Impact of Rising Air Temperatures on the Growth and Water Quality of Blue swimming Crab (*Portunus pelagicus*) Culture in Grow-Out Ponds: A Comparative Study of 2022 and 2023

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ABSTRACT

This study examined the effects of increased air temperatures on the growth and water quality of blue swimming crabs (BSC), *Portunus pelagicus*, cultured in grow-out ponds in Prachuap Khiri Khan province, Thailand, over the years 2022 and 2023. Geographic data indicated that the average lowest temperature and maximum temperature in 2022 were 31.0°C and 36.0°C, respectively, while these values increased to 31.0°C and 39.0°C in 2023. Consequently, the average maximum temperature fluctuation increased from 33.5°C in 2022 to 35.0°C in 2023. Analysis of BSC culture across five batches per year ($n = 5$) revealed no significant differences in initial carapace width (CL) and body weight (BW) between 2022 and 2023. However, at 90 days of cultivation, BSC in 2023 showed a significantly ($p<0.05$) lower mean BW (52.66±1.45 g) compared to 2022 (61.55±5.50 g), while CL remained statistically similar between the years. Additionally, the mean specific growth rate was lower in 2023 (6.25±0.03%/day) compared to 2022 (6.48±0.10%/day) ($p<0.05$). These findings suggest that BSC growth in 2023 was adversely affected by higher temperatures, likely due to climate change. Increased temperatures also led to variations in average water quality parameters, with higher salinity (35.40±1.19 psu) and water temperature (32.19±1.83°C) observed in 2023 (34.09±1.75 psu, and 31.13±2.05°C in 2022) ($p<0.05$). However, parameters such as pH, dissolved oxygen, total ammonia, nitrite, and alkalinity did not exhibit consistent changes in response to increased temperature fluctuation. This study underscores the need for adaptive management strategies to mitigate the impacts of climate change on aquaculture systems.

Keyword: Climate change/ Blue swimming crab culture/ *Portunus pelagicus*/ Temperature fluctuations/ Water quality

1. INTRODUCTION

Climate change was identified as one of the most pressing global challenges of the 21st century, with rising temperatures being a central concern. The increase in global average temperatures due to greenhouse gas emissions had far-reaching implications for various ecosystems and industries, including aquaculture [1]. Aquaculture, the farming of aquatic organisms such as fish, crustaceans, and mollusks, was particularly sensitive to changes in environmental conditions. Temperature fluctuations (TF) profoundly affected the growth, health, and productivity of aquatic species, leading to significant economic and ecological consequences [2, 3].

The blue swimming crab (*Portunus pelagicus* Linnaeus 1758), in this paper is referred to as BSC, was a key commercial species found in the coastal waters of tropical regions spanning the western Indian Ocean and eastern Pacific [4]. In 2020, fishery trends showed that BSC catches remained at their highest levels [2]. Notably, the demand for seafood increased while natural marine resources decreased due to overexploitation and habitat destruction, with the BSC being one of the species under threat in many Asian countries [5]. Developing culture methods for BSC represented a promising long-term solution to this issue. As a result, considerable research focused on BSC culture and related topics [6-9].

The growth of aquatic animals was profoundly influenced by various environmental factors, including temperature [3, 10]. The previous study confirmed that temperature had a direct impact on the growth of BSC, with the optimal reared temperature range as 28-31°C [6-9]. However, repeated studies on the effects of temperature previously reported were necessary, particularly studies conducted in grow-out pond conditions where environmental factors cannot be controlled as precisely as

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in laboratory settings. Specifically, the impact of TF on BSC rearing and the effects on other environmental factors, such as salinity changes during rearing, need further investigation. There are several reasons to study and confirm the effects of TF in field grow-out pond conditions. Firstly, to verify the consistency of previous findings under different study conditions. Secondly, to improve rearing methods, such as pond management practices, to optimize outcomes. Thirdly, testing under varying environmental conditions, such as annual TF, will provide a more comprehensive understanding of the impacts. Lastly, expanding the knowledge base through repeated studies will contribute to the better development of BSC rearing in field grow-out pond conditions.

Climate change, characterized by rising temperatures and unpredictable weather patterns, may impact BSC cultivation in pond systems over the long term. The aims of this study were to evaluated the effects of climate change, particularly increasing air temperatures, on the growth and water quality of BSC cultivation in grow-out pond. The research involved analyzing data from BSC reared in earthen ponds and correlating it with Geographic Information System (GIS) data on regional air temperature fluctuations. The knowledge gained from this study will be used as a basis for developing strategies to enhance the resilience of BSC culture in grow-out pond against the impacts of climate change.

2. METHODOLOGY

2.1 Study site and data source

The study was conducted at the Klongwan Fisheries Research Station (KFRS) in Prachuap Khiri Khan province, Thailand. Prachuap Khiri Khan province is located in the upper southern region of Thailand, covers an area of 6,367.62 square kilometers. It is positioned between latitude 10.9º - 12.6º N and longitudes 99.2º - 100.0º E (Figure 1).

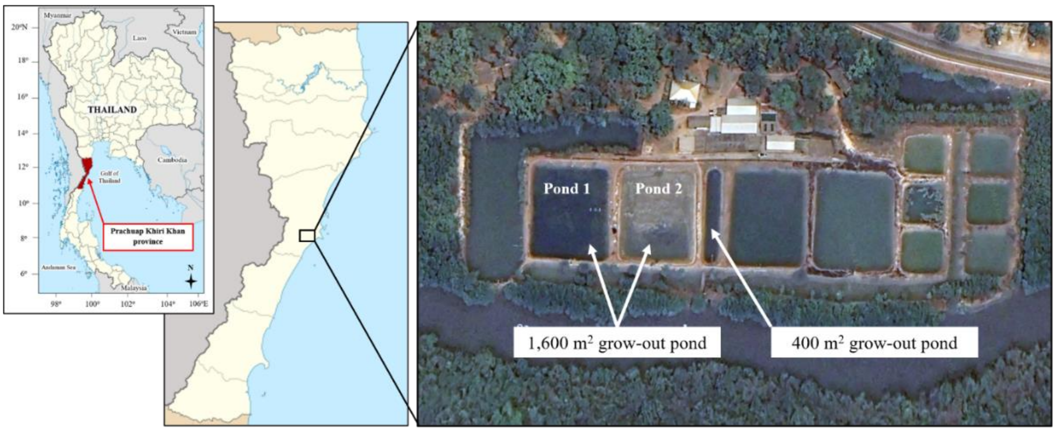

Figure 1. A map showing the location of the blue swimming crab (*Portunus pelagicus*) culture site (11º45´19´´N, 99º47´35´´E) at the Klongwan Fisheries Research Station (KFRS), located in Prachuap Khiri Khan province, Thailand, and the grow-out ponds of crab culture of this study.

The juvenile BSC, with a carapace width of approximately 1 cm or around 40-45 days post-hatch, were sourced from the KFRS hatchery and stocked into earthen ponds at a density of 3 crabs/m^2. The ponds included one 400 m^2 pond and two 1,600 m^2 ponds. Each year, crabs were reared in three batches in the 1,600 m^2 ponds and two batches in the 400 m^2 pond (five batches per year, n = 5). Each batch was cultured for 150 days to produce broodstock for academic purposes and KFRS's CSR activities.

The BSC was fed artificial shrimp feed as outlined by Oniam et al. [11]. During the first 30 days of the 120-day culture period, BSC was fed shrimp feed No. 2 (STARTEQC™, pellet size 0.8-1 mm, 38% protein) at a rate of 30% of body weight per day. From days 31 to 60, they were fed shrimp feed No. 4S (STARTEQC™, pellet size 3.5 mm, 38% protein) at 5% of body weight per day. After day 60,

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the feed was adjusted to 3% of body weight per day. Feeding occurred twice daily at 9:00 a.m. and 5:00 p.m.

During the culture of each batch of BSC, the water in the grow-out ponds was changed weekly, with approximately 30% of the water replaced each time. Additionally, water quality parameters were assessed twice a week at 6:00 a.m. and 2:00 p.m. These parameters included salinity, pH, dissolved oxygen concentration (DO), temperature, total ammonia, nitrite, and alkalinity, which were measured using analytical instruments and standard methods from APHA, AWWA, and WEF [12].

2.2 Data collection

Specific growth rate (SGR) of the BSC was evaluated at the 90-day culture mark by sampling 30 crabs per batch from each grow-out pond, with five batches per year from January 2022 to December 2023. The TF was recorded using Geographic Information System (GIS) data from©WeatherSpark.com on air temperature changes in Prachuap Khiri Khan Province during the same period and were subsequently analyzed. The SGR was calculated [8], using equations:

$$\text{SGR (\%/day)} = 100 \times [\ln(\text{final body weight}) - \ln(\text{initial body weight})] / \text{culture period}$$

2.3 Data analysis

The collected data were consolidated and tallied in a spreadsheet. The data were then analyzed using a statistical software package. Variance was evaluated for the BSC growth and water quality data in grow-out ponds before conducting further statistical tests. Levene's test was used to assess the homogeneity of variances. Independent-sample t-tests were then performed to analyze differences in means for carapace width, body weight, SGR, and each water quality parameter between the years 2022 and 2023. All analyses were conducted at a 95% confidence level. The data were analyzed using IBM SPSS Statistics for Windows software (version 21.0; IBM Corp.; Armonk, NY, USA).

3. RESULTS AND DISCUSSION

The geographic data showed the changes in air temperature in Prachuap Khiri Khan province from January 2022 to December 2023, as shown in Figure 2. Analysis of this data indicated that the average lowest temperature of the highest temperature (*l*-T) and the maximum temperature (*m*-T) in 2022 were 31.0°C and 36.0°C, respectively. In 2023, these values increased to 31.0°C and 39.0°C, respectively. Overall, the average maximum temperature fluctuation (TF) in 2022 was 33.5°C, which was lower compared to the average maximum TF of 35.0°C recorded in 2023.

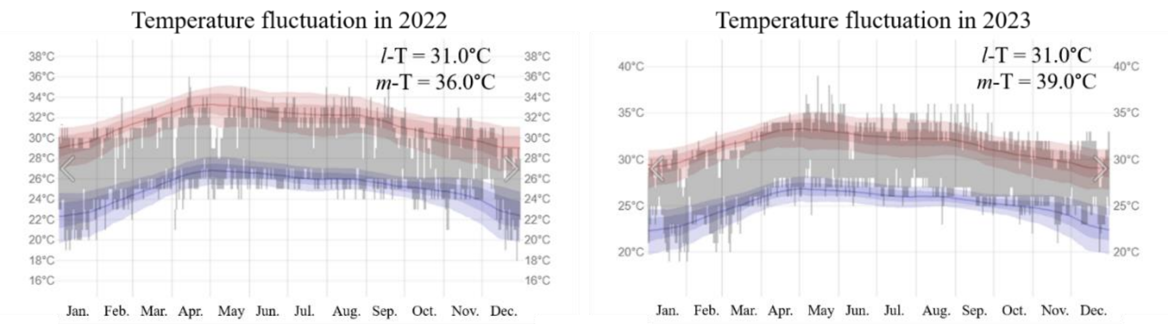

Figure 2. Annual temperature in Prachuap Khiri Khan province, Thailand (in 2022-2023); the graph illustrates the daily range of reported temperatures (gray bars), alongside the 24 h high (red bars) and low (blue bars) temperatures overlaid on the average daily high temperature values (faded red line) and daily average high and low temperature values (faded blue line), and showed average lowest temperature of the highest temperature (*l*-T) and maximum temperature (*m*-T) of the year (Data source: Adapted from geodatabase of ©WeatherSpark.com).

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From the synthesis and analysis of data on BSC culture in grow-out ponds, it was found that in 2022, the BSC had an initial carapace width of 1.08±0.23 cm and an initial body weight of 0.18±0.04 g. In 2023, an initial width and weight were 1.12±0.31 cm and 0.19±0.06 g, respectively. The mean initial size of the BSC released into the ponds were not significantly different ($p>0.05$). At 90 days of cultivation, BSC in 2023 had a lower body weight ($p<0.05$) compared to those from 2022, while the carapace width of BSC showed no significant difference ($p>0.05$) between the years. In addition, the BSC reared in 2023 had a lower mean SGR ($p<0.05$) than in 2022 (Table 1). This indicated that BSC reared in grow-out ponds in 2023 exhibited decreased growth compared to those in 2022, likely due to the effects of climate change during that year.

Table 1. Carapace width, body weight, and specific growth rate (SGR) of blue swimming crab (*Portunus pelagicus*) cultured in grow-out ponds in 2022 and 2023, for 90 days of the cultivation (mean ± SD).

Traits	Cultivation period (n = 5)		P-value
	In 2022	In 2023	
Initial carapace width (cm)	1.08±0.23[a]	1.12±0.31[a]	0.865
Initial body weight (g)	0.18±0.04[a]	0.19±0.06[a]	0.814
Final carapace width (cm)	8.72±0.58[a]	8.74±0.22[a]	0.893
Final body weight (g)	61.55±5.50[a]	52.66±1.45[b]	0.020
SGR (%/day)	6.48±0.10[a]	6.25±0.03[b]	0.026

Note: Means within a row with different superscripts are significantly different ($p<0.05$).

Furthermore, the increase in temperatures resulted in variations in the mean water quality parameters in the grow-out ponds between 2022 and 2023. Specifically, both mean salinity and water temperature exhibited an upward trend with increasing TF. Salinity increased from 34.09±1.75 psu in 2022 to 35.40±1.19 psu in 2023 ($p<0.05$), while water temperature increased from 31.13±2.05°C in 2022 to 32.19±1.83°C in 2023 ($p<0.05$). However, other water quality parameters, including pH, DO, total ammonia, nitrite, and alkalinity, did not show significant differences between the years and did not exhibit consistent trends in response to the increase in TF (Figure 3).

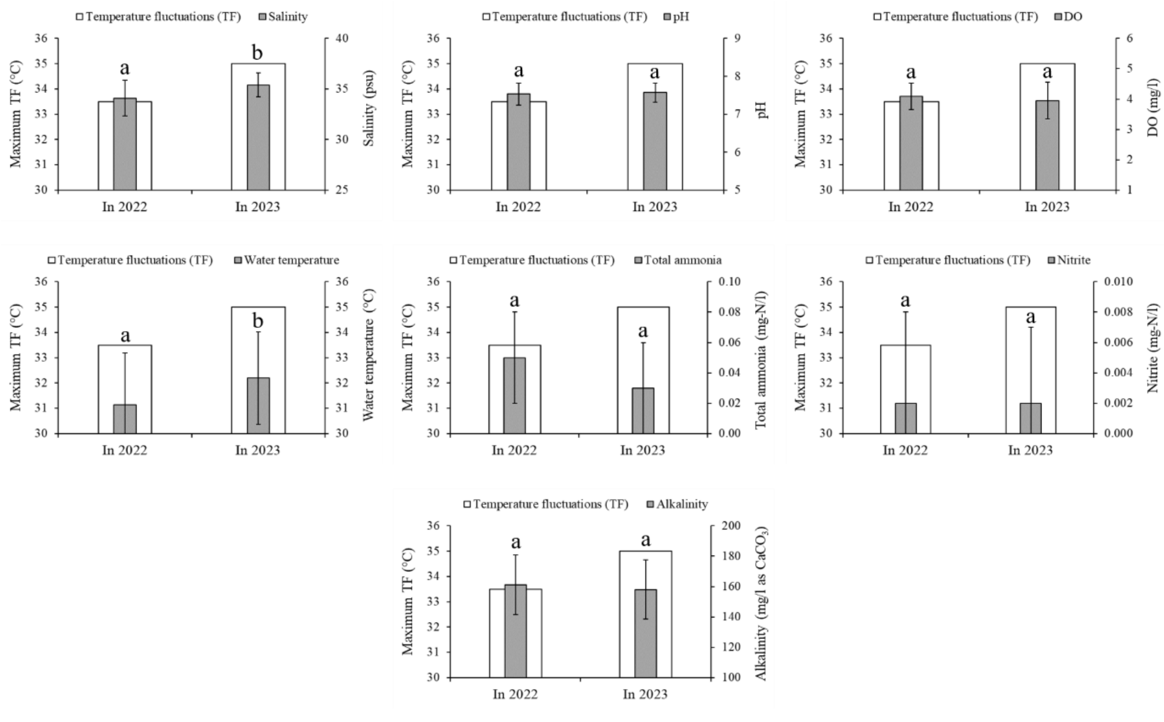

Figure 3. Trends in water quality changes in blue swimming crab (*Portunus pelagicus*) ponds in relation to climate warming from 2022 to 2023. Different lowercase letters above bars indicate significant ($p<0.05$) differences between 2022 and 2023. Error bars indicate SD.

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The impact of temperature on aquaculture had been extensively studied, with various research efforts focusing on how different temperature regimes affected aquatic species. The current study found that higher water temperatures negatively affected the growth of BSC, with the SGR of crabs showed a tendency to decline in warmer climates. Temperature played a crucial role in the culture of BSC, with optimal growth and health of this crab being highly dependent on maintaining suitable water temperatures of 28-31°C [6-9]. Temperature had a direct impact on the development and growth of BSC. Variations in temperature influenced the crab's feeding behavior; as temperatures rose, the crab's metabolism increased, leading to a higher demand for energy in the form of food. However, when the temperature exceeded the optimal range for BSC culture, it adversely affected growth. The growth rate declined as the crab expended energy to cope with the elevated temperatures, leaving less energy available for growth. Conversely, when temperatures dropped, the crab's metabolism decreased, reducing its food intake and slowing its growth [13, 14]. This temperature-related impact on growth was also observed in other crustaceans, such as white shrimp, *Litopenaeus vannamei* [15] and mud crab, *Scylla paramamosain* [16].

The increase in mean global temperature resulting from climate change and atmospheric warming subjected all organisms to potential thermal stress [17]. In aquaculture systems, climate change profoundly impacted operations by altering water temperature, salinity, and oxygen levels. Temperature changes influenced various critical factors, including metabolic rates, feeding behavior, disease dynamics, and the overall growth performance of cultured species [1, 18-20]. In the current study, it was found that although the average temperature in 2023 led to a significant increase in salinity level compared to 2022, the salinity remained within a tolerable range of 25-35 psu for the BSC cultivation, which did not impact its growth [6-9]. Additionally, other water quality parameters, such as pH, DO, total ammonia, nitrite, and alkalinity, were not significantly affected by the elevated temperatures and remained at levels that did not influence BSC growth [6-9]. Therefore, the reduction in BSC growth rates observed in 2023, compared to 2022, was attributed to the increase in the average maximum temperature, which was 1.5°C higher than in the previous year.

Higher temperatures were found to accelerate metabolic rates, increasing food consumption and growth in some species, such as shrimp and tilapia, while also raising oxygen demand and stress levels, which compromised health and survival. Moderate temperature increases enhanced growth and productivity, but excessive temperatures induced thermal stress, reduced oxygen levels, and heightened disease susceptibility, particularly in species with narrow temperature tolerance ranges, leading to significant declines in growth rate [1, 3, 21], as observed in this study. A comprehensive review by Thirukanthan et al. [19] highlighted the critical role of temperature management in marine crab aquaculture systems, emphasizing the necessity for advanced monitoring technologies and adaptive management practices to sustain optimal conditions for cultured species. Similarly, Azra et al. [20] reported that increased water temperatures significantly impacted the reproduction and development of brachyuran crabs, leading to reductions in growth, thermal resistance, maturation, spawning, and embryonic development. Additionally, Collins et al. [21] examined the economic implications of temperature changes, noting that rising temperatures could lead to increased production costs and reduced profitability due to associated challenges. Therefore, careful temperature management is essential to optimize growth performance and ensure the sustainability of BSC culture.

To address the challenges posed by climate change, aquaculture practitioners employed various strategies. Temperature-control measures, such as shading or insulation, were used to stabilize water temperatures in outdoor culture systems, reducing the impact of temperature fluctuations on aquatic animal growth, or the use of greenhouse concepts for cultivation was explored to further mitigate temperature-related issues [22, 23]. Additionally, the use of GIS data to analyze air temperature changes in cultivation areas provided valuable insights into local climate dynamics and their effects on aquatic animals. Integrating GIS data into culture management allowed for informed decisions on site and species selection, thus enhancing the sustainability of aquaculture operations amid climate change. Previous studies demonstrated that GIS significantly improves farming efficiency and helps develop

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strategies to address climate change impacts on aquatic species [24]. Studies indicated that incorporating climate projections into aquaculture planning and management can help mitigate these risks.

Overall, while some studies had indicated potential benefits of higher temperatures, such as accelerated growth, the primary concern remains the adverse effects of extreme temperature fluctuations. Future efforts should focus on developing temperature-resilient strains and implementing effective temperature control measures to mitigate these effects. Adaptation strategies will be crucial for sustaining aquaculture practices amid the challenges posed by climate change.

4. CONCLUSIONS

Based on data analysis in this study. Some conclusions were drawn as follows:

1. The study was conducted to analyze the impact of air temperature changes in Prachuap Khiri Khan province on the cultivation of blue swimming crab in grow-out ponds during 2022 and 2023. Geographic data indicated a temperature increased, with the average maximum temperature recorded at 36.0°C in 2022, which increased to 39.0°C in 2023. This temperature increase resulted in the average maximum temperature fluctuation rising from 33.5°C in 2022 to 35.0°C in 2023.

2. The analysis of crab cultivation data indicated that crab reared in 2023 exhibited lower mean body weight and specific growth rate compared to those reared in 2022, likely due to the effects of climate change during that year.

3. In terms of water quality, both mean salinity and water temperature showed an upward trend in 2023. However, other water quality parameters, including pH, dissolved oxygen, total ammonia, nitrite, and alkalinity, did not exhibit significant differences between 2022 and 2023.

4. Recommendations for future research, considering the impact of temperature changes on crab growth in grow-out ponds, it is recommended that future studies focus on improving cultivation methods to mitigate the effects of climate change. Additionally, further research on water conditioning techniques to maintain optimal water quality for crab growth under increasingly extreme temperature fluctuations is advised.

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