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MACROPHYTE DIVERSITY AND HABITAT SUITABILITY FOR *Hirudo orientalis* IN AZERBAIJAN'S FRESHWATER ECOSYSTEMS

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РАЗНООБРАЗИЕ МАКРОФИТОВ И ПРИГОДНОСТЬ МЕСТООБИТАНИЙ ДЛЯ *Hirudo orientalis* В ПРЕСНОВОДНЫХ ЭКОСИСТЕМАХ АЗЕРБАЙДЖАНА

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Abstract. Aquatic macrophytes are essential components of freshwater ecosystems and play a crucial role in maintaining suitable habitats for leeches (*Hirudinea*). This review evaluates the ecological significance of six common macrophyte species (*Elodea canadensis* Fraser ex Spach, *Ceratophyllum demersum* L., *Lemna minor* L., *Nymphaea alba* L., *Phragmites australis* (Cav.) Trin. ex Steud., and *Typha latifolia* L.) for leech distribution in Azerbaijan. Information was synthesized from international scientific literature, taking into account regional wetland conditions. Submerged macrophytes provide oxygen-rich microhabitats, floating species regulate light and temperature, and littoral vegetation offers substrate stability, breeding sites, and refuges. These functional groups collectively support habitat suitability for ecologically and medically important species, including *Hirudo orientalis*. The review highlights that macrophyte diversity and structural complexity, together with environmental conditions, are major determinants of leech distribution and long-term population stability in freshwater ecosystems of Azerbaijan.

Аннотация. Водные макрофиты являются важнейшими компонентами пресноводных экосистем и играют ключевую роль в поддержании подходящих местообитаний для пиявок (*Hirudinea*). В настоящем обзоре оценивается экологическое значение шести широко распространённых видов макрофитов (*Elodea canadensis* Fraser ex Spach, *Ceratophyllum demersum* L., *Lemna minor* L., *Nymphaea alba* L., *Phragmites australis* (Cav.) Trin. ex Steud. и *Typha latifolia* L.) в формировании и поддержании местообитаний пиявок в Азербайджане.

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Обобщены данные международной научной литературы с учётом региональных особенностей водно-болотных экосистем Азербайджана. Погружённые макрофиты формируют богатые кислородом микроместообитания, плавающие виды регулируют освещённость и температуру воды, а прибрежная растительность обеспечивает стабильность субстрата, места размножения и укрытия. Совокупность этих функциональных групп способствует формированию благоприятных условий для обитания экологически и медицински значимых видов, включая *Hirudo orientalis*. Подчёркивается, что разнообразие и структурная сложность макрофитов, наряду с экологическими условиями среды, являются важными факторами, определяющими распространение пиявок и долгосрочную стабильность их популяций в пресноводных экосистемах Азербайджана.

Keywords: aquatic plants, biodiversity, ecological functions, freshwater ecosystems, *Hirudo orientalis*, macrophytes

Ключевые слова: водные растения, биоразнообразие, экологические функции, пресноводные экосистемы, *Hirudo orientalis*, макрофиты.

Freshwater ecosystems are among the most sensitive and dynamic ecological systems in terms of biodiversity maintenance and ecosystem functioning. In Azerbaijan, these ecosystems - including rivers, floodplain lakes, irrigation canals, and wetlands of the Kura-Araz lowland, as well as mountain water bodies of the Greater Caucasus and subtropical wetlands of the Lankaran region - represent highly heterogeneous environments shaped by strong seasonal hydrological fluctuations and varying degrees of anthropogenic pressure. Within these systems, interactions between aquatic macrophytes and aquatic invertebrates constitute a key component of ecological stability. Azerbaijan has a rich and diverse plant diversity [3].

Macrophytes are fundamental structural elements of freshwater habitats, providing physical complexity, substrate availability, and refuge conditions for a wide range of aquatic organisms [17].

Recent studies have demonstrated that macrophyte diversity and structural complexity significantly influence the distribution patterns, population dynamics, and long-term stability of freshwater invertebrates [4].

In particular, structurally complex vegetation enhances habitat heterogeneity, thereby increasing the availability of ecological niches and providing protection against environmental stressors and predation [14, 15].

Leeches (*Hirudinea*) represent an ecologically important component of freshwater benthic communities and are widely recognized as bioindicator organisms for assessing aquatic ecosystem health [12].

In Azerbaijan, the Eastern medicinal leech (*Hirudo orientalis*) is included in the Red Book of Azerbaijan and is nationally assessed as Endangered (EN A2ac). The species has been recorded in freshwater habitats of the Karabakh, Mil–Mughan, Siyazan, Gabala, Lankaran region, Nakhchivan Autonomous Republic, floodplain lakes and oxbows associated with the Kura River, and the Lesser Gizilaghaj Bay. These habitats are typically characterized by shallow, weakly flowing waters with abundant aquatic vegetation, highlighting the close ecological relationship between medicinal leeches and macrophyte-rich freshwater ecosystems [10].

Previous studies have shown that the distribution of leeches is closely linked not only to physicochemical properties of water but also to the composition, abundance, and structural diversity of macrophyte vegetation [1].

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Different macrophyte groups perform distinct ecological functions: submerged plants provide surfaces for attachment, movement, and reproduction; floating plants regulate light penetration and thermal conditions; while emergent and littoral vegetation contributes to substrate stabilization and the formation of protected refugia. Despite this ecological importance, studies focusing on macrophyte–leech interactions remain limited, particularly in regional contexts such as the freshwater ecosystems of Azerbaijan. In Azerbaijan, previous regional investigations, particularly those conducted in the Kura–Araz lowland, have indicated a relatively high diversity of macrophyte communities in certain freshwater habitats. According to Musayev (2010), these structurally rich vegetation zones create favorable microhabitats that support the establishment and persistence of benthic invertebrate communities, including leeches. However, increasing anthropogenic pressure—such as irrigation expansion, river regulation, and wetland modification—has led to significant alterations in macrophyte structure and habitat continuity in many freshwater systems of the country [9].

Recent ecological studies emphasize that macrophytes function not only as habitat-forming organisms but also as “ecosystem engineers,” regulating nutrient cycling, trophic interactions, and overall ecosystem functioning in aquatic environments [5].

A decline in macrophyte diversity is therefore expected to reduce benthic invertebrate abundance, including Hirudinea, and to weaken ecosystem resilience. Additionally, contemporary research highlights the increasing impact of climate change, eutrophication, and anthropogenic pollution on macrophyte communities. Rising temperatures, altered hydrological regimes, and changes in water chemistry directly affect both macrophyte distribution and the structure of associated faunal communities, including medicinal leeches [18].

These effects are particularly pronounced in shallow and slow-flowing water bodies, which are the primary habitats of *H. orientalis*. At the same time, advances in molecular biomonitoring techniques, particularly environmental DNA (eDNA) approaches, have significantly improved the detection and assessment of freshwater biodiversity. These methods are especially valuable for monitoring rare, cryptic, or low-density species, including members of Hirudinea. Recent studies indicate that eDNA-based approaches provide higher sensitivity compared to traditional morphological methods and represent an important tool for evaluating the ecological status of aquatic ecosystems [13].

The aim of this study is to evaluate the role of different macrophyte groups in shaping the habitat structure of *Hirudo orientalis* and to synthesize their ecological functions based on international literature, with a particular emphasis on freshwater ecosystems of Azerbaijan.

Materials and methods

The present study was mainly conducted through a comparative analysis of international scientific literature. Numerous national and international sources related to macrophyte and leech relationships in freshwater ecosystems were investigated and methodically assessed during the research process. Studies investigating the ecological role of aquatic vegetation in the distribution areas, habitat, and population stability of leeches, especially representatives of the class *Hirudinea*. The literature review included scientific articles, ecological reports, hydrobiological studies, and biodiversity assessments published in peer-reviewed journals. Both classical hydrobiological approaches and recent ecological studies focusing on freshwater ecosystem dynamics, bioindicator organisms, and aquatic vegetation structure were considered in the analysis. In addition, regional studies conducted within the freshwater ecosystems of Azerbaijan, particularly in the Kura–Araz Lowland, were also included to compare local ecological conditions with international findings [2].

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During the study, macrophyte plants were studied in three main ecological groups according to the characteristics of their habitat: a) Submerged macrophytes - plant species that grow completely or mainly under water; b) Floating macrophytes - plant species that float freely or partially on the water surface; c) Emergent (littoral) macrophytes - plant species that are rooted in shallow water and whose aerial shoots extend above the water surface.

For more detailed studies, 2 main plant species that are considered ecologically important for each group were selected for study. At this time, attention was paid to the impact of the selected macrophyte plants on the complexity of the habitats, their contribution to the regulation of the oxygen regime, and their protective and shelter-forming functions in aquatic ecosystems. The study examined in more detail the role of macrophytes in the formation of habitats for the medically and ecologically important species Hirudo orientalis. Based on all the collected data, analyses were conducted to determine the ecological relationships between the distribution areas and habitats of various macrophytes and leeches [15, 16].

Results and Discussion

In freshwater ecosystems, macrophytes are not only a plant component but also one of the main ecological factors shaping habitat structure. In Azerbaijan, particularly in the Kura–Araz Lowland and southern wetland systems, macrophyte-dominated habitats play a key role in maintaining freshwater biodiversity and supporting benthic invertebrate communities. Various macrophyte groups regulate oxygen dynamics, create microhabitats, and provide refuge conditions for hydrobionts. In Azerbaijan, H. orientalis has been recorded mainly from shallow freshwater habitats rich in aquatic vegetation, including floodplain lakes, oxbows, marshes, and weakly flowing water bodies. According to the Red Book of Azerbaijan, the species is distributed in the Karabakh, Mil–Mughan, Siyazan, Gabala, Lankaran and Nakhchivan regions, where macrophyte-rich habitats constitute one of the principal ecological requirements for its survival. In this regard, macrophyte-driven habitat complexity is a key factor influencing their distribution and population stability.

Elodea canadensis Fraser ex Spach (*Hydrocharitaceae*) is one of the widely distributed submerged macrophytes in freshwater systems, particularly in artificial canals and slow-flowing water bodies in Azerbaijan. It forms dense underwater stands that create stable microhabitats for benthic organisms. In irrigation networks of the Kura–Araz Lowland, such vegetation is frequently associated with habitats where medicinal leeches occur. The species increases oxygen availability through photosynthesis and provides attachment surfaces for movement and cocoon deposition. Dense *Elodea* stands therefore enhance reproductive success of *Hirudo orientalis* by providing stable and protected substrates.

Ceratophyllum demersum L. (*Ceratophyllaceae*), although a rootless submerged macrophyte, forms complex three-dimensional structures in many stagnant and semi-stagnant water bodies of Azerbaijan, including floodplain lakes and irrigation ponds. These habitats are common in the Kura–Araz basin. Its dense structure supports microorganisms and small invertebrates, contributing to increased food availability for leeches. In addition, such structurally heterogeneous vegetation provides refuge from predators and stabilizes habitat conditions [8].

Lemna minor L. (Araceae) is a common floating macrophyte in eutrophic and slow-flowing freshwater systems across Azerbaijan, particularly in lowland canals and small ponds of the Kura–Araz and Lankaran regions. It forms dense surface mats that reduce light penetration and stabilize water temperature fluctuations. In many semi-natural irrigation systems, *Lemna*-covered habitats are frequently associated with high organic content and reduced flow conditions, which are favorable for medicinal leeches. These mats also enhance microclimatic stability and reduce predation risk.

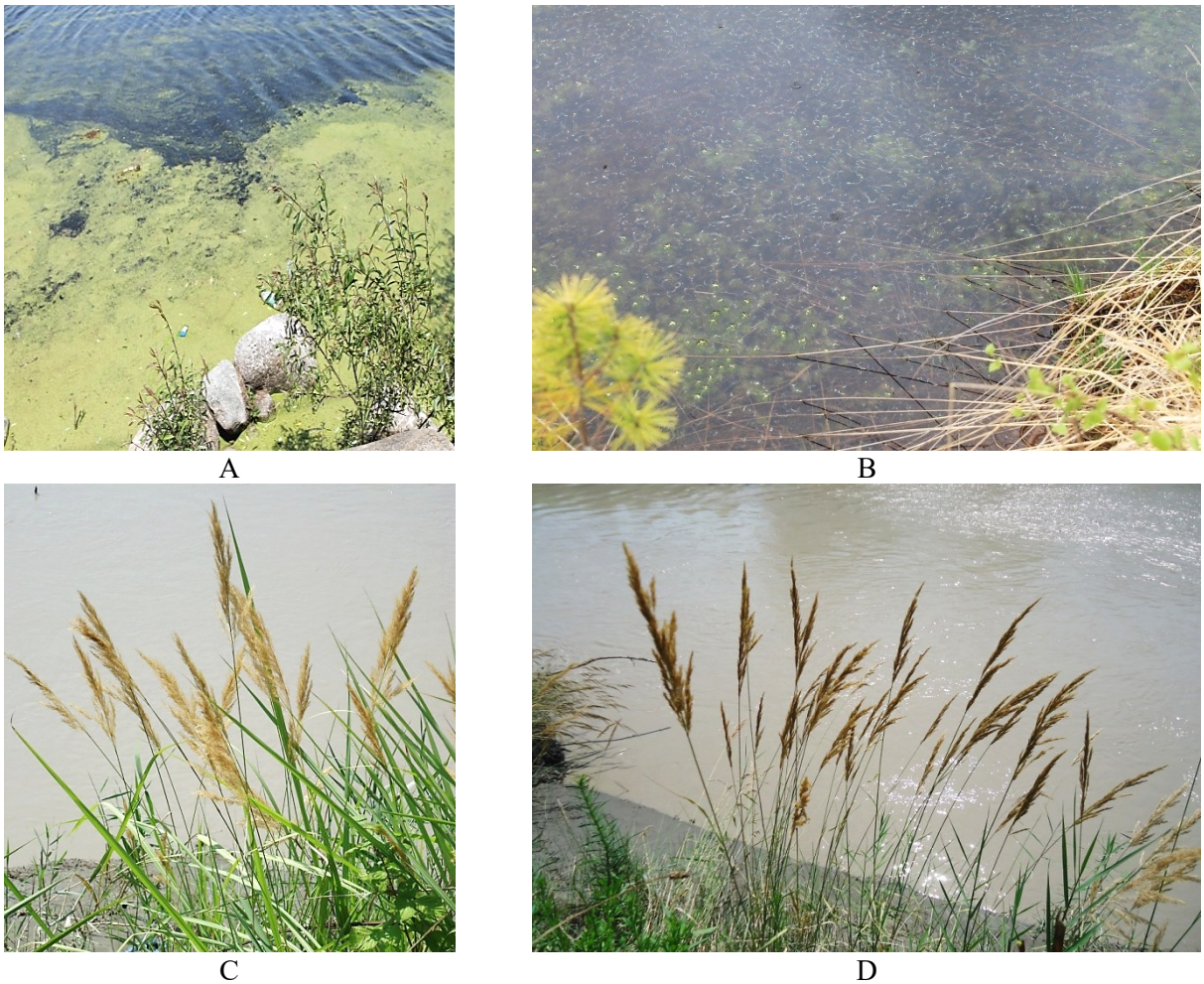
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Nymphaea alba L. (Nymphaeaceae) occurs in relatively stable freshwater bodies such as floodplain lakes and artificial reservoirs in northern and central parts of Azerbaijan. Its large floating leaves create shaded microhabitats that reduce thermal fluctuations. In such environments, medicinal leeches may benefit from increased habitat stability and reduced predation pressure. The root system of *N. alba* also supports colonization by invertebrate communities, enhancing overall habitat complexity.

Phragmites australis (Cav.) Steud. (Poaceae) is one of the dominant macrophytes in littoral zones of freshwater ecosystems across Azerbaijan, especially in the Kura–Araz lowland, Absheron reservoirs, and wetland margins of Lankaran and Greater Caucasus (Gabala and etc. districts). It forms extensive reed beds that stabilize sediments and reduce water flow velocity. In these regions, *Phragmites*-dominated habitats are strongly associated with organic matter accumulation and provide suitable conditions for medicinal leech populations. These reed beds also function as important refugia and breeding areas.

Typha latifolia L. (Typhaceae) is widely distributed in marshes and shallow water bodies of Azerbaijan, particularly in southern wetland systems and floodplain depressions. It contributes to the formation of muddy substrates with high organic content, which are commonly used by medicinal leeches for hiding and overwintering. Dense stands of *Typha* reduce predation pressure and increase habitat stability in shallow aquatic ecosystems.



A B C D

Figure. Macrophyte species of freshwater habitats: (a) *Lemna minor* (Lankaran district), (b) *Ceratophyllum demersum* (Lankaran district), (c, d) *Phragmites australis* (Gakh district)

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In Azerbaijan, freshwater ecosystems such as the Kura-Araz lowland wetlands, Lankaran floodplain systems, and selected foothill river valleys demonstrate a strong relationship between macrophyte diversity and benthic invertebrate communities. Medicinal leeches are particularly associated with structurally complex habitats dominated by mixed submerged, floating, and emergent vegetation [11].

Numerous studies indicate that in Azerbaijani freshwater systems, habitats with high macrophyte diversity support more stable populations of *H. orientalis*. This is primarily due to the presence of multiple functional vegetation types that simultaneously regulate oxygen availability, microclimatic conditions, and substrate stability. Submerged vegetation dominates oxygen dynamics, floating plants regulate light and temperature regimes, while emergent vegetation provides physical protection and breeding habitats. In the Kura-Araz irrigation network, structurally heterogeneous macrophyte communities create highly suitable microhabitats for leeches, whereas simplified or heavily modified systems show reduced suitability and lower population density.

Conservation significance and ecological implications

In Azerbaijan, the Eastern medicinal leech (*Hirudo orientalis*) is included in the Red Book of Azerbaijan and is nationally assessed as Endangered (EN A2ac). The species has been recorded in freshwater habitats of the Karabakh, Mil–Mughan, Siyazan, Gabala, Lankaran region, Nakhchivan Autonomous Republic, floodplain lakes and oxbows associated with the Kura River, and the Lesser Gizilaghaj Bay. These habitats are typically characterized by shallow, weakly flowing waters rich in aquatic vegetation, highlighting the crucial role of macrophyte communities in the survival of the species [2].

Freshwater ecosystems in Azerbaijan have undergone considerable anthropogenic transformation in recent decades. The regulation of river systems, expansion of agricultural activities, drainage of wetlands, pollution of water bodies, and uncontrolled harvesting of medicinal leeches have negatively affected habitat quality and population stability. According to available data, populations of *H. orientalis* have shown a declining trend during recent decades. The reduction of macrophyte diversity affects not only vegetation structure but also the ecological functioning of freshwater habitats. Loss of submerged, floating, and littoral vegetation leads to habitat simplification, decreases the availability of suitable breeding and shelter sites, and reduces habitat heterogeneity. Such changes may negatively influence feeding opportunities, cocoon deposition, overwintering success, and long-term population persistence of medicinal leeches [4].

Climate change represents an additional threat to freshwater ecosystems supporting *H. orientalis*. Increasing temperatures, altered hydrological regimes, and more frequent drought events may reduce water availability and accelerate the degradation of shallow lakes, marshes, and floodplain wetlands. These processes are particularly relevant for lowland freshwater habitats within the Kura–Araz basin and other regions where the species has been recorded [9].

From a conservation perspective, the protection of medicinal leeches should be closely linked to the conservation of aquatic vegetation and wetland ecosystems. Particular attention should be given to the preservation of macrophyte-rich habitats in the Kura floodplain lakes, the Lesser Gizilaghaj Bay, the wetlands of the Lankaran region, and other freshwater habitats known to support *H. orientalis* populations. Strengthening control over illegal collection, reducing anthropogenic pressures on aquatic ecosystems, and maintaining habitat quality are essential measures for ensuring the long-term conservation of this species in Azerbaijan.

Conclusion

The literature review conducted in this study demonstrates that macrophyte diversity and structural complexity are among the principal ecological factors determining the suitability of freshwater habitats for medicinal leeches. Submerged, floating, and littoral macrophytes perform

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complementary ecological functions, including oxygenation of water, regulation of microclimatic conditions, stabilization of substrates, and provision of shelter and breeding sites. Together, these plant communities create structurally heterogeneous habitats that support the survival and reproduction of leech populations. The available literature and regional data indicate that the Eastern medicinal leech (*H. orientalis*) is closely associated with shallow, weakly flowing freshwater ecosystems rich in aquatic vegetation. In Azerbaijan, the species has been recorded from the Karabakh, Mil–Mughan, Siyazan, Gabala, Lankaran, and Nakhchivan regions, as well as from floodplain lakes and oxbows of the Kura River and the Lesser Gizilaghaj Bay. The common ecological characteristic of these habitats is the presence of well-developed macrophyte communities, highlighting their importance for the persistence of the species [5]. As a nationally endangered species included in the Red Book of Azerbaijan, *Hirudo orientalis* faces increasing pressure from habitat degradation, wetland drainage, water pollution, hydrological alterations, and other anthropogenic impacts. The reduction of macrophyte cover and habitat complexity may negatively affect breeding success, shelter availability, and long-term population stability [1, 10]. Therefore, the conservation of *H. orientalis* should be closely linked to the protection and restoration of freshwater and wetland ecosystems. Maintaining macrophyte diversity in floodplain lakes, marshes, shallow ponds, and other vegetation-rich water bodies should be regarded as an essential component of conservation strategies for the species in Azerbaijan. Future studies should focus on detailed field-based assessments of medicinal leech habitats, mapping of macrophyte-rich freshwater ecosystems, long-term population monitoring, and the application of modern molecular and GIS-based approaches. Such research would improve our understanding of the ecological requirements of *H. orientalis* and provide a stronger scientific basis for its effective conservation and management in Azerbaijan.

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