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A survey of Odonata diversity in continental saltmarshes of Serbia

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Abstract

This study provides the first comprehensive survey of Odonata species in the continental saltmarshes of Serbia, focusing on three key locations: Lalinačka Saltmarsh Area, Aleksandrovačka Saltmarsh, and Bresničićka Saltmarsh. Over a single season from May to October 2023, 31 Odonata species were documented across these sites, representing 44.26% of the Odonata fauna recorded in Serbia. The research highlights the ecological significance of these areas, which are characterized by their unique halomorphic soils in both terrestrial and aquatic environments. Unfortunately, these areas are exposed to significant anthropogenic pressures, including agricultural expansion, waste disposal, and habitat fragmentation. Of particular note is the presence of *Coenagrion ornatum* (Selys, 1850), a species listed as Near Threatened in Europe and included in Annex II of the EU Habitat Directive and the Bern Convention. Despite existing protections, such as their designation as Natural Monuments and Protected Habitats, ongoing threats underscore the need for continued and expanded research efforts.

Keywords: dragonflies, damselflies, *Coenagrion ornatum*, continental saltmarshes, biodiversity, conservation, bioindicators, halomorphic soils.

Sažetak

Ovo istraživanje predstavlja prvi sveobuhvatni pregled vrsta vilinskih konjica (Odonata) na kontinentalnim slatinama Srbije, sa fokusom na tri ključne lokacije: Lalinsko slatinsko područje, Aleksandrovačka slatina i Bresničićka slatina. Tokom jedne sezone, od maja do oktobra 2023. godine, zabeležena je 31 vrsta vilinskih konjica na ovim lokalitetima, što predstavlja 44.26% faune vilinih konjica Srbije. Istraživanje naglašava ekološki značaj ovih područja, koja karakteriše prisustvo soli u zemljištu i vodenim telima. Nažalost, ova područja trpe jak antropogeni pritisak, koji se zasniva na širenju poljoprivrede, odlaganju otpada i dalju fragmentaciju staništa. Posebno je značajno prisustvo vrste *Coenagrion ornatum* (Selys, 1850) koja je na evropskom nivou klasifikovana kao gotovo ugrožen takson (NT) i nalazi se na Aneksu II EU Direktive o staništima, kao i na Bernskoj konvenciji. Uprkos postojećim režimima zaštite, kao što su proglašenje ovih područja za spomenike prirode i zaštićena staništa, prisutne pretnje naglašavaju potrebu za kontinuiranim i proširenim istraživanjima.

Ključne reči: Vilinski konjici, Kontinentalne slatine, Biodiverzitet, Konzervacija, Bioindikatori, Halomorfna zemljišta

Introduction

Continental (inland) saltmarshes most commonly occur in areas of former salt lakes and seas (ZZPS 2013). Halomorphic soils in northern Serbia, within the Pannonian Plain, are found within agricultural landscapes and in the former floodplains of major rivers: the Danube, Tisa, and Tamiš (Puzović & Panjković 2015), representing remnants of the Pannonian Sea. Saltmarshes are fragile and extremely endangered habitat types, characterized by the presence of specific flora and vegetation. Additionally, these habitats are known for their fragmented distribution, which means that species associated with them have highly fragmented ranges (Zlatković et al. 2005). South of the Sava and Danube rivers, such habitats occur only locally around Niš, Prokuplje, and Vranje. These continental saltmarshes represent relict habitats that develop under conditions of isolation and significant anthropogenic pressure (Zlatković et al. 2005; Nikolić & Ilić 2021) and differ in their origins, flora, and fauna from the Pannonian saltmarshes.

The formation of continental saltmarshes requires specific conditions, primarily the absence of natural drainage, meaning the area lies within a natural depression or an extensive flat plain with limited water runoff (Bjelić et al. 2014). During the formation of continental saltmarshes, salts originate from surface and groundwater, which transport the products of rock weathering, including soluble salts that accumulate in measurable concentrations (Zlatković 2021). Under the influence of climatic factors, chemical processes enable the gradual dissolution of salts within parent rocks, while surface and groundwater flows transport these dissolved salts to their places of accumulation (Luković 2019), in this case, to the saltmarshes. Salt accumulation in soil and water occurs under climatic conditions where evaporation surpasses the total annual water input (Miljković 1963).

Salt concentration increases as water volume decreases, particularly during the summer months when lower water levels result in higher salinity. In some saltmarshes or their sections, complete evaporation during this period may occur, leading to crystallization of salts on the soil surface (Boros 2003).

The differences are reflected in a phytogeographical sense, as continental saltmarshes host endemic plants such as *Stachys milanii, Camphorosoma monospeliaca* and *Allium guttatum* subsp. *dalmaticum*, and lack succulent halophytes characteristic of Pannonian saltmarshes (Zlatković et al. 2014; Luković & Šilc 2021). Also, other types of salt ions are present in these habitats, such as Na^{+} / HCO_{3}^{-}, and the pH value of the water is high (Lengyel et al. 2016). Due to their natural value, they are mainly classified as Important Plant Areas (IPA), Important Bird Areas (IBA), or as strictly protected Annex I habitat type under the EU Habitats Directive (1340 - Inland salt meadows). These ecologically important and fragile areas are also under national legal protection as Natural Monuments and Protected Habitats. Despite their ecological importance, the Odonata fauna of continental saltmarshes remains poorly studied.

The study of Odonata is of significant scientific importance due to their widespread distribution, ecological diversity, and sensitivity to environmental changes, making them

important bioindicators of ecosystem health (Corbet 2004; Oertli 2008) or impairment. They are sensitive to changes in water chemistry and environmental conditions, which can affect their survival and reproduction. As a result, monitoring Odonata populations can provide valuable information about the ecological condition of wetlands and certain specific aquatic habitats (Manu et al. 2023).

Given the significant role of Odonata as bioindicators, the study of their populations in the fragile and fragmented habitats of continental saltmarshes can provide critical insights into the ecological situation of these areas.

The aim of this study is to address this knowledge gap by conducting a comprehensive survey of the Odonata species present in these areas and compiling an odonatological checklist for each saltmarsh location.

Material and Methods

Study sites

Continental saltmarshes in Serbia, located outside the Pannonian Plain region, are found only in a few isolated areas near Niš, Prokuplje, and Vranje (Fig. 1).

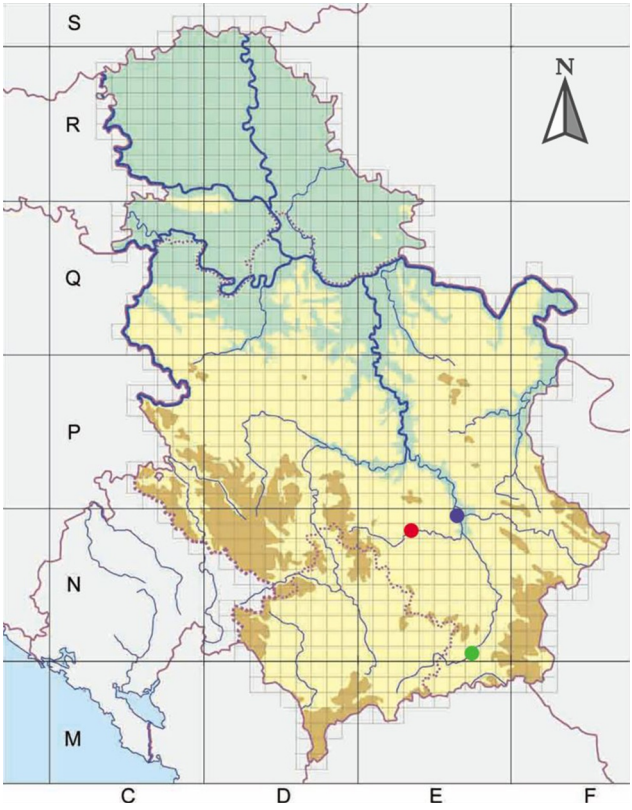

Figure 1: Locations surveyed from May to October 2023 (Aleksandrovačka saltmarsh – green, Bresničićka saltmarsh – red, Lalinačka Saltmarsh Area – blue) mapped in the grid system with precision of 10 km² (Serbia, Zone 34T), based on UTM projection.

Aleksandrovačka saltmarsh (42.488992°N, 21.903551°E) encompasses several smaller localities (Aleksandrovac, Oslare, Levosoje, Bujanovac, Strezovac, and Neradovac) (Fig. 2). Aleksandrovac saltmarsh is located several kilometers southeast of Vranje, in the Southern Morava valley. Today, only a small area of salt marsh vegetation has survived on the elevated eastern bank of an artificial lake (Fig. 3). Aleksandrovac Lake is an artificial reservoir constructed in 1964, with a dam height of 10 meters on the Aleksandrovačka River. It was intended for irrigating orchards and vegetable gardens in the valley of the Aleksandrovačka River, but over the past century, the lake has increasingly served recreational and fishing purposes, while its irrigation function has diminished alongside agricultural activities (Anonymous 2023).

Figure 2: Aleksandrovačka saltmarsh - small fragments of saline soil around Aleksandrovačko Lake with no bushes or reeds present on the banks (photo: Marko Nikolić).

Bresničićka saltmarsh (43.247666°N, 21.453940°E) developed in several fragments in the Toplica River valley, between Prokuplje and Kuršumlija (Fig. 4). Unfortunately, most of these fragments are small and highly degraded by agriculture and human negligence (waste disposal). They are mostly small surface belts in the alluvial plain of the Toplica, legally protected as a Protected Habitat (Official Gazette of the City of Prokuplje 3/2018).

The Lalinačka Saltmarsh Area (43.348311°N, 21.746491°E) developed in several locations at the foothills of Mali Jastrebac, where groundwater enriched with mineral salts emerges from deep within the substrate, forming halomorphic soils (Zlatković et al. 2005).

Figure 3: Aleksandrovačko Lake, an open and sunny habitat without shrubs or forested banks (photo: Marko Nikolić).

Figure 4: Bresničićka saltmarsh, a habitat that is deeply overgrown with reeds on all sides without open banks (photo: M. Nikolić).

These saltmarshes are collectively encompassed within the Lalinačka Saltmarsh Area, named after the largest and best-preserved one among them, the Lalinačka Saltmarsh (Fig. 5). The area was designated as a natural monument in 2015 (Official Gazette of the City of Niš 17/2015; 74/2015). This area is located in eastern Serbia, about ten kilometers northwest of the city of Niš. The Natural Monument Lalinačka Saltmarsh is situated on the river terraces on the left bank of the South Morava River, in the Dudulajska River

Figure 5: Natural Monument Lalinačka Slatina, a protected site within the Lalinačka Saltmarsh Area, canals and ponds as ephemeral water bodies without tall vegetation (photo: Marko Nikolić).

Figure 6: Oblačinsko Lake, the largest and deepest water body within the Lalinačka Saltmarsh region (photo: Marko Nikolić).

valley. This part of the Dudulajska River basin has several tributaries, with the Cerovak stream standing out due to its length (ZZPS 2013). Both the riverbed and the Cerovak stream bed have been deepened and regulated for the drainage of the saltmarsh, causing the salt from saline springs to be carried into the river flows and drying out saline and semi-saline hygrophilous habitats (ZZPS 2013). In areas where the deepening of the streambed has not been carried out, there are extensive waterlogged surfaces covered with reed (*Phragmites australis*) or saltmarsh fragments with zones of whitish soil (Zlatković et al. 2005).

Due to strong anthropogenic pressure, the vegetation of the saltmarsh has been degraded and devastated, yet various habitat types still form, providing suitable conditions for different representatives of the fauna. In addition to Lalinačka, this area also includes the Oblačinska (Fig. 6) and Lepajska saltmarshes.

Given that all continental saltmarshes in Serbia are situated within natural depressions, in addition to the described standing waters, small springs emerge on the slopes of the surrounding hills, forming short watercourses, typically several hundred meters or less, that flow into the saltmarsh basins. These watercourses support the development of a small number of dragonfly species that are less tolerant to salinity, along with species typical of running waters.

Field research

The research at all three saltmarsh areas was conducted from May to October 2023, over the course of 20 field days. During the research, the focus was placed exclusively on adult individuals (imagines). Specimens were observed, photographed, and captured with an entomological net before being released back into their habitat. Microsoft Office Excel was used for data storage and organization, while a handheld GARMIN eTrex Vista 10 GPS device (with an accuracy below 5 meters) was employed for precise georeferencing of data. Species identification was carried out using field guides (Đurđević et al. 2020; Dijkstra et al. 2020; Smallshire & Swash 2020).

Results

Field research yielded a total of 152 records across 31 documented species within 6 families (Lestidae, Calopterygidae, Platycnemididae, Coenagrionidae, Aeshnidae and Libellulidae). The highest number of species was recorded within the Lalinačka saltmarsh area (Lalinačka, Oblačina and Lepaja saltmarsh) with 25 species, followed by the Aleksandrovačka saltmarsh with 21 species, and the Bresničićka saltmarsh with 20 species (Table 1).

In the accompanying graph (Fig. 7), we see the representation of families across the surveyed locations. What stands out is the dominance of the family Libellulidae at all locations, with as many as ten Odonata species recorded in the Lalinačka Saltmarsh area. The least represented family is Calopterygidae, with one species (*Calopteryx splendens*) (Fig. 8) recorded at the Bresničićka Saltmarsh.

Discussion

The collected data represent the first published records of the Odonata fauna of continental saltmarshes in Serbia. Of the 70 odonate species recorded in Serbia (Đurđević

Table 1. List of recorded Odonata species by family and location.

Species	Aleksandrovačka saltmarsh	Bresničićka saltmarsh	Lalinačka saltmarsh area
Lestidae			
Chalcolestes parvidens (Artobolevsky, 1929)		♂ ♀	
Lestes barbarus (Fabricius, 1798)	♂ ♀ Tan	♂ ♀ Juv/Ten	♂
Lestes dryas Kirby, 1890	♂	♂ ♀	
Lestes virens (Charpentier, 1825)		Cop	♂
Sympecma fusca (Vander Linden, 1820)			♀
Calopterygidae			
Calopteryx splendens (Harris, 1780)		♂ ♀	
Platycnemididae			
Platycnemis pennipes (Pallas, 1771)	♂ ♀	♂ ♀	♂ ♀ Juv/Ten Cop
Coenagrionidae			
Ischnura elegans (Vander Linden, 1820)	♂ ♀ Cop	♂ ♀ Cop	♂ ♀ Juv/Ten Tan Cop Ovip
Ischnura pumilio (Charpentier, 1825)		♂ ♀ Juv/Ten Cop	♂ ♀ Cop Ovip
Enallagma cyathigerum (Charpentier, 1840)	♂		♂ ♀
Coenagrion ornatum (Selys, 1850)		♂	♂ ♀
Coenagrion puella (Linnaeus, 1758)	♂	♂ Juv/Ten Cop	♂ ♀ Cop
Coenagrion scitulum (Rambur, 1842)	Ovip		
Erythromma lindenii (Selys, 1840)	♂ ♀ Tan Ovip		
Erythromma viridulum (Charpentier, 1840)	♂ ♀ Juv/Ten Ex Tan Ovip		♂ ♀ Ovip
Pyrrhosoma nymphula (Sulzer, 1776)		♂ ♀	
Aeshnidae			
Aeshna affinis Vander Linden, 1820	♂	♂ ♀ Tan	♂ ♀ Cop
Isoaeschna isoceles (Müller, 1767)	♂ ♀ Ovip	♂	Ovip
Aeshna mixta Latreille, 1805			♂
Anax imperator Leach, 1815		♂	♂ ♀ Ovip
Anax parthenope (Selys, 1839)	♂		♂ ♀ Ovip
Libellulidae			
Libellula depressa (Linnaeus, 1758)	♂	♂ ♀ Ovip	♂
Orthetrum albistylum (Selys, 1848)	♂ ♀ Ovip		♂ ♀
Orthetrum brunneum (Fonscolombe, 1837)	♂	♂	♂
Orthetrum cancellatum (Linnaeus, 1758)	♂ ♀ Cop Ovip		♂ ♀ Ovip
Orthetrum coerulescens (Fabricius, 1798)	♂ ♀ Cop		♂
Sympetrum fonscolombii (Selys, 1840)	♂ ♀ Tan Ovip	♂	♂ ♀ Juv/Ten
Sympetrum meridionale (Selys, 1841)	♂ ♀ Ovip	♂ ♀	♂ Juv/Ten
Sympetrum sanguineum (Müller, 1764)	♂	♂	♂
Sympetrum striolatum (Charpentier, 1840)			♂ ♀ Cop
Crocothemis erythraea (Brullé, 1832)	♂ ♀ Cop Ovip	♂	♂ ♀

***Abbreviations used: ♂ – male(s), ♀ – female(s), MA – mature adult(s), Juv/Ten – juvenile(s)/teneral(s), Lar – larva(e), Ex – exuvia(ae), Cop/Tan – copula(e)/tandem(s), Ovip - oviposition.**

et al. 2024; Nikolić & Samardžić 2025), 31 species were documented in the continental saltmarshes during a single season (44.26% of Serbia's Odonata fauna). Considering that the research focused on adult specimens during 2023, it is likely that the actual number of species in these areas is somewhat higher, which warrants continued research over a longer period.

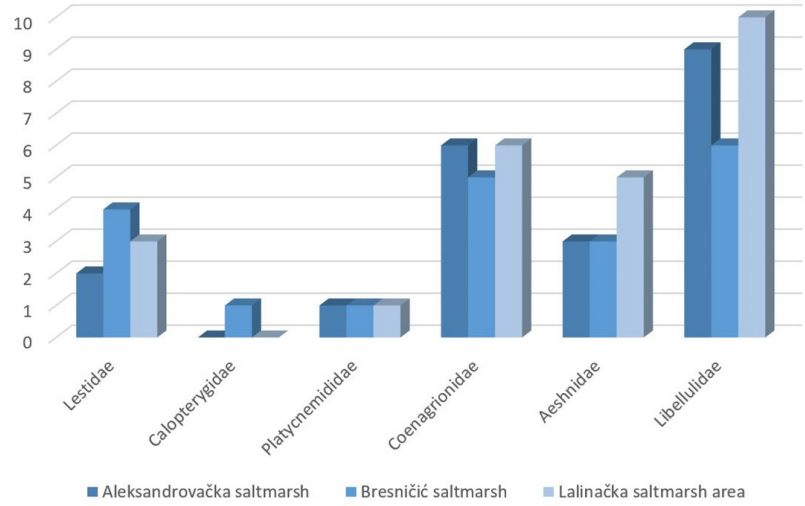

Figure 7. Overview of the recorded Odonata families across the surveyed localities.

Figure 8: *Calopteryx splendens* near banks of Bresničićka saltmarsh (the individual was photographed in front of the reed belt on the saltmarsh) (photo: Marko Nikolić).

Of the 31 species recorded across the studied saltmarshes, 12 were detected at all three sites: *L. barbarus, P. pennipes, I. elegans, C. puella, A. affinis, I. isoceles* (Fig. 9), *L. depressa, O. brunneum* (Fig. 10), *S. fonscolombii* (Fig. 11), *S. meridionale, S. sanguineum*, and *C. erythraea*. The Lalinačka Saltmarsh, which supports the highest species richness (25 species), harbors nearly half of these shared components. In comparison, the Bres-

Figure 9: *Isoaeschna isoceles* in flight over the water surface on Aleksandrovačka saltmarsh (photo: Marko Nikolić).

Figure 10. Male of *Orthetrum brunneum* perching on reeds at Aleksandrovačka saltmarsh (photo: Marko Nikolić).

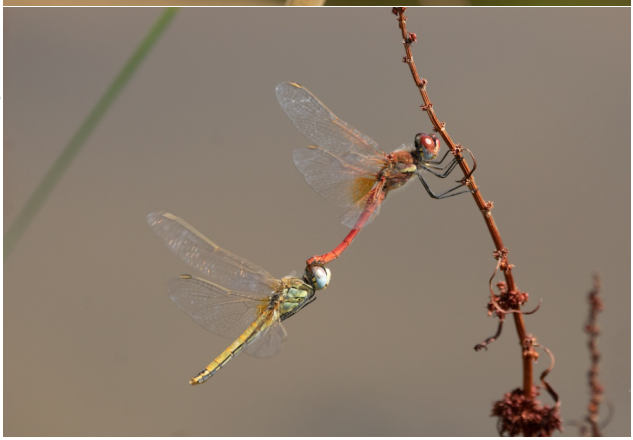

Figure 11: *Sympetrum fonscolombii*, tandem on Aleksandrovačka saltmarsh (photo: Marko Nikolić).

ničićka and Aleksandrovačka saltmarshes, with 20 and 21 species respectively, exhibit a slightly higher degree of overlap, accounting for more than half of their recorded fauna. Thus, approximately half of the faunal elements are shared among all three saltmarshes.

This trend is further reflected at the family level. The two most species-rich families are Coenagrionidae (9 species) and Libellulidae (10 species). Within Coenagrionidae, only two species occur across all sites, whereas within Libellulidae six species are shared among the saltmarshes. This pattern suggests that saltmarsh habitats in Serbia provide particularly favorable conditions for representatives of the family Libellulidae. It should be noted that *I. elegans*, a common element of the fauna across all three saltmarshes, represents an European species that is considered most tolerant of high salinity concentrations (Chovanec et al. 2023).

The mutual relationships between individual saltmarshes are quite different. The Aleksandrovačka and Bresničićka saltmarshes share 13 species in total, including one (*L. dryas*) that is not present in the Lalinačka Saltmarsh. The Bresničićka and Lalinačka saltmarshes share 16 species overall, four of which (*L. virens, I. pumilio, C. ornatum,* and *A. imperator*) are not recorded in the Aleksandrovačka Saltmarsh. The greatest similarity is observed between the Aleksandrovačka and Lalinačka saltmarshes, which share 18 species in total. In addition to the 12 taxa common to all three sites, these two habitats have six additional species in common (*E. cyathigerum, E. viridulum, A. parthenope, O. albistylum, O. cancellatum,* and *O. coerulescens*), corresponding to 18/21 species in the Aleksandrovačka and 18/25 species in the Lalinačka Saltmarsh.

Despite the observed overlaps and similarities, each saltmarsh harbors species that are, at present, unique to the locality. The Aleksandrovačka Saltmarsh contains two such species, *C. scitulum* and *E. lindenii*. The Bresničićka Saltmarsh supports three unique species: *C. parvidens, C. splendens*, and *P. nymphula* (Fig. 12). Similarly, three species were also recorded exclusively in the Lalinačka Saltmarsh: *S. fusca, A. mixta*, and *S. striolatum*.

Figure 12: *Pyrrhosoma nymphula* on the banks of Aleksandrovačka saltmarsh (photo: Marko Nikolić).

The occurrence of *C. scitulum* and *E. lindenii* in the Aleksandrovačka Saltmarsh is most likely linked to specific habitat requirements, as both species favor sunny waters with *Myriophyllum* sp. and elevated oxygen levels. These conditions are characteristic of this site, which is not surrounded by forest and has an extensive open-water surface.

The exclusive presence of *C. parvidens* in the Bresničićka Saltmarsh is attributable to the patch of shrubby vegetation along part of the water body, absent in the other habitats. *C. splendens* was likely recorded while dispersing from a nearby stream in search of food or mates. This site does not provide suitable breeding conditions, but the species occurs in high numbers along the stream. *P. nymphula* favors stagnant waters with dense aquatic vegetation, and the overgrowth of submerged plants in the Bresničićka Saltmarsh makes it an ideal habitat for this species. In the Lalinačka Saltmarsh, *S. fusca* was found in a small, isolated, but deeper water body, shaded and overgrown with rushes, a microhabitat absent from the other sites. *A. mixta*, also recorded only here, was most likely observed in flight while foraging. This behavior is typical of this migratory and wide-ranging species, but the site could nevertheless serve as a potential breeding ground. Finally, the presence of *S. striolatum* exclusively in the Lalinačka Saltmarsh can be explained by the predominance of small, shallow water bodies that warm rapidly during summer and by the species' tolerance for elevated salinity.

During the research, no nationally significant species listed in the annexes of the Rulebook on Declaration and Protection of Strictly Protected and Protected Wild Species of Plants, Animals, and Fungi (Official Gazette of RS No. 5/2010, 47/2011, 32/2016, and 98/2016) were recorded. However, at the international level, the most notable species in terms of threat and conservation is *Coenagrion ornatum* (Fig 13). Although this species is classified as Least Concern (LC) at the global level (Boudot 2014), it is considered

Figure 13: Female of *Coenagrion ornatum* at Lalinačka Saltmarsh (photo: Marko Nikolić).

Near Threatened (NT) in the Mediterranean Basin (Riservato et al. 2009). In Europe it was considered NT with a decreasing population trend (Kalkman et al. 2010), but with the last status revision (De Knijf et al. 2024) the status of the species was changed to Unthreatened. Additionally, this species is listed in Annex II of the EU Habitat Directive (Council Directive 92/43/EEC) and the Bern Convention, highlighting its international conservation importance. This species was recorded at the Lalinačka Saltmarsh and Bresničićka Saltmarsh, in the small streams that cross these areas, also highlighting the importance of these locations in international conservation efforts. Despite the existing protection regimes at these sites, designated as the Natural Monument Lalinačka Slatina and Protected Habitat Bresničićka Slatina, numerous threats were also observed during the research.

The Lalinačka Saltmarsh area is located between the fertile lands of the Jastrebac foothills, where the primary threat is the expansion of agricultural activities, particularly crop farming and vegetable cultivation (Zlatković et al. 2005). Over the years, the gradual expansion of agricultural lands has encroached upon portions of the saline soil, and in some cases, areas with typical saltmarsh vegetation have been plowed. The reclamation of these areas, specifically the attempts to channel water from saline springs into the South Morava River through small canal systems, has significantly dried out the saline and semi-saline hygrophilous habitats (Zlatković et al. 2005), which could endanger the Odonata fauna in this region.

Another major issue is the increasing occurrence of fires in this area, mostly caused by human negligence, such as the burning of crop residues and illegal dumping sites (Ilić 2023; Jovanović et al. 2024). Moderate-level threats include abandonment and improper land management, habitat fragmentation, and uncontrolled disposal of municipal and other waste (Zlatković et al. 2005; Drndarević 2014).

Another important site for this species is the Bresničićka Saltmarsh. Previously, there were also several saltmarsh fragments in the area between Prokuplje and Kuršumlija, in the alluvial plain of the Toplica River (Zlatković et al. 2022). Their soils barely exhibited any halomorphic characteristics, and the halomorphic flora and vegetation were subsequently destroyed. The saltmarsh near the village of Bresničić remains one of the better-preserved saltmarsh fragments (Zlatković et al. 2022).

A significant threat to this location is waste disposal, the discharge of municipal water affecting the physico-chemical properties of the water, and the burning of reed beds to reduce overgrowth. This saltmarsh is also situated between the highly fertile lands of the Jastrebac foothills, making the expansion of agricultural activities, particularly crop farming and vegetable cultivation, a high-level threat. Livestock grazing, though a somewhat lower-level threat, also poses a risk (Zlatković et al. 2005).

As mentioned above, the recorded number of species may be higher than expected. Since not every species is suitable for every season, they appear in varying numbers and can be easily overlooked. The same applies to stray species that occasionally inhabit these habitats for reasons that have nothing to do with reproduction. This is supported by the results of a two-year survey of Odonata in Austria on a similar habitat (saltmarsh) (Chovanec et al. 2023), where 30 species were recorded in the first year, 34 in the second, while 28 species were common in both years. Lalinačka and Aleksandrovačka saltmarsh are located very close to the corridors used by Mediterranean and

tropical species that are conquering new habitats in Serbia (Đurđević et al. 2024, Nikolić & Samardžić 2025), and therefore their presence on salt marshes also can be expected. It is necessary to conduct further multi-year studies of the Odonata fauna in these areas, with a particular focus on sampling exuviae and larvae at the sites, to confirm the reproduction of species in the locality. Monitoring this group at selected locations is of great importance due to their bioindicator capabilities, for example using the Dragonfly Biotic Index (DBI) (Simaika & Samways 2008) as a biological tool to assess freshwater habitat quality. The combination of their sensitivity to environmental changes and the specific conditions of continental saltmarshes makes the study of Odonata fauna not only relevant but essential for understanding the broader ecological dynamics and conservation needs of these endangered habitats. Immediate and sustained research efforts are crucial to ensure that these fragile ecosystems and their unique species are preserved for future generations.

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