

# Assessing Climate Change Effects on Mahseer Growth Properties

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**Abstract.** Heatwaves are becoming more common and severe due to rising CO<sub>2</sub> and temperature levels, while changes in precipitation patterns have significant consequences for ecosystems and aquatic creatures, including fish. This study assessed the growth parameters of the valuable mahseer, a key species in fisheries and ecological balance, under different temperature and CO<sub>2</sub> concentration conditions: (26°C + 400 ppm CO<sub>2</sub>), (34°C + 400 ppm CO<sub>2</sub>), (26°C + 600 ppm CO<sub>2</sub>), and (34°C + 600 ppm CO<sub>2</sub>). The experimental setup included controlled aquaria where mahseer were reared for a specified period. Growth parameters such as body weight gain (BWG) and specific growth rate (SGR) were measured and analyzed using appropriate statistical methods. The results showed that the highest growth parameters, including BWG and SGR, were observed in mahseer reared at 26°C with 400 ppm CO<sub>2</sub>. Conversely, the lowest growth parameters were recorded in mahseer raised at 34°C with 600 ppm CO<sub>2</sub>. These findings indicate that moderate temperatures and lower CO<sub>2</sub> levels provide optimal conditions for mahseer growth, while elevated temperatures and higher CO<sub>2</sub> concentrations, conditions expected to become more prevalent with ongoing climate change, negatively impact their growth. This preliminary study provides a foundation for future research on mahseer rearing in a changing climate, emphasizing the need to maintain favorable environmental conditions and develop strategies to mitigate the adverse effects on this valuable species. Further investigations should include more extensive sampling, varied environmental parameters, and long-term studies to fully understand the implications of climate change on mahseer and other aquatic organisms.

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## 1 Introduction

Since the industrial revolution, carbon emissions from fossil fuel use and deforestation have been on the rise. The burning of fossil fuels such as coal, oil, and natural gas releases significant amounts of CO<sub>2</sub>, a greenhouse gas, into the atmosphere. Additionally, deforestation reduces the number of trees available to absorb CO<sub>2</sub>, exacerbating the problem. CO<sub>2</sub> plays a critical role in trapping heat in the Earth's atmosphere, a phenomenon known as the greenhouse effect, which is essential for maintaining the planet's temperature [4]. However, the enhanced greenhouse effect due to increased CO<sub>2</sub> levels leads to global warming and climate change. As CO<sub>2</sub> levels rise, they trap more heat, causing average global temperatures to increase, which in turn disrupts climatic patterns [4].

The rising levels of CO<sub>2</sub> and temperatures result in widespread effects such as more frequent and intense heatwaves and alterations in precipitation patterns [17]. These changes have far-reaching consequences for the environment and aquatic organisms, including fish. Heatwaves can cause thermal stress in aquatic environments, leading to reduced oxygen levels and altering the habitats that fish rely on. Changes in precipitation patterns can affect water levels in rivers and lakes, further impacting aquatic life. Among the affected species is the mahseer (*Tor spp.*), a valued and threatened fish found in South and Southeast Asia. The mahseer is renowned for its economic and ecological significance but could see its population status exacerbated by climate change. As water temperatures rise and acidity levels increase, the habitats that mahseer rely on become less hospitable [11].

Prior research suggests that increased concentrations of CO<sub>2</sub> inhibit foraging behavior in fish, resulting in reduced growth [8]. Elevated CO<sub>2</sub> levels can affect the sensory systems of fish, impairing their ability to locate food and avoid predators. The effect of temperature, however, varies between species. For instance, studies have shown that elevated temperatures can either enhance or impede fish growth depending on the species and their thermal tolerance ranges [12]. Some fish species may experience accelerated growth rates in warmer waters if those temperatures fall within their optimal thermal range. However, if temperatures exceed this range, it can lead to stress and reduced growth. For mahseer, these environmental changes may similarly result in adverse effects, as high temperatures and acidic conditions can negatively impact juvenile fish [7]. Young fish are particularly vulnerable as they are still developing and are less capable of coping with extreme environmental changes.

In Malaysia, mahseer species such as *Tor tambroides* and *Tor douronensis* have experienced significant population declines, with estimates indicating a reduction of 50-70% in some river systems over the last three decades [3]. In India, the population of Golden Mahseer in the Ganges River basin has decreased by about 50% over the last 20 years [9], while in Nepal, surveys in the Karnali River have documented a 40% decline in mahseer populations over the past decade [14]. Similarly, Thailand has seen a 30-50% decline in mahseer populations in the past 15 years due to dam construction and habitat destruction [16]. The IUCN Red List (2023) classifies several mahseer species found in these countries as Endangered or Vulnerable, underscoring the need for international conservation efforts to address common threats such as habitat loss, overfishing, pollution, and the impact of hydropower projects.

Therefore, this study aims to investigate the ripple effects of climate change on the growth parameters of mahseer. By understanding how different temperature and CO<sub>2</sub> conditions affect their growth, we can better prepare for the challenges posed by climate change. This research will help identify the specific environmental thresholds that mahseer

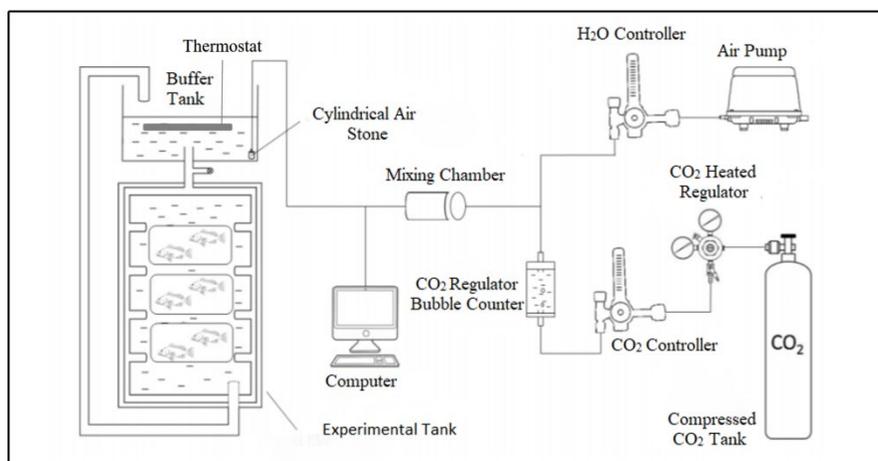
can tolerate and inform conservation strategies. Developing strategies to mitigate the impact of climate change on mahseer is crucial for maintaining their populations and ensuring their ecological and economic contributions continue. Conservation efforts may include habitat restoration, regulated fishing practices, and possibly breeding programs to enhance the resilience of mahseer populations to changing environmental conditions.

## **2 Objective**

These studies are conducted to assess the impact of climate change on the growth properties of Mahseer. By examining various environmental factors and how they influence the development and sustainability of Mahseer populations, researchers aim to understand the broader implications of climate change on this species. This comprehensive approach not only helps in predicting future changes in their growth patterns but also aids in formulating effective conservation strategies to mitigate potential adverse effects. Through these studies, valuable insights are gained that contribute to the sustainable management and preservation of Mahseer in their natural habitats.

## **3 Methodology**

In this study, 120 juvenile mahseer (initial length of  $5.0 \pm 0.1$  cm and initial weight of  $2.4 \pm 0.01$  g) were gathered from a hatchery in Terengganu, Malaysia. The fish were acclimated to the experimental conditions before being subjected to different CO<sub>2</sub> and temperature treatments ( $26^{\circ}\text{C} + 400$  ppm CO<sub>2</sub>), ( $34^{\circ}\text{C} + 400$  ppm CO<sub>2</sub>), ( $26^{\circ}\text{C} + 600$  ppm CO<sub>2</sub>), and ( $34^{\circ}\text{C} + 600$  ppm CO<sub>2</sub>) for a duration of 31 days as illustrated in Figure 1. Three replicates per treatment were required as the standard. CO<sub>2</sub> concentrations of 400 ppm, 600 ppm, and 800 ppm were created by steadily diffusing CO<sub>2</sub> enriched air into the experimental tanks. The CO<sub>2</sub> concentration for the experiment was maintained at a consistent level using the Hero Tech CO<sub>2</sub> regulator flow meter until the target level was attained. The concentration was increased steadily by 100 ppm per day. Precision pressure regulator and needle valve were utilized to control the precise amounts of CO<sub>2</sub> introduced into each test tank. A real-time infrared CO<sub>2</sub> probe linked to a computer consistently monitored the CO<sub>2</sub> levels in every experimental tank. The computer utilized Gaslab v2.0.8.14 to analyze the CO<sub>2</sub> levels in each storage container. The fish in the study were housed in a 356-liter tank measuring  $1.23 \times 63 \times 46$  cm. The water temperature were controlled by submersion aquarium thermostat. Following by that, to ensure optimal growth conditions, the mahseer were fed to satiation twice daily with a standardized feed. At the onset of the experiment, and subsequently every five days, each fish in every experimental tank was individually weighed. Prior to being weighed, the fish were gently sedated with  $\alpha$ -methyl quinoline (TransmoreR; Nika Trading, Puchong, Malaysia) at a concentration of  $0.22 \text{ ml L}^{-1}$  in 3 L of fresh water. This anesthetic solution was used to sedate the fish for 10–15 minutes, ensuring minimal stress and movement during the weighing process. The growth properties of the mahseer were meticulously analyzed using established formulas [2]. The BWG and SGR measurements allowed for precise tracking of growth parameters, providing valuable data on how different environmental conditions affect the growth rates of juvenile mahseer. By analyzing these growth properties, the study aims to contribute to a deeper understanding of the effects of climate change on this valuable species, informing future conservation and aquaculture practices



**Fig. 1.** Experimental Setup

## 4 Results and discussion

The results of this study indicate that body weight gain (BWG) and specific growth rate (SGR) were significantly affected by both temperature and CO<sub>2</sub> concentration ( $p < 0.05$ ). Table 1 shows that the growth properties of mahseer slightly declined as CO<sub>2</sub> concentration increased from 400 ppm to 600 ppm at a temperature of 26°C. The decline in growth was more pronounced at a higher temperature of 34°C. Previous studies have highlighted the complex relationship between temperature and fish growth. For instance, Simon et al. (2018) reported that mahseer exhibits good growth performance at higher temperatures, with an optimum around 30°C. This aligns with the general understanding that many tropical fish species thrive at elevated temperatures within their thermal tolerance range. However, our study demonstrates that exceeding this optimal temperature threshold, reaching 34°C, results in a significant decline in growth performance. This suggests a critical temperature limit beyond which physiological stress impedes growth.

**Table 1.** Growth parameters.

	26°C + 400 ppm	26°C + 600 ppm	34°C + 400 ppm	34°C + 600 ppm
BWG	11.16±0.11 <sup>a</sup>	10.8±0.04 <sup>a</sup>	9.6±0.4 <sup>ab</sup>	8.28±0.03 <sup>ab</sup>
SGR	1.57±0.13 <sup>a</sup>	1.38±0.03 <sup>a</sup>	1.22±0.03 <sup>ab</sup>	1.06± 0.05 <sup>ab</sup>

The impact of elevated CO<sub>2</sub> on fish growth can be attributed to the acid-base equilibrium. High CO<sub>2</sub> concentrations lead to an increase in the energy expenditure required to maintain acid-base homeostasis, as described by Portner and Farrell (2008). This increased energy demand can divert resources away from growth-related processes, with energy typically allocated to growth and metabolic activities instead used to counteract the acidifying effects of elevated CO<sub>2</sub> levels. This is consistent with the observed decline in BWG and SGR in mahseer exposed to higher CO<sub>2</sub> concentrations in our study. Furthermore, Munday et al. (2009) found that increased CO<sub>2</sub> levels can impair the sensory systems of fish, affecting their

ability to forage efficiently. Reduced foraging efficiency can lead to decreased food intake, further contributing to the observed reduction in growth rates. This is particularly relevant for juvenile fish, which have higher metabolic rates and are more sensitive to environmental changes.

The interaction between temperature and CO<sub>2</sub> concentration is also crucial. Elevated temperatures can exacerbate the effects of high CO<sub>2</sub> levels. For example, in our study, the combination of 34°C and 600 ppm CO<sub>2</sub> resulted in the lowest growth performance. This aligns with the findings of Portner and Farrell (2008), who suggested that fish exposed to both high temperatures and high CO<sub>2</sub> levels face compounded physiological challenges, leading to reduced growth and survival rates. Overall, our findings underscore the importance of considering both temperature and CO<sub>2</sub> levels when assessing the impacts of climate change on aquatic organisms. The observed decline in growth performance at elevated temperatures and CO<sub>2</sub> concentrations highlights the vulnerability of mahseer to changing environmental conditions. Future research should focus on identifying the specific physiological mechanisms underlying these effects and exploring potential mitigation strategies to support the conservation and sustainable management of this valuable species.

Recent studies have reinforced the detrimental effects of combined temperature and CO<sub>2</sub> stress on fish physiology. For example, Kasihmuddin et al. (2024) highlighted that fish exposed to high CO<sub>2</sub> levels exhibit reduced aerobic scope, limiting their capacity for growth and activity. Furthermore, Dahlke et al. (2020) reported that prolonged exposure to elevated CO<sub>2</sub> can lead to physiological stress and reduced reproductive success in fish, emphasizing the potential long-term impacts on fish populations. Moreover, Rummer and Munday (2017) discussed that climate change-induced alterations in temperature and CO<sub>2</sub> levels can lead to shifts in fish distribution and abundance, particularly affecting species like mahseer that are sensitive to environmental changes. These shifts can have cascading effects on local fisheries and biodiversity, potentially disrupting ecosystem services and human livelihoods. These recent studies, combined with our findings, underscore the urgency of addressing climate change impacts on aquatic ecosystems.

Another significant aspect to consider is the interactive effect of temperature and CO<sub>2</sub> on fish metabolism and behavior. According to Jutfelt et al. (2018), fish exposed to high temperatures and elevated CO<sub>2</sub> levels show altered metabolic rates and behavioral changes, which can further compromise their growth and survival. These behavioral alterations include reduced predator avoidance and impaired foraging efficiency, which could exacerbate the negative impacts on growth and overall fitness.

Overall, our findings underscore the importance of considering both temperature and CO<sub>2</sub> levels when assessing the impacts of climate change on aquatic organisms. The observed decline in growth performance at elevated temperatures and CO<sub>2</sub> concentrations highlights the vulnerability of mahseer to changing environmental conditions. Future research should focus on identifying the specific physiological mechanisms underlying these effects and exploring potential mitigation strategies to support the conservation and sustainable management of this valuable species.

## **5 Conclusion**

The results of this study underscore the critical impact of rising temperatures and elevated CO<sub>2</sub> concentrations on the growth performance of mahseer. The significant decline in body weight gain (BWG) and specific growth rate (SGR) at 34°C and 600 ppm CO<sub>2</sub> indicates that

mahseer are particularly vulnerable to the combined stressors of high temperature and CO<sub>2</sub>, conditions that are becoming increasingly common due to climate change. This study highlights the necessity of maintaining optimal environmental conditions specifically, moderate temperatures around 26°C and CO<sub>2</sub> levels at 400 ppm, to ensure the healthy growth of mahseer. To mitigate the adverse effects of climate change on mahseer, it is recommended to adopt adaptive aquaculture practices, such as implementing controlled environments that regulate temperature and CO<sub>2</sub> levels. Furthermore, investing in selective breeding programs to enhance the resilience of mahseer to environmental stressors is crucial. Future research should focus on elucidating the physiological mechanisms behind these stress responses and exploring long-term impacts on mahseer populations to inform conservation and sustainable management strategies. Proactive measures are essential to safeguard the future of this valuable species in the face of ongoing climate change.

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