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Aquatic Invertebrates and Ecosystem Research

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Editorial

The vulnerability of aquatic invertebrates to climate change: A threat to ecosystem stability

Hadi Hamli*

[1] *Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Kampus Bintulu Sarawak, Jalan Nyabau, 97008 Bintulu, Sarawak, Malaysia*

Article info

Article history
Received: 01 January 2025
Revised: 08 January 2025
Accepted: 08 January 2025
Published: 10 January 2025

Keywords
Climate change
Aquatic invertebrates
Ecosystem stability
Biodiversity
Conservation strategies

Abstract

Climate change represents one of the most pressing global environmental challenges of the 21st century. Among the various ecosystems affected, aquatic environments critical for biodiversity, fisheries, and global carbon cycling are particularly vulnerable. Aquatic invertebrates, key players in aquatic food webs, are highly sensitive to climate change stressors, including rising temperatures, ocean acidification, and hypoxia. These stressors threaten not only the survival of these organisms but also the broader ecosystem stability. This editorial provides an overview of the current understanding of the impacts of climate change on aquatic invertebrates, highlights ongoing research, and suggests policy and management strategies to mitigate these effects. Urgent action is required to protect these critical organisms and preserve the ecosystem services they provide.

Climate change is a global environmental crisis that threatens ecosystems worldwide. Aquatic ecosystems, crucial for maintaining biodiversity, supporting fisheries, and regulating global carbon cycles, are particularly vulnerable to these changes. Among the most affected organisms are aquatic invertebrates, which are sensitive to fluctuations in temperature, oxygen levels, and water acidity. Understanding how climate change impacts these groups is critical for preserving the elusive balance of aquatic ecosystems and safeguarding the biodiversity that sustains them.

Global climate change affects aquatic invertebrates through various mechanisms. Rising temperatures influence their metabolism, growth, and reproductive cycles, often leading to physiological stress and population changes (Collier *et al.*, 2017). Oxygen depletion, or hypoxia, caused by reduced oxygen solubility in warmer waters, compromises respiration and survival for many species (Breitburg *et al.*, 2018). Ocean acidification, driven by increased carbon dioxide absorption, reduces the availability of carbonate needed for shell formation, threatening species like mollusks and crustaceans (Mai & Chen, 2024). Furthermore, climate-induced habitat alterations, such as shifts in habitat distribution, wetland loss, and changes in freshwater systems, further threaten species diversity and ecosystem stability (Oliver and Morecroft, 2014). These combined effects highlight the exposure of aquatic invertebrates to ongoing climate change.

The effects of climate change on aquatic ecosystems are broad. Disruptions to invertebrate populations trigger dropping impacts throughout the food web. As the abundance and distribution of invertebrates alter, fish, birds, and mammals that depend on them for food may suffer, destabilizing the entire ecosystem. This can lead to reduced biodiversity, with sensitive species at a higher risk of extinction, which diminishes the overall resilience of the ecosystem (Mori *et al.*, 2013). Moreover, the decline in invertebrate populations disrupts essential biogeochemical cycles, affecting nutrient cycling, sediment turnover, and water filtration, ultimately compromising the health of aquatic environments (Prather *et al.*, 2013).

Recent studies highlight the significant impact of climate change on both freshwater and marine invertebrates. Temperature increases are driving range alterations and population declines in freshwater species, such as freshwater shrimp and freshwater snails (Cordellier *et al.*, 2012; Tropea *et al.*, 2015). Ocean acidification presents a serious challenge for marine ecosystems, particularly coral reefs, where reduced carbonate availability threatens coral survival and disrupts invertebrate communities. Additionally, hypoxia in coastal zones, often resulting in “dead zones,” severely impacts benthic invertebrates by depleting oxygen levels, which reduces survival rates and alters community structures (Altieri and Diaz, 2018; Breitburg *et al.*, 2018). These situations emphasize the complex impact of climate change on invertebrate populations and the ecosystems they support.

Effective conservation efforts are essential to mitigating the effects of climate change on aquatic ecosystems. Strategies such as the establishment of protected areas, habitat restoration, and biodiversity preservation are critical for safeguarding vulnerable species (Ranius *et al.*, 2023). Adaptive management approaches, which use monitoring tools to track and respond to climate induced changes, offer dynamic solutions to evolving ecosystem conditions (Malhi *et al.*, 2020). Furthermore, implementing sustainable practices, such as reducing CO_2 emissions, controlling pollution, and managing fisheries responsibly is essential for promoting long-term ecosystem resilience.

***Corresponding authors**
Email address: hadihamli@upm.edu.my (Hadi Hamli)

doi: https://doi.org/10.69517/aier.2025.02.01.0001

Addressing key research gaps is crucial for understanding the full extent of climate change's impact on aquatic ecosystems. Comprehensive studies on the synergistic effects of multiple stressors, such as temperature fluctuations, oxygen depletion, and acidification, are needed. Technological advancements, like predictive models, can help forecast ecosystem responses and guide management strategies. Additionally, community engagement and education are essential to raising awareness about the importance of aquatic ecosystems and promoting climate adaptation strategies that encourage collective action.

Addressing climate change is urgently needed to protect aquatic biodiversity and the essential ecosystem services provided by aquatic environments. The degradation of these ecosystems has influential consequences for both natural ecosystems and human well-being, affecting food security, water quality, and climate regulation. It is essential for both global and local efforts to mitigate climate change impacts and adapt to the changing conditions that threaten aquatic environments. Through concerted action, we can preserve aquatic biodiversity and ensure the sustainability of the services they offer for future generations.

Acknowledgments

The author would like to thank the technical support of Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus.

Ethical approval statement

None to declare.

Data availability

Not applicable.

Informed consent statement

Not applicable.

Conflict of interest

The author declare no competing interests.

Authors' contribution

Hadi Hamli: Conceptualization, writing first draft, review and revision. All of the enlisted authors have read and approved the final version of the published editorial.

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