



The Impact of Climate Change on the Sustainability of Tiger Prawn Cultivation in Tropical Waters

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Abstract

Global climate change has become a serious threat to the aquaculture sector, including tiger prawn (*Penaeus monodon*) cultivation in tropical waters. This research aims to analyze the impact of climate change on the sustainability of tiger prawn cultivation in Indonesia. The method used is a literature study and secondary data analysis from various trusted sources. The research results show that climate change has a significant impact on aquatic environmental parameters, such as increasing water temperature, changes in salinity, and ocean acidification. This condition affects the physiology, growth, and survival rate of black tiger prawns. Increasing water temperature causes stress in shrimp, reduces growth rate, and increases disease susceptibility. Changes in salinity due to erratic rainfall and rising sea levels disrupt the shrimp's osmotic balance. Ocean acidification hurts the calcification process of shrimp shells. In addition, climate change also increases the risk of natural disasters such as floods and storms, which can damage farm infrastructure. To maintain the sustainability of tiger prawn cultivation, an adaptation strategy is needed which includes improving cultivation technology, developing shrimp strains that are resistant to environmental changes, and implementing environmentally friendly cultivation practices. Further research is needed to develop more accurate climate change impact prediction models and effective mitigation strategies for the tiger prawn cultivation industry in tropical waters.

Keywords: Climate change, Tiger prawns, Sustainability of cultivation

1. Introduction

Global climate change has become one of the greatest challenges faced by the fisheries and aquaculture sectors in the 21st century [1]. This phenomenon is characterized by an increase in global average temperature, changes in rainfall patterns, sea level rise, and an increase in the frequency and intensity of extreme weather events [2]. The impact of climate change is felt in tropical regions, including Indonesia, which is one of the main producers of tiger prawns (*Penaeus monodon*) in the world [3].

Tiger prawns are an aquaculture commodity that has high economic value and contributes significantly to the national economy and the country's foreign exchange [4]. However, the sustainability of tiger prawn cultivation is now threatened by various changes in environmental parameters caused by climate change [5]. These changes include increased water temperature,

salinity fluctuations, and ocean acidification which can affect the physiology, growth, and survival of black tiger prawns [6].

Given the importance of tiger prawns for the Indonesian aquaculture industry, a comprehensive understanding of the impact of climate change on the sustainability of their cultivation is needed. This research aims to analyze various aspects of the impact of climate change on tiger prawn cultivation in tropical waters, as well as identify adaptation strategies that can be implemented to maintain the sustainability of production in the future.

Research shows that increased water temperature can cause physiological stress in shrimp, reduce growth rates and increase susceptibility to disease. In addition, changes in salinity caused by rising sea levels and erratic rainfall can disrupt the osmotic balance of shrimp, potentially reducing survival rates. Ocean acidification also negatively impacts the calcification process of shrimp shells, which is essential for their growth and protection. Thus, an in-depth understanding of the impacts of climate change on the environmental parameters and physiology of tiger shrimp is necessary to formulate effective adaptation strategies.

In this context, this study aims to analysis various aspects of climate change impacts on the sustainability of tiger shrimp farming in tropical waters, and identify adaptation strategies that can be implemented by farmers and policy makers. Some of the strategies that will be discussed include the development of environmentally friendly farming technologies, breeding shrimp that are resistant to environmental changes, and implementing sustainable farming practices. With this comprehensive approach, it is hoped that this research can make a significant contribution to maintaining the sustainability of tiger shrimp farming in Indonesia amidst the increasing challenges of climate change.

In this research, we will discuss in detail the influence of changes in environmental parameters on tiger prawn physiology and growth, the impact on cultivation infrastructure, and the implications for production and the economy. Apart from that, various adaptation strategies will also be explained that can be implemented by farmers and policymakers to face the challenges of climate change in the tiger prawn cultivation industry.

2. Materials and Methods

This research adopts a comprehensive literature study approach and secondary data analysis to evaluate the impact of climate change on the sustainability of tiger prawn cultivation in tropical waters. The data collection process involved an extensive search of the latest scientific literature from accredited international and national journals, as well as secondary data collection from various research institutions, meteorological agencies, and related agencies. The main focus of the literature search was on studies that discussed climate change, tropical aquatic environmental parameters, and tiger prawn cultivation.

Data analysis was carried out through a systematic evaluation of the impact of climate change on tropical aquatic environmental parameters relevant to tiger prawn cultivation. This includes analysis of changes in water temperature, salinity fluctuations, and ocean acidity levels. Next, an in-depth analysis was carried out on the effect of changes in these environmental parameters on the physiology, growth, and survival rate of black tiger prawns. Identification of natural disaster risks related to climate change that have the potential to affect farm infrastructure is also an integral part of the analysis.

Information synthesis was carried out by integrating findings from various sources to obtain a comprehensive understanding of the impact of climate change on tiger prawn cultivation. Based on this synthesis, an adaptation strategy was developed which includes improving



cultivation technology, developing shrimp strains that are resistant to environmental changes, and implementing environmentally friendly cultivation practices. To ensure the validity of the findings and recommendations, consultations were carried out with experts in the field of aquaculture and climate change. This method was chosen to provide a holistic picture and produce relevant and applicable recommendations for the sustainability of tiger prawn cultivation in tropical waters in facing the challenges of climate change.

3. Results

3.1 Impact of Climate Change on Aquatic Environmental Parameters

Global climate change has had a significant impact on the environmental parameters of tropical waters which are the natural habitat of tiger prawns (*Penaeus monodon*). Analysis of data from various sources shows consistent changing trends in three main parameters: water temperature, salinity, and ocean acidity levels.

Rising water temperatures are one of the most obvious impacts of climate change. Based on IPCC (Intergovernmental Panel on Climate Change) projections, water temperatures in tropical regions are expected to increase gradually until the end of this century. Table 1 shows the projected increase in water temperature:

Table 1. Projected Increase in Water Temperature in Tropical Regions [7]

Year	Increased temperature (°C)
2030	0,5 - 1,0
2050	1,0 - 1,5
2100	1,5 - 3,0

This increase in temperature is expected to have a direct impact on tiger prawn metabolism and physiology, as well as affecting the balance of the aquatic ecosystem as a whole.

Changes in rainfall patterns and rising sea levels due to climate change also have an impact on salinity fluctuations in tropical waters. Analysis of historical data and future projections suggests that salinity variations will become more extreme and unpredictable.

This graph shows an increase in the amplitude of salinity fluctuations, with longer dry periods (high salinity) and more intense wet periods (low salinity). This condition will create a big challenge for tiger prawns in maintaining their osmotic balance.

Ocean acidification is a direct consequence of increasing CO₂ concentrations in the atmosphere. Recent studies show that ocean acidity levels are projected to increase significantly, with pH decreasing by 0.3-0.4 units by the end of the century [8]. Table 2 shows projected changes in ocean pH until 2100:

Table 2. Projected Changes in Ocean pH

Year	Ocean pH
2000	8,1
2050	7,9
2100	7,7

This decrease in pH will have a significant impact on the calcification process of marine organisms, including tiger prawns, especially during the growth and shell replacement phases.



3.2 Effect of Changes in Environmental Parameters on Tiger Prawns

Changes in environmental parameters due to climate change have a multi-dimensional impact on tiger prawn physiology, growth, and survival.

Increasing water temperature causes an increase in metabolic rate and oxygen consumption in tiger prawns. Laboratory studies show that at temperatures above 32°C, the survival rate of black tiger prawns decreases by 15-20% [9]. In addition, high temperatures also increase shrimp's susceptibility to disease, especially White Spot Syndrome Virus (WSSV).

Extreme salinity fluctuations cause disruption of the osmotic balance in tiger prawns, resulting in significant physiological stress. Research shows that rapid and extreme fluctuations in salinity can cause a 10-15% reduction in growth rates [10]. Table 3 shows the effect of salinity variations on tiger prawn growth rate:

Table 3. Effect of Salinity Variations on Tiger Prawn Growth Rate

Variation in Salinity (ppt)	Decrease in Growth Rate
0-5	15
5-10	10
10-15	5
>15	0

Ocean acidification has a direct impact on the calcification process of tiger prawn shells. At a pH below 7.6, the survival rate of tiger prawn larvae decreases by 20-25% [11]. In addition, shells that are more fragile due to disruption of the calcification process increase the vulnerability of shrimp to predators and disease.

3.3 Impact on Production and Economy

Climate change is projected to have a significant impact on tiger prawn production globally. Based on analysis of FAO data and climate change projections, it is estimated that there will be a gradual decline in tiger prawn production until the end of this century [3]. Table 4 shows the projected decline in production:

Table 4. Projected Decline in Tiger Prawn Production

Year	Production Decline (%)
2030	5-10
2050	10-20
2100	20-30

This decline in production will have a significant impact on the economies of tiger prawn-producing countries, especially in the Southeast Asia region. It is estimated that there will be a decrease in income from the aquaculture sector, an increase in shrimp prices on the global market, and potential disruption to the seafood industry supply chain.

3.4 Adaptation Strategy

Facing the challenge of climate change, several adaptation strategies have been identified to maintain the sustainability of tiger prawn cultivation. These strategies include developing cultivation technology, breeding shrimp that are resistant to environmental changes, implementing environmentally friendly cultivation practices, and diversifying cultured species.

Development of cultivation technology includes the implementation of biofloc systems



and recirculating aquaculture systems (RAS). Biofloc systems have been proven to increase water and nutrient use efficiency by up to 30%, while RAS allows better control of environmental parameters, reducing the risk of temperature and salinity fluctuations by up to 50%.

Breeding shrimp that is resistant to environmental changes focuses on developing tiger shrimp strains that are tolerant to high temperatures and salinity fluctuations. Recent research shows that shrimp strains resulting from genetic selection can increase tolerance to temperatures up to 2°C higher than normal strains.

Environmentally friendly farming practices, such as integrated multitrophic farming (IMTA) systems, have shown the potential to increase nutritional efficiency by up to 25% and reduce the environmental impact of shrimp farming.

Diversification of aquaculture species, especially with the introduction of the name shrimp (*Litopenaeus vannamei*) which is more resistant to environmental changes, has proven effective in reducing production risks in several shrimp-producing countries.

3.5 Policy Recommendations

Based on the research results, several policy recommendations are proposed to support the adaptation of the tiger prawn cultivation sector to climate change. The development of a climate change early warning system specifically for the aquaculture sector can help farmers anticipate and respond to environmental changes more effectively. Providing incentives for the adoption of sustainable cultivation technologies and practices can accelerate the sector's transformation towards production systems that are more resilient to climate change. In addition, increasing investment in research and development of shrimp strains that are adaptive to climate change is seen as a crucial step to ensure the sustainability of the tiger shrimp industry in the future.

4. Discussion

The results of this research reveal the complexity of the impact of climate change on tiger prawn cultivation in tropical waters. Changes in environmental parameters, especially increased water temperature, salinity fluctuations, and ocean acidification, significantly affect tiger prawn physiology and productivity [7]. These findings are in line with previous studies conducted by Cao et al. [9], which emphasize the vulnerability of tropical aquaculture species to climate change.

The projected decline in tiger prawn production of up to 30% by 2100 shows the urgency to develop effective adaptation strategies. This emphasizes the importance of a multidisciplinary approach to overcoming the challenges of climate change in the aquaculture sector, as proposed by De Silva and Soto [1].

The adaptation strategies identified in this research, such as the development of shrimp cultivation and breeding technology that is resistant to environmental change, show the potential to increase the resilience of this sector. The implementation of bio floc and RAS systems, for example, has been proven effective in increasing production efficiency and reducing environmental impacts [12]. However, adoption of this technology in developing countries is still limited due to cost and technical expertise constraints.

Breeding shrimp that is resistant to environmental change offers a promising long-term solution. Recent research by Palaiokostas et al. [13] demonstrated the potential of genomic selection in developing shrimp strains that are more resistant to environmental stress. However, significant investment in research and development is required to realize this potential.

Diversification of aquaculture species, especially with the introduction of the name shrimp, has become a popular adaptation strategy in several countries [3]. Although effective in



reducing production risks, this approach needs to be implemented carefully to avoid undesirable ecological impacts.

The policy recommendations proposed in this research emphasize the importance of collaboration between government, the private sector, and the scientific community. The development of early warning systems and providing incentives for sustainable farming practices is in line with FAO recommendations for the adaptation of the fisheries and aquaculture sectors to climate change [14].

5. Conclusions

Climate change poses significant challenges to the sustainability of tiger prawn cultivation in tropical waters. Rising water temperatures, salinity fluctuations, and ocean acidification are negatively impacting black tiger prawn physiology, growth, and survival, potentially leading to production declines of up to 30% by the end of the century.

However, the various adaptation strategies identified in this research indicate that the tiger prawn farming sector has the potential to adapt to climate change. Developing cultivation technology, breeding shrimp that are resistant to environmental changes, and implementing environmentally friendly cultivation practices are key steps to increase the resilience of this sector.

To realize effective adaptation, an integrated approach is needed that involves collaboration between stakeholders, investment in research and development, and implementation of supporting policies. In this way, the tiger prawn cultivation sector can continue to contribute to food security and the global economy amidst the challenges of climate change.

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