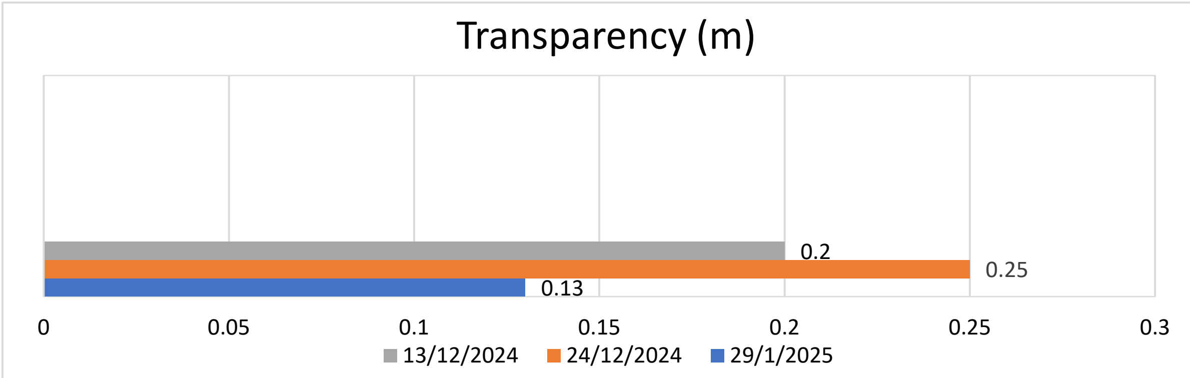

FIGURE 17. Average water transparency (m) in Bang Sai.

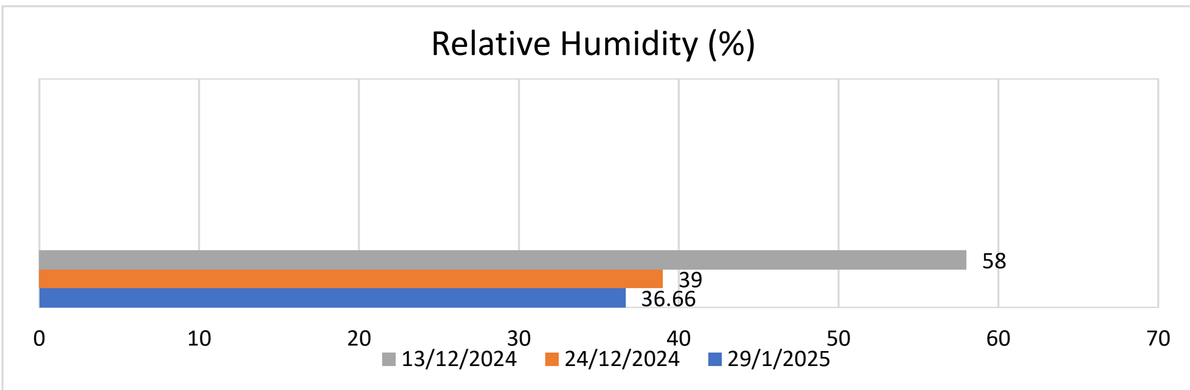

FIGURE 18. Average relative humidity (%) in Bang Sai.

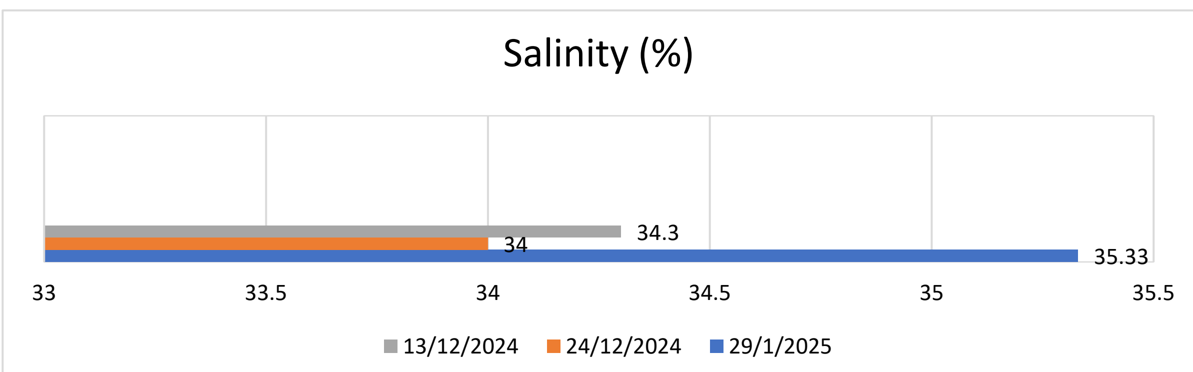

FIGURE 19. Average salinity level (%) in Bang Sai.

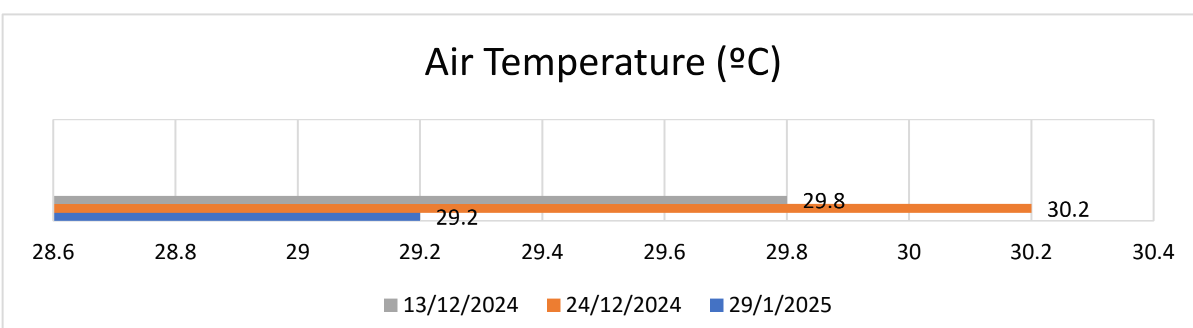

FIGURE 20. Average air temperature (ºC) in Bang Sai.

Figure 12 to 20 shows the average results of all factors measured in Bang Sai, Chonburi. The average range for water temperature in Bang Sai was 22.80°C – 27.16°C. Average Dissolved oxygen ranges from 1.75 mg/L – 2.63 mg/L. Average TDS ranges from 3056 ppm – 3248.0 ppm. Average electrical conductivity ranges from 6201.0 μS/cm – 6424.0 μS/cm. Average water transparency ranges from 0.13 m – 0.20 m. Average water pH ranges from 7.42- 8.58. Average salinity ranges from 34.00 % – 35.33 %. Average relative humidity ranges from 36.66 % – 58.00 %. Lastly, average air temperature ranges from 29.20°C – 30.20°C. As seen from Figure 12-20, there were variations among the physico-chemical factors measured for 3 consecutive times.

TABLE 2. The result of Phytochemical screening of the secondary compounds of mangrove plants.

Phytochemicals	Red Mangrove	Tall-stilt mangrove
Alkaloids	Positive	Positive
Saponins	Negative	Negative
Tannins	Positive	Positive
Phenolic Compounds	Positive	Positive
Flavonoid	Positive	Positive
Leucoanthocyanins	Positive	Negative

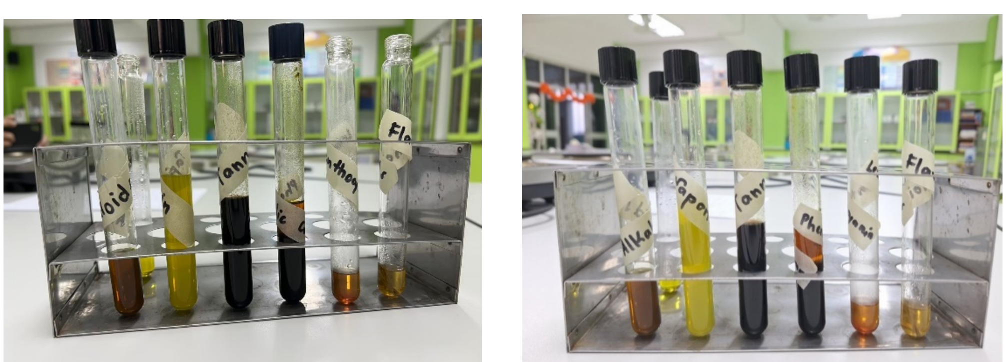

Figure 21. Secondary compounds of Red mangrove (*Rhizophora mangle*) and Tall-stilt mangrove (*Rhizophora apiculata*).

Table1 to Figure 22 shows the results of phytochemical screening of the secondary compounds of Red mangrove (*Rhizophora mangle*) and Tall-stilt mangrove (*Rhizophora apiculata*). Red mangrove contains alkaloids, tannins, phenolic compounds, flavonoids, and leucoanthocyanins. While, tall-stilt mangrove possesses alkaloids, tannins, phenolic compounds, and flavonoids.

Discussion

In natural world, plants face various competitors and thus possess a countless of defense and have evolved multiple defense mechanisms by which they are able to cope with various kinds of biotic and abiotic stress (Ballhorn et al., 2009). Plants produce natural products or secondary metabolites with a prominent function in the protection against predators and microbial pathogens on the basis of their toxic nature and repellence to herbivores and microbes and some of which also involved in defense against abiotic stress and also important for the communication of the plants with other organisms (Schafer et al., 2009).

Secondary metabolites are chemical compounds that occur naturally in plants are biologically active, naturally occurring chemical compounds found in plants, which provide health benefits for humans further than those attributed to macronutrients and micronutrients (Hasler CM, & Blumberg JB., 1999). As stated by Mathai, K. (2009) it protects plants from disease and damage and contribute to the plant's color, aroma and flavor. In general, the plant chemicals that protect plant cells from environmental hazards such as pollution, stress, drought, UV exposure and pathogenic attack.

The marine water in the study site changed significantly 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 a significant difference ($p<0.05$) in all of the physico-chemical parameters measured after 3 series of experiments.

The lowest average water temperature recorded from the 3 days was 22.80°C and the maximum average water temperature was 27.16°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 average amount of dissolved oxygen measured from the site is lower compared to the normal level of DO in seawater which ranges from 1.65 mg/L – 2.63 mg/L. 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.

Average TDS ranges from 3056 ppm – 3248 ppm as seen from Figure 14. Average electrical conductivity ranges from 6201 μS/cm – 6424 μS/cm as seen from Figure 15. 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 Bang Sai is higher than the normal range for a typical seawater but in normal range for saline water.

The average pH of seawater from the area ranges from 7.42 – 8.58 (Figure 15). 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).

The situations above and the results of all experiments only proved that despite of many factors surrounding the mangroves, they are still able to survive and adapt to the changes brought by the environment such as change in water temperature, pH, TDS, electrical conductivity, soil pH, depth of the water or even the presence of pathogenic microbes and various organic matters. The experimental plants possessed different kinds of secondary compounds and these biochemical substances, protected them in their ever-changing natural habitat in the past, also present and in the future.

Conclusion

Based on the experimentations, results and gathered data, the researchers concluded that there was a significant difference ($p<0.05$) in all of the physico-chemical factors measured in the natural habitat of mangroves in Bang Sai, Chonburi, Thailand such as water temperature, transparency, dissolved oxygen, total dissolved solids, electrical conductivity, water pH, air temperature, salinity, and relative humidity. Furthermore, the selected mangroves contain diverse biochemical compounds that protect them from varying physico-chemical conditions in their habitat.

Recommendations

For the improvement of the study, the researchers recommended conducting further research to evaluate the other parameters in the seawater and expanding the investigations to more locations in Bang Sai, Chonburi for the current physico-chemical factors that could affect the survival of various mangrove species in the intertidal zones.

GLOBE Badges

I am a Collaborator

This current environmental science research was done successfully because of the united 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 Bang Sai District where many mangrove species 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. Moreover, the administration of the school provided the transportation needs of the students for effective and efficient movement from the school to the study site. 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 Bang Sai would give them valuable information about the current condition of Bang Sai seawater where many mangrove species are thriving like Red mangrove (*Rhizophora mangle*) and Tall-stilt mangrove (*Rhizophora apiculata*). 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 Bang Sai, Chonburi, Thailand where Red mangrove (*Rhizophora mangle*) and Tall-stilt mangrove (*Rhizophora apiculata*) 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) as suggested by the statistician of the school. 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 organisms. 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.

Acknowledgment

The researchers of the study would like to acknowledge the following for making this science project possible. First, they would like to convey their genuine thanks to the administrators of Chonradsadornumrung School and Head of the English Program, Ms. Rawadee Meesuk for their utmost support, suggestions, and encouragement as well as for providing all the Laboratory equipment and chemicals that they need in their study. Second, heartfelt thanks are also conveyed by the researchers to their Science teacher- Mr. Marvin Servallos for his thorough guidance towards the completion of the study. Third, sincere gratitude is given by the researchers to the administration of the Center of Expertise on Eco-tourism for Mangrove Conservation, Chonburi Province Office for allowing them to conduct a study in the coastal area of Bang Sai, District, Chonburi. Finally, the researchers would like to give their special thanks to the committee of Globe International Virtual Symposium (IVSS) 2025 for conducting this prestigious event that enabled young scientists to share their scientific discoveries.

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Appendix 1

ANOVA (Analysis of Variance) for water temperature that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	27.1	24.9	22.9
	27.2	24.6	22.8
	27.2	24.8	22.7

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	28.6956	2	14.3478	1,173.9091	1.6563e-08
error	0.0733	6	0.0122		
total	28.7689	8			

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	37.6008	0.0010053	** p<0.01
A vs C	68.4125	0.0010053	** p<0.01
B vs C	30.8117	0.0010053	** p<0.01

Appendix 2

ANOVA (Analysis of Variance) for dissolved oxygen that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	2.02	3.15	1.75
	2.04	2.53	1.74
	2.07	2.22	1.75

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	1.2223	2	0.6111	8.1522	0.0195
error	0.4498	6	0.0750		
total	1.6721	8			

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	3.7323	0.0851950	insignificant
A vs C	1.8767	0.4333857	insignificant
B vs C	5.6090	0.0173065	* p<0.05

Appendix 3

ANOVA (Analysis of Variance) for total dissolved solids (TDS) that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	3248.0	3212.0	3089.0
	3248.0	3212.0	2975.0
	3249.0	3212.0	3106.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	62,184.6667	2	31,092.3333	18.3809	0.0028
error	10,149.3333	6	1,691.5556		
total	72,334.0000	8			

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	1.5301	0.5581511	insignificant
A vs C	8.0717	0.0030088	** p<0.01
B vs C	6.5416	0.0085242	** p<0.01

Appendix 4

ANOVA (Analysis of Variance) for electrical conductivity that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	6497.0	6424.0	6212.0
	6388.0	6424.0	6179.0
	6388.0	6388.0	6212.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	94,551	2	47,275	29.8247	0.0008
error	9,511	6	1,585		
total	104,061	8			

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	0.5366	0.8999947	insignificant
A vs C	9.7159	0.0011381	** p<0.01
B vs C	9.1794	0.0015408	** p<0.01

Appendix 5

ANOVA (Analysis of Variance) for transparency that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment ⟶	A	B	C
Input Data ⟶	0.2	0.2	0.15
	0.2	0.2	0.14
	0.2	0.2	0.1

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	0.0098	2	0.0049	21.0000	0.0020
error	0.0014	6	0.0002		
total	0.0112	8			

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	0.0000	0.8999947	insignificant
A vs C	7.9373	0.0032763	** p<0.01
B vs C	7.9373	0.0032763	** p<0.01

Appendix 6

ANOVA (Analysis of Variance) for water pH that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	7.35	8.57	7.94
	7.44	8.57	8.03
	7.48	8.6	8.04

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	2.0068	2	1.0034	387.5837	4.5313e-07
error	0.0155	6	0.0026		
total	2.0224	8			

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	39.3742	0.0010053	** p<0.01
A vs C	19.7439	0.0010053	** p<0.01
B vs C	19.6304	0.0010053	** p<0.01

Appendix 7

ANOVA (Analysis of Variance) for salinity that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	35.0	34.0	36.0
	34.0	34.0	35.0
	34.0	34.0	35.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	2.8889	2	1.4444	6.5000	0.0315
error	1.3333	6	0.2222		
total	4.2222	8			

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	1.2247	0.6719476	insignificant
A vs C	3.6742	0.0897524	insignificant
B vs C	4.8990	0.0308323	* p<0.05

Appendix 8

ANOVA (Analysis of Variance) for relative humidity that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	60.0	40.0	37.0
	58.0	39.0	36.0
	56.0	38.0	37.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	821.5556	2	410.7778	231.0625	2.1056e-06
error	10.6667	6	1.7778		
total	832.2222	8			

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	24.6817	0.0010053	** p<0.01
A vs C	27.7128	0.0010053	** p<0.01
B vs C	3.0311	0.1605092	insignificant

Appendix 9

ANOVA (Analysis of Variance) for air temperature that was measured for 3 consecutive times in the coastal zone of Bang Sai, Chonburi, Thailand.

Treatment →	A	B	C
Input Data →	29.7	30.5	28.9
	29.8	30.0	29.3
	29.9	30.1	29.4

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	1.5200	2	0.7600	15.2000	0.0045
error	0.3000	6	0.0500		
total	1.8200	8			

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	3.0984	0.1510293	insignificant
A vs C	4.6476	0.0381389	* p<0.05
B vs C	7.7460	0.0037119	** p<0.01