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# A Survey of Current Practices in Limnological Research

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**Abstract**

Limnology, the study of inland aquatic ecosystems, has gained increasing importance due to concerns over water quality, biodiversity loss, and climate change impacts. This study surveys recent advancements in limnological research from 2010 to 2022, highlighting key contributions in biodiversity monitoring, environmental DNA (eDNA) applications, the effects of anthropogenic activities, and the role of biological indicators in assessing freshwater ecosystem health. Despite these advancements, research gaps persist, including the need for long-term limnological data, deeper insights into microbial diversity, and the integration of AI-based remote sensing for water quality monitoring. Additionally, comprehensive assessments of invasive species, emerging pollutants, and the socioeconomic dimensions of limnological changes remain underexplored. Addressing these gaps, this study proposes a framework for future research, emphasizing interdisciplinary approaches and sustainable management strategies to enhance the resilience of freshwater ecosystems against environmental challenges.

**Keywords:** Limnology, ecosystem, biodiversity, monitoring., framework, environmental challenges.

## 1. Introduction

Limnology is the scientific study of inland aquatic systems, encompassing the physical, chemical, biological, and geological characteristics of freshwater bodies such as lakes, rivers, and wetlands. This multidisciplinary field integrates various aspects of ecology, hydrology, and environmental science to understand the dynamics of freshwater ecosystems. The significance of limnology has grown in recent years due to increasing concerns about water quality, biodiversity, and the impacts of climate change on freshwater resources. For instance, studies have shown that limnological factors such as nutrient concentrations, temperature, and hydrological variations significantly influence phytoplankton dynamics and overall ecosystem health Martins et al. (2011). Furthermore, limnology plays a crucial role in assessing the ecological status of water bodies, as evidenced by the use of biological indicators like diatoms and testate amoebae to evaluate environmental conditions and anthropogenic impacts (Antoniades et al., 2014; Degefu et al., 2014).

Research in limnology has also highlighted the importance of understanding the interactions between biotic and abiotic components within freshwater systems. For example, the influence of hydrological events on limnological variables has been documented, revealing how seasonal changes can affect nutrient cycling and species composition in aquatic environments (Palijan, 2014; Ferreira et al., 2019). Additionally, limnological studies have explored the effects of geodiversity on species distributions, demonstrating that variations in physical and chemical parameters can lead to significant differences in community structure across different freshwater ecosystems (Macario-González et al., 2022; Seekell et al., 2014). As freshwater systems face increasing pressures from human activities and climate change, the insights gained from limnological research are essential for effective management and conservation strategies aimed at preserving these vital ecosystems (Andrade et al., 2022; Thienpont et al., 2012).

Considering these facts, the present research work is devoted to the advancements in limnology in the last decade, and devoted to the contributions of researchers in the field. The research paper acknowledges the selected contributions and concludes with the investigated gaps in the research and objectives of a new research.

## 2. Contributions of Researchers in the field of Limnology

The field of limnology has seen significant advancements from 2010 to 2022, particularly in understanding the ecological status of freshwater systems through various biological indicators. A notable approach is the use of phytoplankton functional groups, which can provide a quality assessment method, exemplified by the Q assemblage index utilized in Lake Mogan, Turkey. This method highlights the importance of taxonomic knowledge and ecological data in monitoring lake health, especially during peak phytoplankton biomass periods in late summer (Demir et al., 2014). Furthermore, studies have shown that submerged macrophytes serve as critical indicators of lake ecological quality, with their biomass reflecting the overall health of aquatic ecosystems (Sender, 2018).

In addition to biological assessments, limnological research has increasingly focused on the impacts of anthropogenic factors on freshwater ecosystems. Climate change and nutrient enrichment are significant threats that alter the ecological balance of lakes, as evidenced by studies linking these changes to shifts in planktonic diatom communities and overall lake structure (Seelen et al., 2019; Saros et al., 2012). The integration of morphometric analyses and ecological modeling has further enhanced our understanding of how lake characteristics influence ecological health and water management strategies (Shang, 2013; Shang & Shang, 2018). As the field progresses, the need for comprehensive assessments that incorporate both biological indicators and environmental factors becomes paramount, ensuring the sustainability of freshwater resources in the face of ongoing ecological challenges (Yan et al., 2022). Table 2.1 shows some selected research contributions in the field.

**Table 2.1: Research contributions in the field on Limnology**

| S.No | Researcher(s) (year) | Contribution | Research Highlight |
|---|---|---|---|
| 1. | Tecklie and Yosef (2022) | Assessed wetland contributions to local livelihoods. | Explored the socio-economic dimensions of wetlands and their importance for community well-being |
| 2. | Marrone et al. (2022) | Explored cryptic diversity in aquatic microorganisms. | Highlighted the gaps in understanding the ecology and taxonomy of aquatic microorganisms, affecting biodiversity knowledge |
| 3. | Priyono et al. (2022) | Implemented eDNA for biodiversity monitoring in aviation security. | Demonstrated the effectiveness of eDNA in identifying aquatic species in previously unexplored environments |
| 4. | Gu et al. (2022) | Studied impacts of small hydropower stations on aquatic biodiversity. | Conducted a systematic study revealing the effects of hydropower on plankton, benthic animals, and |

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| | | | fish diversity |
| 5. | Barros and Seena (2022) | Advocated for the conservation of aquatic hyphomycetes. | Suggested integrating fungal biodiversity into conservation strategies to enhance funding and research opportunities |
| 6. | Tzafesta et al. (2021) | Reviewed DNA-based applications for assessing macroinvertebrate biodiversity. | Discussed the potential of DNA metabarcoding to enhance biomonitoring of aquatic ecosystems |
| 7. | Rivers-Moore et al. (2021) | Analyzed species distributions in Zambian aquatic ecosystems. | Identified distinct assemblages of aquatic macroinvertebrates and macrophytes, emphasizing the need for conservation in these areas. |
| 8. | Bertoni and Bertoni (2021) | Highlighted the heritage of limnology in Italy. | Reflected on the importance of preserving scientific heritage in limnology for future research and conservation efforts |
| 9. | Popescu et al. (2020) | Quantified biodiversity trade-offs in energy development. | Analyzed the impacts of renewable energy development on species with large habitat requirements, highlighting cumulative effects |
| 10. | Dorber et al. (2020) | Investigated biodiversity impacts of hydropower reservoirs. | Showed the need for strategic site selection to minimize biodiversity loss in aquatic and terrestrial ecosystems |
| 11. | Yang et al. (2020) | Proposed using riverine water eDNA for biodiversity monitoring. | Suggested a cost-effective approach to simultaneously monitor aquatic and terrestrial biodiversity using eDNA |
| 12. | Bunting et al. (2020) | Examined invertebrate | Investigated the dynamics of |

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| | | community responses to drying in chalk streams. | temporary stream ecosystems and their biodiversity during varying flow conditions |
| 13. | Huang et al. (2020) | Studied transformations in aquatic plant diversity in Lake Taihu. | Documented shifts from native to invasive aquatic plants, impacting ecosystem functions due to anthropogenic activities |
| 14. | Slimani et al. (2019) | Proposed surrogates for macroinvertebrate diversity in Mediterranean ecosystems. | Suggested using Ephemeroptera and Coleoptera as effective biodiversity indicators in North African aquatic ecosystems |
| 15. | Grossart et al. (2019) | Reviewed the role of fungi in aquatic ecosystems. | Highlights the importance of fungal diversity in aquatic systems and calls for interdisciplinary research to understand their ecological roles. |
| 16. | Thakur et al. (2019) . | Systematic review of soil biodiversity theories | Discusses how key biodiversity theories can explain patterns of soil biodiversity, emphasizing the scale-dependent nature of these patterns. |
| 17. | Alves et al. (2019) | Examined limnological features in tropical floodplain lakes. | Discussed the influence of climate change on limnological variables and aquatic biodiversity in the Cerrado region |
| 18. | Xu et al. (2019) | Conducted a meta-analysis on biodiversity impacts of water level changes. | Found varied impacts on biodiversity across different wetland types due to hydrological changes |
| 19. | Mao et al. (2018) | Analyzed urban expansion impacts on | Discussed how urbanization leads to wetland degradation, reducing |

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| | | wetlands. | their water management capacity |
| 20. | Bird et al. (2018) | Reviewed invertebrate fauna in southern African temporary wetlands. | Emphasized the significance of temporary wetlands and their invertebrate communities in regional biodiversity |
| 21. | Deiner et al. (2017) | Introduced eDNA metabarcoding as a tool for biodiversity surveys. | High-throughput sequencing enables rapid assessment of species richness in various ecosystems using environmental DNA. |
| 22. | Shogren et al. (2017) | Investigated eDNA movement in streams. | Identified environmental factors affecting eDNA transport, enhancing species monitoring and management capabilities |
| 23. | Valentini et al. (2016) . | Tested eDNA metabarcoding for monitoring aquatic biodiversity | Validated the use of eDNA from water samples to address ecological and conservation questions for amphibians and bony fish |
| 24. | Thomsen and Willerslev (2015) | Discussed the use of eDNA in conservation. | Emphasized the potential of eDNA as a monitoring tool for past and present biodiversity, aiding conservation efforts |
| 25. | Handa et al. (2014) | Investigated the impact of biodiversity loss on litter decomposition | Found that reduced functional diversity of decomposers slows carbon and nitrogen cycling across various ecosystems |
| 26. | Costanza et al. (2014) | Estimated the global value of ecosystem services. | Emphasized the high value of wetlands for ecosystem services, informing conservation strategies |

## 3. Gaps in the Research and Objectives of Proposed Research

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Following points represent the gaps in the research:

- Most studies emphasize short-term ecological changes, while long-term data on limnological shifts due to climate change, land use, and human activities remain sparse;
- While some studies highlight aquatic fungi, there is limited research on microbial diversity, interactions, and their roles in nutrient cycling in lakes and wetlands;
- The application of AI-driven data analysis and satellite-based remote sensing for monitoring limnological parameters remains underdeveloped;
- A detailed research is needed on the cumulative impact of invasive species on water quality and native biodiversity;
- The role of pollutants like microplastics, pharmaceuticals, and heavy metals in altering limnological parameters remains largely unexplored;
- There is a need for more interdisciplinary research integrating socioeconomic aspects with limnological changes; and
- Detailed investigations on how hydropower development affects nutrient dynamics, sediment transport, and thermal stratification are needed.

Following points represent the objectives of a proposed research:

- To analyze long-term limnological changes in selected aquatic ecosystems using historical and recent data;
- To investigate microbial community diversity and its role in biogeochemical cycles within lakes, rivers, and wetlands;
- To integrate AI-based models and remote sensing techniques for real-time monitoring and predictive analysis of water quality and biodiversity in freshwater bodies;
- To assess the impact of invasive aquatic species on native biodiversity, water chemistry, and ecosystem stability;
- To study the occurrence and effects of emerging contaminants (microplastics, heavy metals, pharmaceuticals) on limnological parameters and aquatic biodiversity;
- To explore the socioeconomic dimensions of limnological changes, linking ecosystem health to community livelihoods and policy recommendations;

- To evaluate the impact of hydropower projects on limnological characteristics such as sediment load, temperature regimes, and oxygen levels; and
- To propose sustainable conservation and management strategies for maintaining freshwater ecosystem health based on scientific evidence and stakeholder participation.

## 4. Conclusion

The present research work highlights the survey of current practices in limnological research, and concludes with the investigated gaps in the research and objectives of proposed research, which seems to be appropriate considering the dire need of time and should be fruitful for upcoming researchers.

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