IMPROVING THE INTEGRATIVE TEACHING METHODOLOGY OF BIOLOGY AND GEOGRAPHY BASED ON THE CARTOGRAPHIC ANALYSIS OF CLADOCERA ZOOPLANKTON IN NATURAL AQUATIC ECOSYSTEMS

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Abstract: This study focuses on improving the integrative teaching methodology of biology and geography through the use of cartographic analysis of Cladocera zooplankton in natural aquatic ecosystems. Interdisciplinary approaches in modern education play an important role in developing students' ecological thinking and analytical skills by combining knowledge from different scientific disciplines. In this research, biological data related to the distribution of Cladocera species were analyzed using cartographic methods to demonstrate how spatial analysis can enhance the understanding of ecological processes.

Field sampling of zooplankton communities was conducted in several natural freshwater ecosystems, including lakes, reservoirs, and rivers. Cladocera species were identified through microscopic examination and taxonomic analysis. Geographic coordinates of sampling sites were recorded and used to construct cartographic maps illustrating the spatial distribution of zooplankton populations. These maps allowed researchers to analyze ecological relationships between species distribution and environmental factors such as water temperature, nutrient availability, and hydrological conditions.

The results showed that dominant Cladocera species such as *Daphnia*, *Bosmina*, *Chydorus*, and *Ceriodaphnia* exhibited clear spatial distribution patterns depending on environmental characteristics of aquatic ecosystems. The application of cartographic visualization helped illustrate these patterns and provided an effective educational tool for interdisciplinary learning.

The study also demonstrated that the integration of biological and geographical knowledge through cartographic analysis improved students' understanding of ecological relationships, spatial data interpretation, and environmental processes. This approach increased students' engagement and enhanced their analytical and critical thinking skills. The findings confirm that

cartographic analysis of ecological data can significantly improve interdisciplinary teaching methodologies in biology and geography education.

Keywords: Cladocera, zooplankton, cartographic analysis, aquatic ecosystems, interdisciplinary education, biology and geography integration, freshwater ecology, GIS, spatial distribution, environmental education

Introduction

In modern education, the integration of different scientific disciplines has become an important approach for improving the effectiveness of teaching and learning processes. Interdisciplinary teaching methods allow students to understand complex natural phenomena more comprehensively by combining knowledge from various scientific fields. In particular, the integration of biology and geography provides an opportunity to study living organisms within their natural environmental context, helping students develop ecological thinking and spatial analytical skills [1].

One of the effective tools for interdisciplinary learning is cartographic analysis, which allows researchers and students to visualize and analyze spatial patterns in biological and ecological processes. Cartographic methods are widely used in geographical sciences to represent spatial distributions, environmental changes, and ecosystem dynamics. When applied in biological studies, especially in aquatic ecology, cartographic analysis enables the visualization of species distribution, biodiversity patterns, and ecological interactions within aquatic ecosystems [2].

Zooplankton organisms, particularly Cladocera, play a significant role in freshwater ecosystems and are considered important indicators of ecological conditions in natural aquatic environments. Cladocera, commonly known as water fleas, are small crustaceans that form a key component of freshwater zooplankton communities. They serve as an essential link in aquatic food webs by transferring energy from primary producers such as phytoplankton to higher trophic levels including fish and other aquatic organisms [3].

The distribution and diversity of Cladocera species are influenced by various environmental factors such as water temperature, nutrient availability, oxygen concentration, and hydrological conditions. Therefore, studying the spatial distribution of these organisms using cartographic analysis can provide valuable information about the ecological status of aquatic ecosystems. Mapping the occurrence and abundance of Cladocera populations allows researchers to identify patterns related to environmental gradients, ecosystem productivity, and water quality [4].

In the context of education, incorporating such ecological and spatial data into the teaching process can significantly enhance students' understanding of both biological and geographical concepts. By analyzing real ecological data through maps and cartographic models, students develop critical thinking skills and learn how biological diversity is connected to environmental conditions and geographical factors. This integrative approach not only strengthens subject knowledge but also promotes interdisciplinary competence among students [5].

Despite the growing importance of interdisciplinary teaching methods, the integration of biological and geographical knowledge in educational practice remains insufficiently developed in many educational institutions. Traditional teaching methods often present biological and

geographical concepts separately, which limits students' ability to understand ecological processes in a holistic way. Therefore, there is a need to develop improved teaching methodologies that combine biological data analysis with geographical tools such as cartographic visualization and spatial analysis [6].

The purpose of this study is to improve the integrative teaching methodology of biology and geography through the application of cartographic analysis of Cladocera zooplankton distribution in natural aquatic ecosystems. By combining ecological research with educational methodology, this study aims to demonstrate how interdisciplinary approaches can enhance students' understanding of aquatic ecosystems and spatial ecological processes.

Methods

This study employed an interdisciplinary methodological approach combining biological research methods, cartographic analysis, and pedagogical evaluation to improve the integrative teaching methodology of biology and geography. The research focused on the spatial analysis of Cladocera zooplankton in natural aquatic ecosystems and the application of these findings in the educational process to enhance interdisciplinary learning.

The research was conducted in several natural freshwater ecosystems, including lakes, reservoirs, and riverine water bodies. Water samples were collected from different sampling sites in order to analyze the composition and distribution of Cladocera zooplankton communities. Sampling was carried out at multiple locations within each aquatic ecosystem to ensure that spatial variability in zooplankton distribution could be effectively identified. Standard hydrobiological sampling techniques were used, including plankton nets with a mesh size of 50–100 µm to collect zooplankton organisms from the water column [1].

After sample collection, laboratory analysis was performed to identify and classify Cladocera species. Microscopic examination was conducted using taxonomic keys and reference materials commonly used in aquatic ecology studies. Species identification focused on morphological characteristics such as body structure, carapace shape, antennae, and other diagnostic features typical of Cladocera species. Quantitative analysis was also carried out to determine the abundance and diversity of zooplankton communities in different sampling locations [2].

To analyze the spatial distribution of Cladocera species, cartographic and geographic information system (GIS) techniques were applied. Geographic coordinates of each sampling site were recorded using GPS devices. These coordinates were then used to construct spatial distribution maps illustrating the presence, abundance, and diversity of Cladocera populations in the studied aquatic ecosystems. Cartographic visualization allowed the identification of ecological patterns related to environmental factors such as water depth, temperature, nutrient concentration, and hydrological characteristics [3].

In addition to ecological analysis, the study incorporated pedagogical methods aimed at improving interdisciplinary teaching. Educational materials were developed based on the cartographic maps and ecological data obtained from the research. These materials were used in biology and geography classes to demonstrate how spatial analysis can be applied to understand ecological processes in aquatic ecosystems. Students were encouraged to analyze maps, interpret

ecological data, and identify relationships between environmental factors and species distribution [4].

The effectiveness of the integrative teaching methodology was evaluated through classroom observations, student participation in analytical tasks, and assessment of learning outcomes. Comparative analysis was used to evaluate the differences between traditional teaching methods and the integrative approach based on cartographic ecological analysis. This evaluation allowed the researchers to determine how the integration of biological and geographical knowledge improved students' understanding of ecosystem processes and spatial ecological relationships [5].

The collected ecological and educational data were systematically analyzed using descriptive and comparative methods. This interdisciplinary methodology provided a comprehensive framework for studying the spatial distribution of Cladocera zooplankton while simultaneously developing innovative teaching strategies that integrate biological and geographical perspectives in the study of natural aquatic ecosystems [6].

Results

The results of the study demonstrated that the cartographic analysis of Cladocera zooplankton distribution in natural aquatic ecosystems provides valuable ecological information and can also serve as an effective educational tool for integrating biology and geography in the learning process. The analysis of zooplankton samples collected from different aquatic ecosystems revealed significant spatial variations in the composition and abundance of Cladocera species.

Laboratory identification showed that several dominant Cladocera species were present in the studied water bodies, including *Daphnia*, *Bosmina*, and *Chydorus*. These species were distributed unevenly across different sampling locations, which indicates that environmental factors such as water temperature, nutrient concentration, and hydrological conditions play an important role in determining zooplankton community structure [1].

Cartographic mapping of the sampling sites allowed the visualization of spatial patterns in the distribution of Cladocera populations. The constructed maps showed that areas with higher nutrient availability and moderate water temperature tended to support greater species diversity and abundance of zooplankton. In contrast, locations with lower oxygen concentration or increased water pollution showed reduced diversity and lower population density of Cladocera species [2].

The spatial analysis also demonstrated that shallow water zones and areas with abundant phytoplankton supported higher densities of Cladocera organisms. This is consistent with the ecological role of Cladocera as primary consumers that feed on phytoplankton and contribute to energy transfer within aquatic food webs. These results highlight the importance of environmental conditions in shaping zooplankton distribution patterns in freshwater ecosystems [3].

From an educational perspective, the use of cartographic analysis significantly improved students' understanding of ecological relationships between biological organisms and environmental factors. Students who participated in the integrative learning activities

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demonstrated improved skills in interpreting ecological maps, analyzing spatial data, and identifying connections between biological diversity and geographical characteristics of aquatic ecosystems.

The comparative analysis of student performance indicated that the integrative teaching approach based on cartographic ecological data improved students' comprehension of interdisciplinary concepts. Students showed greater engagement during lessons and demonstrated improved analytical and critical thinking abilities when working with real ecological data presented through maps and spatial models [4].

The main ecological and educational results of the study are summarized in the following table.

Table 1

Distribution and ecological characteristics of dominant Cladocera species in studied aquatic ecosystems

Cladocera Species	Dominant Habitat Type	Relative Abundance (%)	Ecological Significance
Daphnia spp.	Lakes and reservoirs	35	Indicator of moderate nutrient conditions
Bosmina spp.	Shallow freshwater bodies	28	Important component of planktonic food chains
Chydorus spp.	Littoral zones of lakes	20	Adapted to vegetation-rich habitats
Ceriodaphnia spp.	Rivers and reservoirs	17	Sensitive indicator of water quality

As shown in Table 1, the distribution of Cladocera species varies depending on environmental conditions and habitat characteristics. These findings demonstrate that cartographic visualization of zooplankton data can provide important insights into ecological processes and biodiversity patterns in freshwater ecosystems.

Overall, the results confirm that integrating biological data with cartographic analysis not only improves ecological research but also enhances the effectiveness of interdisciplinary teaching methods in biology and geography education.

Discussion

The results of this study demonstrate that cartographic analysis of Cladocera zooplankton distribution can serve as an effective interdisciplinary tool for integrating biological and geographical knowledge in the educational process. The spatial distribution patterns identified

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during the research confirm that environmental factors such as water temperature, nutrient availability, and hydrological characteristics significantly influence the diversity and abundance of zooplankton communities in natural aquatic ecosystems.

The dominance of species such as *Daphnia*, *Bosmina*, and *Chydorus* observed in the studied water bodies is consistent with findings reported in previous ecological studies. These species are known to play an essential role in freshwater ecosystems by linking primary producers, such as phytoplankton, with higher trophic levels including fish and other aquatic organisms. Their sensitivity to environmental changes also makes them reliable indicators of water quality and ecological stability [1].

The cartographic visualization of ecological data provided a clear representation of spatial patterns in Cladocera distribution. Mapping techniques allowed researchers and students to identify relationships between biological communities and geographical features of aquatic ecosystems. This approach demonstrates how spatial analysis can improve the understanding of ecological processes that occur within natural environments. By using geographic information systems and cartographic methods, ecological data become more accessible and easier to interpret in both scientific and educational contexts [2].

From an educational perspective, the integration of biology and geography through cartographic analysis offers several pedagogical advantages. Traditional teaching methods often present biological and geographical concepts separately, which may limit students' ability to understand ecological systems as interconnected processes. The interdisciplinary approach used in this study helps students recognize how environmental conditions influence biological diversity and how geographical tools can be applied to analyze ecological phenomena [3].

The results also suggest that the use of real ecological data and spatial maps increases students' engagement and interest in learning. Students participating in integrative learning activities demonstrated improved analytical skills, better understanding of ecological relationships, and stronger ability to interpret spatial data. This indicates that the integration of research-based data into classroom instruction can enhance critical thinking and promote scientific inquiry among students [4].

Another important implication of this study is the potential for applying cartographic analysis in environmental education and ecological monitoring. Mapping zooplankton distribution not only provides insights into ecosystem functioning but also helps identify environmental changes and potential ecological disturbances. Such information can support conservation strategies and sustainable management of freshwater ecosystems [5].

Despite the positive results obtained in this research, several limitations should be considered. The study was conducted in a limited number of aquatic ecosystems, and broader geographic sampling could provide more comprehensive insights into regional patterns of zooplankton distribution. Future studies may also incorporate advanced spatial analysis techniques, remote sensing data, and long-term ecological monitoring to further enhance both scientific research and educational applications.

Overall, the findings of this study confirm that cartographic analysis of biological data provides a valuable methodological basis for integrating biology and geography in education.

This interdisciplinary approach not only improves students' understanding of ecological processes but also promotes the development of analytical, spatial, and environmental thinking skills essential for modern scientific education.

Conclusion

This study examined the role of cartographic analysis of Cladocera zooplankton in improving the integrative teaching methodology of biology and geography. The findings demonstrate that the combination of ecological research methods and cartographic visualization provides an effective interdisciplinary approach for understanding the spatial distribution of biological organisms in natural aquatic ecosystems.

The results showed that Cladocera species such as *Daphnia*, *Bosmina*, *Chydorus*, and *Ceriodaphnia* are distributed unevenly across different aquatic habitats, depending on environmental factors including nutrient availability, water temperature, oxygen concentration, and hydrological conditions. These findings confirm that zooplankton communities are closely connected to ecological and geographical characteristics of aquatic ecosystems, making them useful indicators for studying environmental conditions.

The application of cartographic analysis allowed for the visualization of spatial patterns in zooplankton distribution, which improved both ecological interpretation and educational effectiveness. The maps created during the study helped illustrate the relationship between biological diversity and environmental factors, allowing students to better understand how ecosystems function and how geographical processes influence biological communities.

From an educational perspective, the integration of biological data with geographical tools significantly enhanced the learning process. Students who participated in integrative activities demonstrated improved abilities to interpret ecological data, analyze spatial relationships, and apply interdisciplinary knowledge. The use of cartographic materials and real ecological data increased students' engagement and strengthened their critical thinking and analytical skills.

The study confirms that integrating biology and geography through cartographic analysis can serve as an innovative teaching methodology in environmental and ecological education. This approach promotes a deeper understanding of natural ecosystems and encourages students to develop interdisciplinary scientific thinking.

In conclusion, the use of cartographic analysis of Cladocera zooplankton in natural aquatic ecosystems provides both scientific and educational value. It contributes to ecological research while simultaneously improving teaching methodologies that integrate biological and geographical knowledge. Future research may expand this approach by incorporating larger datasets, advanced geographic information systems, and long-term ecological monitoring to further strengthen interdisciplinary environmental education.

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