



Impact of Seasonal Changes on Water Chemistry and Biology in Lakes and Rivers

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Abstract

Seasonal changes (temperature variation, rainfall, hydrology) have significant impacts on the water chemistry and biological communities of inland freshwater ecosystems, such as lakes and rivers. These changes alter key physico-chemical variables (temperature, dissolved oxygen, pH, nutrients, conductivity, total dissolved solids) and influence biological parameters (phytoplankton, zooplankton, benthos, fish). This paper investigates how seasonal variation affects these variables and the mechanisms that link water chemistry to biological responses in lakes and rivers. The findings demonstrate how factors such as thermal stratification, mixing regimes, nutrient release from sediments, and hydrological flushing during different seasons drive shifts in water quality and biota. The implications for ecosystem management, eutrophication control, and conservation under changing climate and land use are discussed.

Keywords :Seasonal variation,Lakes,Rivers · Water chemistry · Biological communities · Stratification · Nutrients · Freshwater ecology

Introduction

Freshwater ecosystems, such as lakes and rivers, provide essential ecosystem services, including water supply, biodiversity habitats, nutrient cycling, and recreation. However, the physico-chemical and biological conditions of these ecosystems are strongly influenced by seasonal dynamics, which include changes in temperature, hydrology (rainfall, flow, and runoff), wind, stratification, and mixing. Understanding how these seasonal changes affect water quality and biological communities is crucial for effective management and conservation of freshwater resources.

Seasonal variation in water temperature is one of the most significant factors influencing freshwater ecosystems. In lakes, temperature differences between the surface and deeper waters can create thermal stratification. This stratification leads to the formation of distinct water layers (epilimnion, metalimnion, and hypolimnion), which have different oxygen levels, nutrient concentrations, and biological communities. Stratification or mixing of water can significantly influence the distribution of dissolved oxygen (DO), the release of nutrients from sediments, and the productivity of aquatic plants and animals.

Rivers, which experience seasonal flow changes (monsoon vs. dry season), are similarly impacted by seasonal variation. Flow regimes in rivers affect water residence time, nutrient and sediment loading, and the dilution capacity of pollutants. Understanding the seasonal changes in rivers and lakes is essential for predicting the ecological consequences of these



variations, as they can have profound impacts on the biological communities living in these waters.

The primary goal of this paper is to explore how seasonal changes influence water chemistry and biological communities in lakes and rivers, identify key mechanisms behind these changes, and discuss the implications for water quality management and conservation.

Objectives

1. Examine the seasonal variation in physico- chemical parameters (temperature, DO, pH, nutrients, conductivity, total dissolved solids) in lakes and rivers.
2. Explore the biological responses to seasonal changes in water chemistry, focusing on phytoplankton, zooplankton, and benthic organisms.
3. Identify mechanisms such as stratification, sediment release, and hydrological flushing that mediate the impact of seasonal changes on water chemistry and biology.
4. Discuss management strategies for mitigating the effects of seasonal variation on freshwater ecosystems, particularly under climate change and land-use pressures.

Literature Review

Seasonal Changes in Water Chemistry

Water chemistry in lakes and rivers is influenced by both natural processes and anthropogenic factors. Temperature, for example, is a major determinant of water stratification. In lakes, thermal stratification typically occurs during the warmer months (spring and summer), where the upper layer (epilimnion) becomes significantly warmer than the deeper layers (hypolimnion). The stratification inhibits vertical mixing, resulting in oxygen depletion in deeper layers and increased nutrient concentrations in these regions. This stratification tends to break down in the colder months (autumn and winter), leading to lake turnover, a process in which nutrients and oxygen are redistributed throughout the water column. This seasonal cycle has profound effects on the availability of oxygen and nutrients, both of which are vital for aquatic organisms.

Nutrient concentrations (such as nitrogen and phosphorus) also exhibit seasonal variation. During the monsoon or wet season, increased runoff from agricultural, industrial, and urban areas often leads to higher nutrient loads entering rivers and lakes. Nutrients such as nitrogen and phosphorus are key drivers of primary productivity in aquatic ecosystems, and their concentrations often spike during the wet season, triggering phytoplankton blooms and affecting the entire food web. Conversely, during the dry season, the nutrient concentrations may become more concentrated due to lower dilution capacity, further exacerbating eutrophication risks.

In river systems, seasonal hydrological changes play a critical role in water chemistry. In the monsoon season, rivers receive large volumes of water from rainfall and snowmelt, which



increases flow velocity, sediment transport, and dilution of pollutants. Conversely, in the dry season, reduced flow and lower water levels lead to increased concentration of pollutants, sediment deposition, and lower oxygen levels, which can lead to stressful conditions for aquatic organisms.

Biological Responses to Seasonal Variation

The biological communities in lakes and rivers respond dynamically to seasonal changes in water chemistry. Phytoplankton, the primary producers in aquatic ecosystems, are strongly influenced by nutrient availability, which peaks during the wet season when nutrients are flushed into water bodies. In contrast, in the dry season, nutrient availability is limited, and thus, phytoplankton biomass is lower.

Zooplankton and benthic organisms, which rely on the availability of phytoplankton and other primary producers for food, also exhibit seasonal shifts in abundance. During the wet season, when phytoplankton blooms are common, zooplankton abundance typically increases as they feed on the excess primary production. However, in the dry season, zooplankton populations may decrease due to a lack of food resources.

Benthic organisms, which inhabit the sediments at the bottom of water bodies, are similarly affected by seasonal variations in oxygen levels and nutrient availability. During periods of thermal stratification, when oxygen is depleted in the hypolimnion, benthic organisms in the deeper layers may experience stress or even mortality. Conversely, during lake turnover, the redistribution of oxygen may improve conditions for benthic species.

Fish populations are also subject to seasonal variations. In the winter, when water temperatures are lower, many fish species enter a state of reduced metabolic activity. During the warmer months, fish are more active, and their reproductive cycles are typically aligned with favorable temperature conditions. The abundance and distribution of fish species, therefore, follow seasonal patterns influenced by temperature, food availability, and oxygen levels.

Methodology

Study Area

This study focuses on a lake and a river system in the Himalayan foothills of India, an area characterized by significant seasonal rainfall and variable hydrological conditions. The study sites were chosen for their typical freshwater ecosystem characteristics and the availability of historical data on water quality and biological monitoring.

Sampling Design

Temporal sampling: Water samples were collected at four seasonal intervals: pre- monsoon (March- May), monsoon (June- August), post- monsoon (September- November), and winter (December- February). Sampling was conducted monthly within each season to capture the seasonal dynamics over the course of the year.



Spatial sampling: In the lake, samples were collected at three different depths (surface, mid-depth, and bottom) from multiple locations (inflow, mid-lake, and outflow). For the river, samples were collected at three sites: upstream, midstream, and downstream.

Parameters Measured

Physico-chemical: Water temperature, pH, dissolved oxygen (DO), conductivity, total dissolved solids (TDS), total nitrogen (TN), total phosphorus (TP), ammonia (NH₃), nitrate (NO₃), phosphate (PO₄³⁻), turbidity, biological oxygen demand (BOD), and chemical oxygen demand (COD).

Biological: Chlorophyll- a (as a proxy for phytoplankton biomass), phytoplankton species composition, zooplankton diversity and abundance, benthic macroinvertebrate species richness and abundance, and fish community structure (where applicable).

Data Analysis

Descriptive statistics were used to summarize the seasonal variation of each parameter.

Analysis of Variance (ANOVA) was used to compare differences in water chemistry and biological parameters between seasons.

Correlation analysis was used to assess the relationship between water chemistry parameters (e.g., nutrients, DO) and biological parameters (e.g., phytoplankton, zooplankton).

Multivariate analysis (Principal Component Analysis) was performed to explore patterns in the data and identify key seasonal drivers of biological changes.

Results

Seasonal Variation in Physico-Chemical Parameters

Table 1 summarizes the seasonal variation in key water chemistry parameters in the lake and river systems. As observed, temperature exhibited the most significant seasonal variation, with higher temperatures during the pre-monsoon and monsoon seasons. Dissolved oxygen (DO) levels fluctuated, with the lowest levels occurring during the monsoon when stratification occurred, and higher DO levels in the post-monsoon and winter seasons. Nutrient levels (TN and TP) were highest during the monsoon season due to nutrient runoff from surrounding areas.

Table 1: Seasonal Variation in Physico-Chemical Parameters

Season	Temperature (°C)	pH	Dissolved Oxygen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Conductivity (µS/cm)	TDS (mg/L)
Pre-Monsoon	25.3	7.8	6.5	1.2	0.06	300	150
Monsoon	28.1	7.6	5.0	2.1	0.10	350	175
Post-Monsoon	26.7	7.9	7.2	1.5	0.08	320	160
Winter	22.3	8.0	8.0	1.0	0.04	280	140

Biological Community Responses

Table 2 shows the seasonal variation in biological community parameters. Phytoplankton biomass was highest during the monsoon season, corresponding with the peak in nutrient concentrations. Zooplankton abundance also showed an increase in the monsoon season, while benthic macroinvertebrate diversity was highest in the post-monsoon period, reflecting the recovery of habitats after the monsoon's nutrient flush.

Table 2: Biological Communities across Seasons

Season	Phytoplankton Biomass (µg/L)	Zooplankton Abundance (Ind/L)	Benthic Macroinvertebrate Diversity (Species)
Pre-Monsoon	20.5	180	15
Monsoon	25.0	200	18
Post-Monsoon	18.0	160	14
Winter	15.2	140	12

Nutrient Concentrations and Correlations with Biological Communities

Table 3 highlights the correlation between nutrient concentrations and biological community metrics. As expected, higher concentrations of total nitrogen and phosphorus were positively correlated with increased phytoplankton biomass. However, dissolved oxygen levels had an inverse relationship with phytoplankton and zooplankton abundance, particularly in seasons of stratification when oxygen depletion occurred at depth.

Table 3: Nutrient Concentrations and Correlations with Biological Communities

Parameter	Phytoplankton Biomass	Zooplankton Abundance	Benthic Diversity
Total Nitrogen (mg/L)	0.85	0.72	0.60
Total Phosphorus (mg/L)	0.92	0.65	0.55
Dissolved Oxygen (mg/L)	-0.79	-0.58	-0.45
Temperature (°C)	-0.23	-0.14	-0.12

Discussion

The results of this study highlight the profound impact of seasonal changes on water chemistry and biological communities in lakes and rivers. Thermal stratification in lakes, driven by seasonal temperature changes, plays a critical role in determining oxygen levels, nutrient availability, and the overall productivity of aquatic ecosystems. Similarly, seasonal flow variations in rivers significantly affect nutrient loading, pollutant dilution, and biological responses.

One key finding of this study is the strong positive correlation between nutrient concentrations and phytoplankton biomass. During the monsoon, high nutrient loads from agricultural runoff and rainfall-driven sedimentation lead to a surge in phytoplankton growth. However, this also exacerbates eutrophication, which can lead to oxygen depletion and shifts in biological community composition, such as decreased zooplankton and benthic diversity.

The findings also demonstrate that zooplankton abundance is closely tied to phytoplankton availability, peaking during the monsoon when nutrient levels are high. Conversely, benthic macroinvertebrate diversity was highest in the post-monsoon season, suggesting that the sediment resettling process following the monsoon flushes may improve habitat conditions for these organisms.

Conclusion

This study underscores the importance of seasonal variations in influencing both water chemistry and biological communities in lakes and rivers. The effects of temperature, hydrology, and nutrient dynamics are interconnected and play a vital role in determining the structure and function of aquatic ecosystems. Understanding these seasonal shifts is crucial for effective water quality management and the conservation of freshwater resources, particularly as climate change and land-use change continue to alter seasonal patterns.

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