
REFINEMENT OF ALGOLOGICAL MONITORING METHODS FOR SMALL RIVERS WITH REGULATED FLOW: SEASONAL AND HYDRODYNAMIC GRADIENTS

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Article Received: 23 January 2026

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Article Revised: 12 February 2026

Department of Ecology, Geography and Nature Management, T.H. Shevchenko

Published on: 04 March 2026

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DOI: <https://doi-doi.org/101555/ijrpa.6550>

ABSTRACT

The article is devoted to the refinement of methodological approaches for the ecological monitoring of small rivers under the influence of low-head hydropower plants (SHPs). The authors substantiate an integrated framework that combines geobotanical analysis of macrophyte substrates with seasonal algological sampling of plankton, benthos, and epiphyton in regulated river sections. The study details the procedures for sampling in shallow-water conditions, which are characteristic of SHP influence zones, and the subsequent laboratory identification using high-resolution light microscopy combined with nomenclatural synchronization via AlgaeBase. Special emphasis is placed on the quantitative assessment of abundance and biomass using counting-volumetric and stereometric methods. The proposed methodology includes a rigorous statistical protocol for evaluating seasonal and hydrodynamic gradients using biodiversity indices and multivariate analysis. The results provide a standardized tool for the long-term ecological assessment of regulated aquatic ecosystems, ensuring the comparability of data on the structural and functional transformations of algal flora.

KEYWORDS: algal monitoring, small hydropower plants, small rivers, seasonal dynamics, hydro-environmental gradient, stereometric method, macrophyte substrate, biodiversity indices, bioindication, regulated aquatic ecosystems.

1. INTRODUCTION

The structural and functional organization of algal communities in river ecosystems is highly sensitive to hydrological transformations caused by small hydropower plants (SHPs). The Sedniv SHP on the Snov River (northern Ukraine) creates a distinct spatial and temporal discontinuity that fundamentally reconfigures the seasonal succession of phytoplankton and phytobenthos. Studying the seasonal dynamics of algal flora in the zones of "upstream stagnation" and "downstream turbulence" requires specialized methodological approaches to account for the redistribution of nutrient loads and changes in thermal regimes.

The Snov River, known for its high ecological status, serves as an ideal natural laboratory for observing how a 2.25-meter hydraulic head affects the drift and settlement of microalgae. Existing monitoring protocols often overlook the fine-scale temporal variations in algal biomass and species richness triggered by the daily regulation of water discharge (Stefanyshyn & Vlasiuk, 2021). Therefore, developing a robust methodological framework for year-round monitoring is essential to distinguish between natural seasonal shifts and anthropogenically induced anomalies in the river's primary production. This study aims to refine the approaches for evaluating the "dam effect" on the rhythmic development of aquatic microflora, ensuring a deeper understanding of the stability of Polissya's river systems (Reshetchenko et al., 2022).

2. RESULTS AND DISCUSSION

2.1. Seasonal dynamics context

The seasonal rhythm of the Snov River determines the structural shifts in the algal flora, starting with the spring flood, when high discharge and turbidity promote the dominance of diatoms while simultaneously washing out plankton from the reservoir. In summer, the stable head of the Sedniv SHP leads to thermal stratification in the upstream section, creating conditions for the development of green and blue-green algae. Conversely, the downstream section experiences intense aeration through the spillway, which accelerates the growth of periphyton on the stone riprap of the dam. The autumn-winter period is characterized by a transition to cold-resistant forms (cryophytes), where the dam serves as a thermal buffer, slowing down the freezing process in the immediate vicinity of the water discharge. Such seasonal variability, exacerbated by the technical parameters of the hydro-node, requires a differentiated approach to sampling to ensure the representativeness of the ecological data (Reshetchenko et al., 2022).

2.2. Methodological framework for seasonal monitoring

The methodological framework for studying the seasonal dynamics of algal flora at the Sedniv SHP is based on a comparative spatial-temporal approach. To ensure the representativeness of the data, sampling is carried out seasonally (spring high water, summer-autumn low water, and winter period) at fixed stations located 200 m upstream and 200 m downstream of the dam. This setup allows for the evaluation of the "barrier effect" on the structural parameters of microalgae under varying hydraulic loads.

The quantitative analysis integrates the calculation of abundance (N) and biomass (B) for each ecological group (plankton, benthos, and epiphyton). In the upstream section, the focus is on sedimentation rates and the development of stagnant-water forms, while in the downstream section, the emphasis shifts to the recovery of rheophilic communities after passing through the turbines. The biomass is determined using the stereometric method, where cell volumes are calculated based on geometric analogies. This differentiated monitoring protocol, combined with the analysis of species richness indices, provides a robust tool for detecting anthropogenic anomalies against the background of natural seasonal successions in the Snov River (Reshetchenko et al., 2022; Stefanyshyn & Vlasiuk, 2021).

2.3. Methods of vegetation field research

To assess the ecological state of the aquatic environment near the Sedniv SHP, the method of geobotanical description was applied (Yakubenko et al., 2018). Four detailed geobotanical descriptions were conducted at the exact locations of algal sampling: two stations 200 m upstream and two stations 200 m downstream of the dam. The research plots varied from 1 to 4 m², depending on the density of the vegetation (Fig. 1).



Fig. 2. A typical sampling plot for the geobotanical description of higher aquatic vegetation in the littoral zone of the Snov River (northern Ukraine). Recording the species composition and projective cover of macrophytes as a substrate for algal flora.

The methodology included a comprehensive analysis of the plant community: identification of vertical stratification (sub-tiers), full species composition, and the quantitative participation of each species in the phytocenosis based on the projective cover percentage (%).

This integrated approach is essential for seasonal monitoring, as higher aquatic plants serve as a primary substrate for epiphytic algal communities. The spatial distribution of macrophytes reflects the long-term hydrological stability of the banks and directly influences the micro-habitats of the algal flora before and after the spillway.

2.4. Sampling procedures for algal communities at the hydropower node

The field stage of the research focuses on capturing the spatial heterogeneity of algal communities caused by the Sedniv SHP's hydraulic structures. Sampling is conducted across three key ecological groups: phytoplankton, phytobenthos, and epiphyton, ensuring a holistic view of the river's primary production.

For phytoplankton, the strategy integrates qualitative and quantitative techniques. In the upstream reservoir, where the current is slow, bathometers are used to collect water from discrete depths, preventing the artificial mixing of stratified algal layers. To account for the high water purity of the Snov River, plankton nets (with a mesh size of 20–35 μm) are

employed to concentrate rare species, which is vital for a comprehensive biodiversity assessment.

The collection of phytobenthos focuses on organisms inhabiting the surface of bottom soils and deposits, including their thickness (up to 1 cm deep) and a specific bottom layer of water (2–3 cm thick). In shallow areas (up to 0.5–1.0 m deep), which are characteristic of the littoral zones and sections near the Sedniv SHP, samples are obtained by extracting a portion of the bottom soil with deposits. This is achieved using a test tube or a siphon, which is lowered to the bottom to suck up the silt. For quantitative analysis, micro-bentometers are used to obtain undisturbed sediment monoliths with a known cross-sectional area. Epiphytic algae are collected by carefully removing biofilms from a pre-measured wet mass of dominant macrophytes, such as *Salvinia natans* L. or *Potamogeton* L. species. Immediate field fixation of all samples is the final mandatory step to "freeze" the community structure, ensuring that the results accurately reflect the impact of the dam's daily regulation (Niepieina, 2010).

2.5. Microscopy and taxonomic identification

Laboratory analysis of the collected algal samples was performed using the method of direct light microscopy. Both live (non-fixed) samples, to observe natural coloration and motility, and fixed samples, for detailed morphological study, were examined. The microscopic analysis was conducted using a binocular light microscope equipped with a built-in illumination system (e.g., Biolam L-211).

The following magnification settings were utilized for visualization and identification: 4x/0.10 objective (tube length 160 mm, cover glass 0.17 mm) for general sample scanning and locating large forms; 40x/0.65 objective (tube length 160 mm, cover glass 0.17 mm) for detailed taxonomic identification and measurement of diagnostic features.

Taxonomic identification of species was carried out using specialized keys for freshwater algae (Topachevsky & Masyuk, 1984). Current nomenclature and systematic positions were verified according to the international electronic database AlgaeBase (Guiry & Guiry, 2026).

2.6. Taxonomic identification: Methods and discussion

The process of taxonomic identification of algal flora at the Sedniv SHP requires a synthesized approach that combines classical morphological analysis with modern nomenclatural updates. While the international electronic database AlgaeBase (Guiry &

Guiry, 2026) serves as the primary tool for verifying valid names and current systematic positions, it cannot fully replace the necessity of using regional "Keys to Freshwater Algae."

The discussion on the most effective identification methods highlights the importance of comparative morphological diagnostics. Classical keys, such as those by Topachevsky & Masyuk (1984) and the multi-volume series "Key to Freshwater Algae of the Ukrainian SSR," provide detailed descriptions of cellular structures, life cycles, and ecological preferences specific to the Polissya region. This is particularly crucial for identifying cryptic species or rare cryophytes found near the dam.

Furthermore, relying solely on electronic databases may lead to errors due to the lack of detailed illustrations for regional ecotypes. Therefore, the most reliable methodology involves a triangulation approach: initial identification based on classical morphological keys; verification of diagnostic features through high-resolution light microscopy; final nomenclatural synchronization via AlgaeBase (Guiry & Guiry, 2026).

This integrated strategy ensures high taxonomic accuracy and comparability of results with standard hydro-ecological monitoring protocols for river systems (Arsan et al., 2006).

2.7. Quantitative assessment and biomass calculation

The quantitative processing of microscopic algae is performed using a standard calculation method (Topachevsky & Masyuk, 1984) employing stamp-pipettes (0.1 cm³) and Goryayev counting chambers. To ensure comparability between different ecological zones of the Sedniv SHP, the abundance of algae in benthos and periphyton samples is calculated per 10 cm² of the substrate surface using the formula:

$$N = (10 \times n \times v) / s.$$

For epiphytic algae, the abundance is normalized to 1 g of the host plant's wet mass:

$$N = (10 \times n \times v) / P \text{ (Arsan et al., 2006).}$$

Biomass determination is carried out using the counting-volumetric method. This involves calculating the individual volume of each species using the stereometric method, where the cell body is equated to a specific geometric shape. The total raw biomass (**B**) is determined by the formula:

$$B = N \times P$$

where **N** is the abundance of the specific species and **P** is the average cell weight (mg).

2.8. Statistical analysis: Methodological requirements

To ensure the objective interpretation of hydrobiological data, the statistical processing of results must follow a rigorous analytical protocol. The comparative analysis of algal communities between upstream and downstream sections should be performed using software packages specialized in biological and ecological statistics (e.g., PAST: Paleontological Statistics or R-environment).

The methodological framework must include:

- biodiversity assessment :calculation of alpha-diversity indices to evaluate community complexity;
- Shannon-Wiener Index (H'): $H' = - \sum (pi \times \ln pi)$, where pi is the relative abundance of each species;
- Simpson Index (D): $D = \sum (pi^2)$, to determine dominance patterns;
- comparative floristic analysis: to quantify the "*dam effect*," it is necessary to apply similarity coefficients;
- Jaccard Index (I_j): $I_j = c / (a + b - c)$, where ' a ' and ' b ' are the number of species at two stations, and ' c ' is the number of common species;
- Sørensen-Dice Index: $I_s = 2c / (a + b)$, which allow for a formal comparison of species composition;
- multivariate analysis: the use of cluster analysis and non-metric multidimensional scaling is recommended to visualize the spatial and seasonal grouping of samples;
- environmental correlation: statistical significance of the differences should be verified using non-parametric tests, such as the Mann-Whitney U-test or Kruskal-Wallis test, due to the typically non-normal distribution of biological data (Arsan et al., 2006).

3. CONCLUSION

The developed methodological approach demonstrates that effective monitoring of algal dynamics near small hydropower plants on small rivers requires a synthesized analytical framework. First, the integration of geobotanical descriptions of macrophytes as a primary substrate for epiphyton is essential for understanding the spatial structure of algal communities under regulated flow conditions. Second, the implementation of a comparative spatio-temporal monitoring scheme (upstream vs. downstream gradients) across all seasons allows for a clear differentiation between natural successional shifts and the anthropogenic "dam effect."

The application of the counting-volumetric method and stereometric biomass calculation remains the most reliable tool for the quantitative assessment of primary producers in high-purity river systems. Finally, the proposed statistical framework, including biodiversity indices (H' , D) and similarity coefficients (I_j , I_s), provides a robust basis for the ecological certification and environmental management of regulated river basins. Thus, the refined methodology ensures high taxonomic accuracy and data comparability, serving as a standardized model for studying the structural and functional transformations of aquatic microflora in the vicinity of small-scale hydro-structures.

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