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Climate Change Impacts on Freshwater Macro-Invertebrates

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Abstract

Freshwater ecosystems are rapidly deteriorating in quality and extent, facing biodiversity loss faster than other ecosystems due to human activities. Despite constituting only 0.01% of Earth's water, freshwater ecosystems support 9.5% of globally described animal species. Anthropogenic changes, such as habitat modification and pollution, are reducing species richness and biomass, altering community structures in aquatic ecosystems. Shifts in molluscan species composition in sediment cores provide a sensitive historical record of ecological changes, tracing over a century of human impact. Metal concentrations in deposit- and filter-feeders like *Viviparus* sp. are closely linked to suspended particles and filtrate content, reflecting environmental contamination.

Keywords: - Conservation, global temperature, pollution, threats

Introduction

Freshwater molluscs are divided into two main groups: Bivalves and Gastropods. They occupy diverse freshwater habitats and exhibit a wide range of life-history strategies. Lifespans vary significantly, from a few months (*pea clams*) to over 120 years (*freshwater pearl mussels, Margaritifera margaritifera*). *Freshwater pearl mussels* (FPMs) are endangered and particularly sensitive to climate change. Studies (e.g., Wagner et al., 2024) highlight the effects of elevated water temperatures on their growth and survival, informing conservation strategies. Fossilized freshwater mollusc shells are common in Quaternary lacustrine sediments, especially in calcareous deposits indicative of non-acidic waters (Miller & Tevesz, 2001). While molluscs are often associated with slow movement ("at a snail's pace"), they can disperse actively or passively. Some invasive species of snails and mussels demonstrate rapid spread, affecting ecosystems across marine, freshwater (limnic), and terrestrial environments.

Molluscs serve as a model group for studying active and passive dispersal in hololimnic macroinvertebrates (Kappes & Haase, 2011).

Climate Change Impacts on Freshwater Mollusc

Climate naturally varies over seasonal to millennial time scales. However, recent decades have witnessed unprecedented rates of warming, posing significant challenges to ecosystems.

Freshwater ecosystems are particularly sensitive to climate change due to:

- Their isolation and fragmentation within predominantly terrestrial landscapes.
- Heavy exploitation by humans for essential resources like drinking water and food (*Woodward, 2009*).
- Combined stressors from climate change and anthropogenic activities exacerbate the threats to these systems (*Malmqvist et al., 2008*).

Regional Impacts – Eastern Mediterranean:

- Climate change predictions for this region include:
    - Increased dryness.
    - Higher temperatures.
    - More frequent hot summer days (*Lelieveld et al., 2012*).
- These changes could have severe implications for water availability and ecosystem health.

Threats On Freshwater Mollusc

- **Construction of Dams:** Streams and other freshwater ecosystems are losing biodiversity faster than terrestrial or marine systems, largely due to alterations in natural flow regimes (Heather *et al.,* 2010). The threat category "Natural system modifications," including water abstraction and dams, affects over 68.8% of threatened and near-threatened freshwater molluscs.
- **Pollution:** Aquatic molluscs are excellent invertebrate models for environmental monitoring and toxicology. Pollution and pathogens together pose a significant and increasingly recognized threat to ecosystem health (Morley N.J., 2010). Freshwater mussels are facing global declines in abundance and species richness. Reduced river flows from over-abstraction, combined with pollution and nutrient enrichment from urban and agricultural effluents, often turn remaining waters into hypertrophic streams.

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Snails from active volcanic sites were found to have the highest metal concentrations (Zaldibar *et al.*, 2006). Both essential and non-essential trace elements are highly accumulated by invertebrates, particularly mollusc species. Gastropods exhibited concentrations of these elements about 20 times higher than bivalves (Gundacker C., 2000).

- **In Context of Biodiversity:** Climate change is significantly altering the composition, diversity, and functioning of many freshwater ecosystems (Woodward *et al.*, 2010). Field surveying is crucial for obtaining up-to-date information on species distribution, threats, sub-population abundance, and connectivity between them (Seddon *et al.*, 2014).
- **Global Temperature:** The increase in temperature is of significant concern, as it can be primarily assessed through seasonal variations in certain organisms. Aquatic environments can be highly stressful for their inhabitants, particularly because most of them are poikilothermic (Dutta *et al.*, 2018). Global surface temperatures were 1.59°C higher (over land) in 2011–2020 compared to 1850–1900, leading to extreme heat events that caused widespread adverse impacts on terrestrial, freshwater, and ocean ecosystems worldwide. Global warming over the 21st century is projected to range from 1.5°C to 4°C, depending on global emissions pathways (Werner *et al.*, 2024). Water temperature is a key environmental factor influencing the growth and survival of juvenile mussels. Moderate warming to temperatures above 14.5°C during the summer period benefits mussels, particularly during their most sensitive life stage, especially in epirhithral stretches. However, depending on the species and prevailing climate (temperature) and environmental (e.g., salinity) conditions, bivalves may reduce or even cease growth during prolonged periods.
- **Geographical Factors Affecting Distribution of Mollusc:** or millions of years, the molluscan fauna of the region has undergone spectacular changes in composition and morphological evolution, driven by the existence of vast lakes with significant salinity gradients and fluctuations, as well as the opportunity for migration among these ecosystems.
- **Conservation Status:** Seafood by-products from species such as fish, shellfish, squid, and bivalves, often discarded as waste, can be repurposed into innovative food products.

The phylum Mollusca, including Cephalopoda, Bivalvia, and Gastropoda, is rich in bioactive compounds like chitin, collagen, peptides, polyunsaturated fatty acids, and antioxidants, making them valuable for nutraceuticals and applications like biodiesel production. As consumer demand for healthier, eco-friendly food grows, the regular consumption of molluscs is recognized for boosting immunity and reducing disease risk. This article highlights the valuable chemicals and functional food ingredients derived from molluscs. Additionally, environmental DNA (eDNA) is being used to track the spread of invasive species and could be utilized in the future to detect mollusc populations. Since molluscs influence the ecology and economy of fish, wildlife, and human health, scientists must equip managers with the necessary tools (e.g., protocols for mollusc management) to address how current and future stressors and their interactions might impact mollusc conservation (Freshwater Mollusc Conservation Society 2016).

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