ABSTRACT

of the dissertation work of Zaparina Yelena
titled **«Study of biodiversity of higher aquatic and semi - aquatic plants of saline and soda lakes of Almaty region»** submitted for the academic degree Doctor of Philosophy (Ph.D), educational program «8D05108-Geobotany»

General characteristics of the work. The dissertation is dedicated to a comprehensive study of the biodiversity of higher aquatic and semi-aquatic plants in the saline and soda lakes of the Almaty region (Alakol, Sasykkol, Zhalanashkol, Balkhash, and Ushkol). The main focus is on identifying the taxonomic composition of higher aquatic plants in the studied lakes, as well as studying and identifying indicator species specific to saline and soda environments. Additionally, this work includes an analysis of the physical and chemical properties of the water and an examination of the soil composition in the coastal zones of the studied lakes.

The relevance of the Research. Translation: The study of biodiversity of higher aquatic and semi-aquatic plants in the saline and soda lakes of the Almaty region is an important task for monitoring within the framework of the sustainable natural resource management program. This research aligns with the Sustainable Development Goals (SDGs) No. 14 "Life Below Water" and No. 15 "Life on Land," particularly under the conditions of anthropogenic impact.

From an ecological perspective, saline and soda ecosystems are considered extreme habitats for higher aquatic and semi-aquatic plants. High mineralization and consistently high pH are the primary structuring factors that significantly influence the species diversity of vegetation. The adaptation of salt-tolerant plants (halophytes) and alkali-tolerant plants (alkalophytes) is facilitated by various mechanisms, including ionic compartmentalization, osmotic regulation, succulence, the activity of antioxidant systems, maintenance of redox reactions, and excretion of absorbed salts. These mechanisms enable halophytes and alkalophytes not only to survive under extreme conditions but also to complete their entire life cycle, whereas non-adapted plants perish.

Thus, high concentrations of salts and alkalis profoundly impact the species composition and structure of plant communities, leading to the dominance of specific plant species capable of adapting and thriving under such conditions. Understanding these changes allows us to predict the consequences of salinization and alkalinization of soils and water bodies and to develop strategies for biodiversity conservation in extreme environments.

In light of increasing environmental challenges, such as changes in salinity and alkalinity levels in water bodies, identifying and studying specific plant species that can serve as indicators of ecosystem changes is becoming increasingly relevant. Research aimed at identifying indicator species characteristic of saline and alkaline environments will facilitate the creation of effective monitoring and assessment methods for water bodies. Using such species as biomarkers can significantly simplify monitoring processes, allowing the assessment of water bodies' conditions without the need for specialized equipment and complex, costly analyses.

Thus, the study of biodiversity of higher aquatic and semi-aquatic plants in the saline and soda lakes of the Almaty region, as well as the identification of indicators of saline and alkaline environments, is a timely and essential task.

Object of the Study

Higher aquatic and semi-aquatic plants, water and soil.

Purpose of the Study

To examine the current state of biodiversity of higher aquatic and semi-aquatic plants in the saline and soda lakes of the Almaty region.

Tasks of the Study:

1. To investigate the physical parameters and chemical composition of water of saline and soda lakes of the Almaty region (Alakol, Sasykkol, Zhalanashkol, Balkhash, Ushkol);
2. To study the soil composition of the coastal zones of the investigated lakes;
3. To analyze the species diversity of higher aquatic and semi-aquatic plants in the soda and saline lakes of the Almaty Region.
4. To characterize the taxonomic composition of the identified higher aquatic flora and conduct an ecological analysis;
5. To identify indicator species among higher aquatic and semi-aquatic plants specific to saline and alkaline habitats.

Research methods

For the research, classical geobotanical and floristic methods were used, including the route-reconnaissance method. Water and soil sampling was conducted in accordance with GOST 17.1.5.05-85 and GOST 17.4.4.02-84 standards. To verify the reliability of the obtained data, modern statistical analysis methods and software tools were used (Past 4, Statistics 6, and ANOVA).

Scientific Novelty of the Research.

- For the first time, the current taxonomic composition of higher aquatic plants in three saline lakes (Alakol, Sasykkol, Balkhash) and two soda lakes (Zhalanashkol, Ushkol) has been clarified;

- For the first time, a comprehensive approach was applied to the study of Lake Ushkol, including physical and chemical water analyses, the examination of mechanical and agrochemical soil composition, and the study of higher aquatic and semi-aquatic plants;

- For the first time, it was proven that the species diversity of semi-aquatic plants in the lakes Alakol, Sasykkol, Zhalanashkol, Balkhash, and Ushkol is higher in alkaline habitats compared to saline ones;

- For the first time, as part of a large-scale geographical study, indicator species characteristic of saline environments were identified: *Juncus gerardi* Loisel., *Salicornia europaea* L., *Suaeda salsa* L.Pall and for soda (alkaline) environments: *Tripolium pannonicum* (Jacq.) Dobrocz., *Puccinellia dolicholepis* (V.I.Krecz.) Pavlov, *Suaeda physophora* Pall.

Theoretical Significance

The comprehensive approach of this study integrates taxonomic, ecological, and chemical analyses, enabling the identification of relationships between the physicochemical characteristics of water bodies, soil, and the distribution of higher

aquatic and semi-aquatic plants. This provides a deeper understanding of ecosystem processes, plant adaptation mechanisms to specific environmental conditions, and ecological interactions. It also establishes a new methodological foundation for further research on aquatic ecosystems, particularly under extreme conditions. The identification of indicator species for saline and soda lakes will enhance our understanding of the processes occurring within these ecosystems and their impact on biodiversity. The results obtained will form the basis for expanding our knowledge of higher aquatic and semi-aquatic plants in extreme environments.

Practical value of the work

The results obtained during the dissertation research can be used to develop strategies for the conservation of plant biodiversity and the sustainable management of water resources. The findings on higher aquatic and semi-aquatic plants can serve as a foundation for the development of "Hydrobotany" as an independent scientific discipline in Kazakhstan. The collected herbarium material can be utilized for practical training sessions for undergraduate, master's, and doctoral students at higher education institutions. The indicator species identified in this study can be used as biomarkers for monitoring the ecological condition of saline and soda lakes. This will help detect early changes in ecosystems and take timely measures for their protection. The indicator species of saline and soda environments can enable the rapid determination of soil and water body types through an express biomonitoring method based on visual observation, eliminating the need for expensive equipment and chemical laboratory analyses.

The main provisions of the dissertation submitted for defense:

- The current composition of higher aquatic plants (102 species) in three saline lakes (Alakol, Balkhash, Sasykkol) and two soda lakes (Zhalanashkol, Ushkol) has been determined, with the clarification of 13 tolerant species.

- The study identified factors positively influencing the diversity of semi-aquatic plants: pH and carbonates (CO_3^{2-}, HCO_3^-), and inhibiting factors: chlorine (Cl^-) and sulfates (SO_4^{2-}).

- Three indicator species for saline environments were identified: *Juncus gerardi* Loisel., *Salicornia europaea* L., *Suaeda salsa* L.Pall and along with three indicator species for soda environments: *Tripolium pannonicum* (Jacq.) Dobrocz., *Puccinellia dolicholepis* (V.I.Krecz.) Pavlov, *Suaeda physophora* Pall.

Connection with the plan of the main scientific work

The dissertation was conducted within the framework of grant-funded projects by the Ministry of Education and Science of the Republic of Kazakhstan: AP08856160 “Assessment of the ecological condition of unique soda and saline ecosystems in Kazakhstan” and AR19674623 “Innovative multi-spatial comprehensive approach to biomonitoring of saline ecosystems in Lake Alakol.” Scientific Supervisor: Inelova Z.A.

Main results and conclusions of the study. The results obtained during the research on higher aquatic and semi-aquatic plants in the saline and soda lakes of the Almaty region allow for the following conclusions:

1. The physical properties and chemical composition of water in saline lakes (Alakol, Balkhash, Sasykkol) and soda lakes (Zhalanashkol, Ushkol) were studied. The pH

levels in all water samples ranged from 7.5 to 10, indicating an alkaline water type. Salinity levels varied within the sub-hypo-meso-hypersaline range (1.3–526 g/L).
2. Analysis of soil samples from the coastal zones of the studied lakes showed that the pH levels in all samples were above 7, classifying all soils as alkaline. The water extract analysis revealed varying degrees of soil salinity. High salinity was characteristic of Lake Alakol, low salinity for Lake Sasykkol, medium salinity for Lake Balkhash, and non-saline soils were typical for the coastal zones of Lakes Zhalanashkol and Ushkol.
3. The flora of higher plants in Lakes Alakol, Sasykkol, Zhalanashkol, and the adjacent areas includes 288 species from 133 genera and 39 families. The flora of higher plants in Lakes Balkhash, Ushkol, and the adjacent areas includes 351 species from 189 genera and 45 families.
4. Taxonomic analysis identified 102 species of higher aquatic plants, belonging to 30 families and 42 genera. The highest index of hydrophytism was recorded for Lake Alakol (Ihd = 0.7) and Lake Balkhash (Ihd = 0.68). A comparison of species diversity across the five lakes did not reveal significant differences in the composition of higher aquatic plants. However, 13 tolerant species were noted. The highest diversity indices (Simpson, Shannon, Margalef, Menhinick) were recorded for Lakes Alakol and Balkhash, while the lowest were observed for Lakes Zhalanashkol and Ushkol. The identified higher aquatic plants were represented by two life forms: perennials (85 species) and annuals (17 species). An ecological analysis of macrophytes classified true aquatic plants into two types and three subtypes: Perennial polycarpics: rooted (87 species), free-floating (9 species). Annual monocarpics: rooted annuals (6 species).
5. For the first time, indicator plant species were identified, including for saline environments: *Juncus gerardi, Salicornia europaea, Suaeda salsa* and soda (alkaline) environments: *Tripolium pannonicum, Puccinellia dolicholepis, Suaeda physophora.*

Approbation of the work

The results of the dissertation have been presented and discussed at international scientific and practical conferences:

The International Scientific Conference of Students and Young Scientists "Farabi World" (2021–2024);

The international scientific-practical conference dedicated to "The 30th Anniversary of Kazakhstan's Independence: Aspects of Biodiversity Conservation" (Almaty, November 26, 2021);

The international scientific-practical conference "Problems of Desertification in the Republic of Kazakhstan and Their Solutions" (September 22, 2023);

- International Scientific Forum «Modern Trends in Sustainable Development of Biological Sciences» BIO Web of Conferences 100, 04015, 2024 , Almaty, Kazakhstan;

- International scientific and practical conference of young scientists: “The ideas of N.V. Pavlov through the eyes of a new generation of botanists”, dedicated to the 130th anniversary of the birth of academician Nikolai Vasilyevich Pavlov, 2024, Almaty, Kazakhstan;

- International Conference on Plant Biology and Biotechnology (ICPBB 2024), 3-6 June 2024, Almaty, Kazakhstan;

Publications

The main content of the dissertation has been published in 13 printed works, including 2 articles in international peer-reviewed journals with an impact factor, indexed in Scopus and/or Web of Science: 1 article published in a scientific journal with an impact factor according to JCR – 1.2 (Q3, 52nd percentile), 1 article published in a journal with an impact factor according to JCR – 1.6 (Q1, 96th percentile); 2 articles in publications included in the list of scientific publications recommended by the Committee for Quality Assurance in Education and Science (CQAES) of the Ministry of Education and Science of the Republic of Kazakhstan, 9 abstracts in the proceedings of international conferences.

The results of the dissertation research are partially included in the reports on scientific research projects AP08856160 and AP19674623.10 thesis in the International conference proceedings.

Personal contribution of the doctoral student consisted of data collection on the research topic, conducting the majority of theoretical and experimental studies, including analysis, interpretation, and presentation of the obtained results, preparation of manuscripts for publication, and writing the dissertation.

Volume and structure of the dissertation

The dissertation is presented on 156 pages and consists of sections including abbreviations and acronyms, introduction, literature review, materials and methods, results and discussion, conclusion, and a list of references comprising 196 sources, 112 of which are in English. The dissertation includes 35 tables, 47 figures, and 3 Appendices.