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Data Paper

An update on the diversity and distribution of alien plant species along the Lower Danube River in Romania

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Abstract

The Danube is highly susceptible to biological invasions, as water is known to be the main vector for the spread and gateway to new areas of many alien plant species. By reviewing the specialized literature, supplemented by field research, we aimed to update previous knowledge regarding the diversity and distribution of alien plant species along the Lower Danube River in Romania. We identified a total of 240 alien plant species, of which 71 are invasive and nine are species of European Union concern (*Ailanthus altissima*, *Asclepias syriaca*, *Elodea nuttallii*, *Humulus scandens*, *Impatiens glandulifera*, *Ludwigia peploides*, *Reynoutria japonica*, *Reynoutria sachalinensis*, *Reynoutria* × *bohemica*). The most widespread taxa are *Ailanthus altissima*, *Amaranthus albus*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Amorpha fruticosa*, *Datura stramonium*, *Erigeron annuus*, *Erigeron canadensis*, *Juglans regia*, *Lycium barbarum*, *Medicago sativa* subsp. *sativa*, *Morus alba*, *Oxalis stricta*, *Phytolacca americana*, *Portulaca oleracea*, *Robinia pseudoacacia*, *Sorghum halepense*, *Xanthium orientale* and the taxa with the highest abundance are *Ailanthus altissima*, *Ambrosia artemisiifolia*, *Amorpha fruticosa*, *Robinia pseudoacacia*, *Xanthium orientale*. We also report five new species for the study area (*Delosperma cooperi*, *Impatiens balfourii*, *Impatiens parviflora*, *Opuntia* sp., *Ambrosia trifida*). With these results, we update the previously known situation of the alien plant species inventory along the Romanian sector of the Danube and make a valuable contribution to the knowledge of their current presence and distribution.

Key words: allochthonous, invasive, freshwater habitats, international river, vascular plants inventory

Introduction

Biological invasions continue to be the second cause of native biodiversity loss (Bellard et al. 2016; Fournier et al. 2019). Once they arrive in new territories, alien plant species (hereinafter referred to as APS) interact with the new environment and, if they overcome the biotic resistance and abiotic constraints, they might establish (Byun et al. 2018), and some might become invasive (Vitousek et al. 1997; Chytrý et al. 2005; Blackburn et al. 2014). In ecosystems where invasive alien plant species (hereinafter referred to as IAPS) become dominant, the effects on their functioning can

be "disastrous" (Richardson et al. 2007; van Oorschot et al. 2017; Pyšek et al. 2020) and the severity of the consequences of biological invasions imposes effective management measures to stop, limit or prevent reintroductions and dispersal (Mack et al. 2000).

With an area over 800,000 km^2, passing through the territories of 10 and collecting the tributary waters from 19 European countries, the Danube River has been designated "the most international river basin in the world" (Sommerwerk et al. 2010). Highly exposed to anthropogenic pressures and threats (Baltzer 2004), such an area has not remained devoid of APS, with numerous studies and research highlighting their presence and impact, the Danube being part of the European inland water network as one of the main gateways for biological invasions (Panov et al. 2010). Insights into alien flora along the Danube River Basin regarding terrestrial, semi-aquatic and aquatic habitats on riverbanks and islands have been provided by Drescher and Prots 2016; Wagner et al. 2020 (Austria); Kremer et al. 2006 (Croatia); Zelnik et al. 2020 (Slovenia); Jehlík et al. 2005, 2019 (Czech Republic, Slovakia); Alexandrov et al. 2007 (Ukraine); Ráth et al. 2003; Biró et al. 2008; Anđelković et al. 2016, 2020, 2022 (Hungary); Petrova and Vladimirov 2012; Petrova et al. 2013 (Bulgaria); Vukov et al. 2006; Tmušić et al. 2019; Petrović et al. 2021 (Serbia); Hinkov et al. 2020 (on the islands shared by Bulgaria and Romania along their common border), among others. Updated inventories of macrophytes along the Danube and its tributaries from upper, middle and lower sections (Janauer et al. 2018; ICPDR 2021b) revealed more than 33 APS (including IAPS), reconfirming that the Danube basin is strongly and continuously impacted by APS. Such results have required an initiative to develop the Danube Black List of APS, which would include both species of EU concern and species specific to the river basin (ICPDR 2021a).

Aquatic ecosystems, along with riparian areas, are known to be some of the most vulnerable and threatened natural habitats (Capon 2020). Connecting aquatic and terrestrial ecosystems, the riparian habitats play a vital role in the environment (Fu et al. 2022) by supporting rich biodiversity, influencing the local microclimate, protecting riverbanks against erosion, and generating goods and services for wildlife and local communities (Sala et al. 2000; Capon 2020). Many of these habitats are included in protected areas (hereinafter referred to as PAs), which are essential today in relation to natural habitats and rare species (Esina and Khapugin 2022), acting as natural filters in limiting or stopping the establishment and dispersal of APS (Pyšek et al. 2003; Foxcroft et al. 2011). However, worldwide, IAPS represent a major problem for PAs managers (Foxcroft et al. 2017; Pyšek et al. 2003). Globally, recent studies on PAs have highlighted 59 taxa considered as the most aggressive plant invaders (Foxcroft et al. 2017), of which six species are also found in Romania (Anastasiu et al. 2023a, b; Dumitrașcu et al. 2016).

Whether mediated by the anthropogenic factor or not, changes in natural, semi-natural and anthropogenic habitats in Romania have occurred in recent decades, enriching the flora with an increasing number of APS (Anastasiu et al. 2023a, c, 2024). The first reports of the presence of APS along the Lower Danube River in Romania (hereinafter LDRR) date back to the 19th century (e.g. Grecescu 1898; Heuffel 1858; Kanitz 1879–1881). After 2000, research was resumed, some of which was carried out in several PAs, among which the Iron Gates Natural Park (hereinafter IGNP) aroused particular interest for researchers (Anastasiu et al. 2005, 2014; Oprea et al. 2004, 2005; Lițescu et al. 2003, 2005; Sârbu et al. 2004; Doroftei 2009; Doroftei and Anastasiu 2014; Matacă 2005; Dumitrașcu et al. 2014; Boruz et al. 2022; Camen-Comănescu and Mihai 2022; Nagodă et al. 2023; Niculescu 2023; Niculescu et al. 2021, 2022, 2024). Most often, the research was localized and consisted of developing presence lists or studying specific taxa with very high frequencies and abundances or known to have negative impacts in natural habitats (Goia et al. 2014; Dumitrașcu et al. 2016; Grigorescu et al. 2020), highlighting the most common and dangerous species.

Through this study, we aimed to 1) provide an updated list of the diversity of APS and 2) update and assess the distribution of APS along the LDRR, to fill the knowledge gap in a geographical area less addressed by researchers. In order to prevent invasions, having the best possible knowledge of the current diversity and distribution of APS along the Danube will be an important addition to botanical research and a benefit to managers of PAs, stakeholders and policy makers in implementing effective management of APS.

Materials and methods

Study area

Our research area covers the middle section of the LDRR (on the left bank of the river), between the IGNP and the city of Brăila. We have divided this area into three sectors, according to the hydro-geomorphological characteristics of the landscape, namely Baziaș – Drobeta-Tn. Severin sector (hereinafter referred to as BDTS) – the gorges, Drobeta-Tn. Severin – Călărași sector (hereinafter referred to as DTSC) – the floodplain and Călărași – Brăila sector (hereinafter referred to as CB) – the ponds sector. Over this territory, the boundaries of Sites of Community Importance (SCIs), Special Protection Areas (SPAs), Special Areas of Conservation (SACs), RAMSAR sites and Natural Parks (corresponding to IUCN category V) overlap (Figure 1). In terms of administrative-territorial boundaries, the study area includes territorial units located in 10 counties (Caraș-Severin, Mehedinți, Dolj, Olt, Teleorman, Giurgiu, Călărași, Ialomița, Constanța and Brăila).

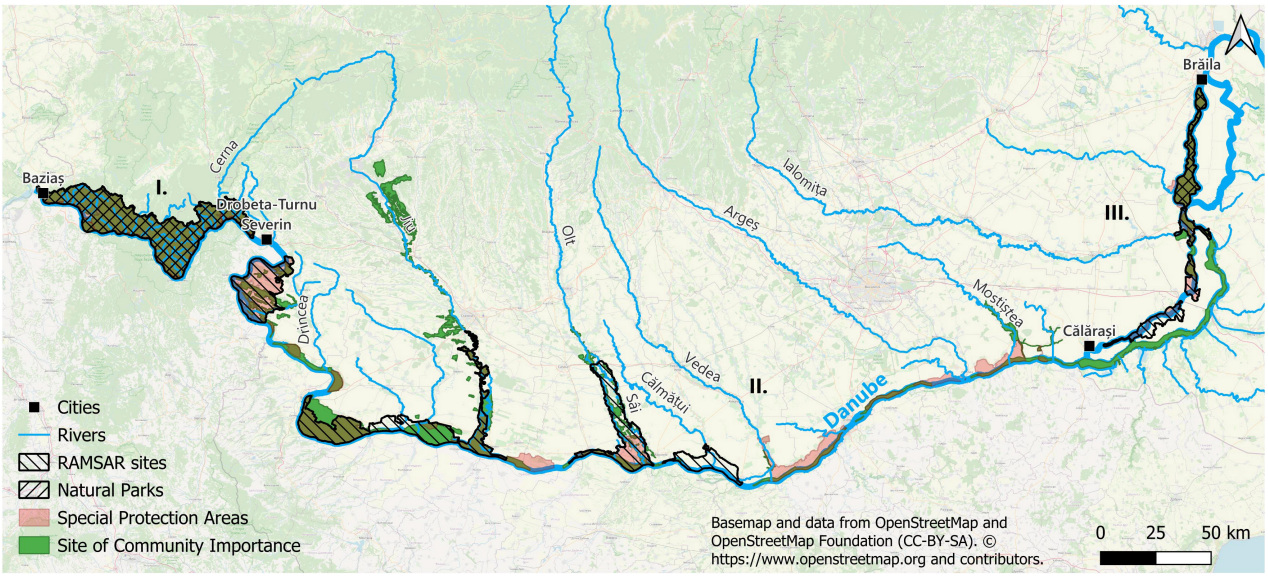


Figure 1. The area surveyed along the Lower Danube River in Romania, between Baziaș (entering the national territory) and Brăila.

Data collection

Distribution data were collected in two ways: 1) a review of the published literature (over 140 published and electronic bibliographic resources were identified and evaluated, with both historical and recent data e.g. Anastasiu et al. 2005; Boruz et al. 2022; Camen-Comănescu and Mihai 2022; Grecescu 1898; Hinkov et al. 2020; Lițescu et al. 2003, 2005; Matacă 2005; Nagodă et al. 2023; Niculescu et al. 2021, 2022; Oprea et al. 2004, 2005; Sîrbu and Oprea 2011; Urziceanu et al. 2022) complemented by 2) field surveys conducted along the left bank of the Danube between 2017–2024.

The recording of APS during the field surveys was carried out through inventory and mapping activities and consisted of recording the presence of species along the Danube by covering longitudinal and transverse transects between the bank area, the major riverbed and the terrace, within a 10 km radius to the north. The transverse transects were located in valleys (tributaries of the Danube), through which seeds and plant fragments could spread from the Danube or the other way around, and the length of the transects was the limit beyond which we did not record the presence of any APS. The presence data were recorded in forest habitats (mainly plantations), alluvial meadows, xerophilous and psammophilous grasslands and aquatic and riparian habitats of the Danube and its tributaries (e.g. Mraconia and Ribiș Valleys – Caraș-Severin County, Mala and Ogradena Valleys – Mehedinți County, Siliștioara Stream – Olt County, Sâi River – Teleorman County). The species were recorded with chorological names. For species reported for the first time in the study area, geographic coordinates were registered using the GPS Essentials (2022) and Gaia GPS (2024) mobile applications installed on the smartphone, in WGS84 system. The coordinates are provided in decimal degrees. The cartographic representation of the study area was created using QGIS software, version 3.40.

Data analysis

Taxon names were used following the Plants of the World Online database (POWO 2025). To clarify some taxonomic inconsistencies, we also consulted the Global Biodiversity Information Facility database (GBIF 2025) and Euro+Med PlantBase (2024).

In order to describe the APS recorded along the LDRR, the following attributes were analysed: family name, relative abundance, invasiveness status in Romania (according to Sîrbu and Oprea 2011; Anastasiu et al. 2019; Sîrbu et al. 2023), the European Union (EU) concern status (EC 2025; EU 2014), and the conservative status (according to Oltean et al. 1994; Dihoru and Negrean 2009). The relative abundance parameter was evaluated for the study area by establishing the relative level of abundance depending on the number of locations identified in the specialised literature, supplemented with field data. In order to perform this analysis, we used the following categories (adapted from Aymerich and Sáez 2019): SL (single location) – single reporting point, R (rare) – less than five known locations; S (scattered) – few locations (typically < 20) and locally scarce or locally abundant; C (common) – widespread and often locally abundant; V (vanished) – reported in one or more locations, but not found for over 50 years).

The results were presented graphically. The terminology for APS follows the recommendations of Richardson et al. (2000), Pyšek et al. (2004), and Blackburn et al. (2014).

Results

We identified 240 taxa distributed across 67 families, 162 genera, 224 species, 9 subspecies and 7 hybrids (Supplementary material Table S1). The most common genera belong to Asteraceae (44 taxa with a share of 65.7% of all families), Amaranthaceae (21 taxa; 31.3%), Poaceae (15 taxa; 22.4%), Fabaceae (13 taxa; 19.4%), Brassicaceae, Rosaceae and Solanaceae (9 taxa; 13.4%), Polygonaceae (7 taxa; 10.4%), Cucurbitaceae (6 taxa; 9%), Euphorbiaceae, Malvaceae, Plantaginaceae and Onagraceae (5 taxa; 7.5%) families. 32 families are represented by only one taxon.

The distribution of the 240 taxa along the LDRR, in each of the three sectors, is as follows: the highest presence was recorded for the BDTS sector – 185 taxa (77.08%), followed by the middle DTSC sector with 157 taxa (65.42%) and the CB sector where we identified the presence of only 109 taxa (45.42%) (Figure 2).

Five species are new reports for the study area, namely *Delosperma cooperi* (Hook.f.) L.Bolus (Moldova Veche locality, 44.722279N, 22.312922 E; Svinița locality, 44.5001986N, 22.1034128E; Dubova locality, 44.62160N, 22.26091E), *Opuntia* sp. (Svinița locality, 44.482172N, 22.152367E), *Impatiens balfourii* Hook.f. (Svinița locality, 44.5007694N, 22.1036177E; Dubova locality,

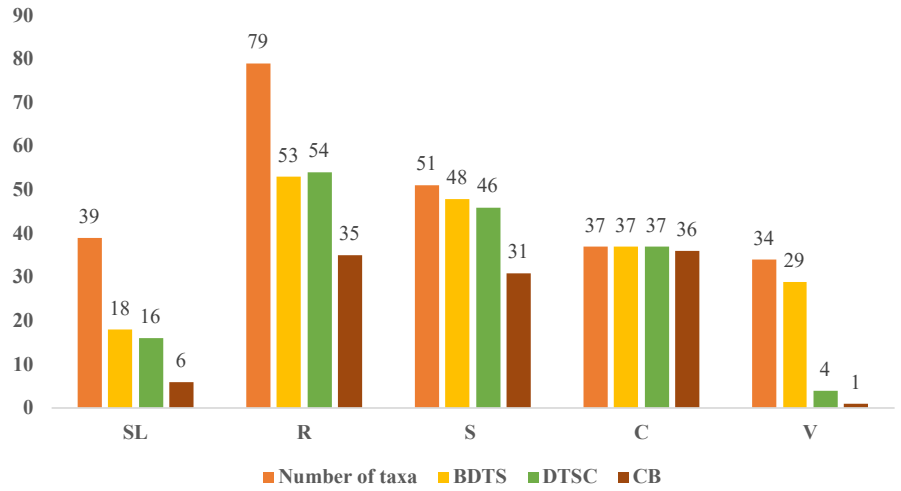


Figure 2. Relative abundance categories correlated with the distribution of taxa along the three sectors of the Lower Danube River in Romania (SL – single location, R – rare, S – scattered, C – common, V – vanished, BDTS: Baziaş – Drobeta-Tn. Severin sector, DTSC: Drobeta-Tn. Severin – Călăraşi sector, CB: Călăraşi – Brăila sector).

44.62303N, 22.25686E) (Caraş-Severin County), *Impatiens parviflora* DC. (Mraconia Valley, 44.674473N, 22.249071E; Mala Valley, 44.722279N, 22.312922E) (Mehedinți County) and *Ambrosia trifida* L. (Lake Suhaia, 43.692277N, 25.226853E) (Teleorman County).

Regarding the relative abundance, the category of rare species predominates (79 taxa; 32.92%), followed by species with scattered distribution (51; 21.25%), species mentioned in a single location (39; 16.25%), common species (37; 15.42%) and vanished species – not found for over 50 years (34; 14.17%) (Figure 2).

In terms of invasiveness status, of the total number of taxa, most species are casual (119; 49.6%), followed by invasive species (71; 29.6%) and naturalized species (50; 20.8%) (Figure 3). Of these, the most common are *Ailanthus altissima* (Mill.) Swingle and *Ambrosia artemisiifolia* L. for which we identified 98 locations, followed by *Amorpha fruticosa* L. with 96 locations, *Robinia pseudoacacia* L. with 94 locations, *Xanthium orientale* L. with 93 locations, and *Erigeron annuus* (L.) Desf. with 65 locations. These species are found throughout the study area, both within and outside the boundaries of PAs. Among the invasive species, nine taxa (8.45%) are revealed as species of EU concern.

Six taxa (2.5%) that have been assigned a conservation status are highlighted in the inventory of plant species along the LDRR.

Discussion

Diversity of alien plant species along the Lower Danube River in Romania

Our updated list of APS along the LDRR includes the current names (POWO 2025) of the 240 taxa recorded in the study area (Table S1). In relation to the total number of APS known in Europe (Kalusová et al. 2024),

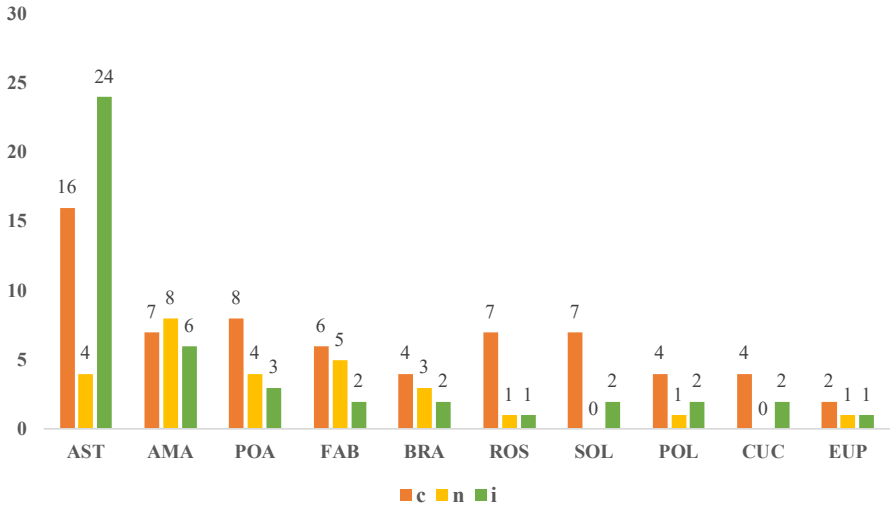


Figure 3. The ten richest families identified along the Lower Danube River in Romania and the invasiveness status of the specific taxa (AST – Asteraceae, AMA – Amaranthaceae, POA – Poaceae, FAB – Fabaceae, BRA – Brassicaceae, ROS – Rosaceae, SOL – Solanaceae, POL – Polygonaceae, CUC – Cucurbitaceae, EUP – Euphorbiaceae; C – casual, N – naturalized, I – Invasive).

our data represent 3.3% of the total. Compared to the most recent national assessments (Sîrbu and Oprea 2011; Anastasiu et al. 2020), the taxa on our list account for approximately one-third (35.75% and 31.29%, respectively).

Most taxa belong to four large plant families, namely Asteraceae (44 species), Amaranthaceae (21), Poaceae (15), Fabaceae (13). Globally, the main families to which APS belong are Asteraceae, Poaceae and Fabaceae (Pyšek et al. 2017), while in Europe the richest families in APS are Asteraceae, Poaceae, Fabaceae, Rosaceae and Brassicaceae (Kalusová et al. 2024). The most numerous families with APS on the national territory are Asteraceae, Poaceae, Amaranthaceae, Fabaceae and Rosaceae (Anastasiu et al. 2024). Comparing these data assessments with our results, we find that the patterns are maintained and there is a very high similarity in the main families that group naturalized species (Asteraceae – 29 species, Amaranthaceae – 14, Fabaceae – 8, Poaceae – 7 and Brassicaceae – 5) and invasive species (Asteraceae – 24, Amaranthaceae – 6 and Poaceae – 3). Among the families with low representation along the LDRR are Balsaminaceae, Euphorbiaceae, Onagraceae, Oxalidaceae and Plantaginaceae. However, it is worth noting that the Simaroubaceae and Phytolaccaceae families are the most prevalent in the studied area due to the frequent occurrence.

Distribution of alien plant species along the Lower Danube River in Romania

The most frequent APS along LDRR are *Robinia pseudoacacia*, *Ailanthus altissima*, *Ambrosia artemisiifolia*, *Erigeron canadensis* L., *Xanthium orientale*, *Erigeron annuus*, *Amaranthus retroflexus* L., *Amorpha fruticosa*,

Sorghum halepense (L.) Pers., *Acer negundo* L., which is consistent with the national situation (Anastasiu et al. 2022, 2023b, 2024). In a more detailed analysis, we identified 24 taxa in the study area that are among the 200 most widespread species in Europe (Pyšek et al. 2017) of which *Amaranthus retroflexus*, *Erigeron canadensis*, *Galinsoga parviflora* Cav., *Robinia pseudoacacia* and *Sorghum halepense* are frequent and very frequent and *Amaranthus viridis* L. and *Eleusine indica* (L.) Gaertn. are very rare. In contrast, the rarest species along LDRR is *Ambrosia trifida* (only one site). Of the total, in subspontaneous form, 12 taxa are known only from the study area (*Achillea ageratum* L., *Cercis chinensis*, *Chaenomeles japonica* (Thunb.) Lindl. ex Spach, *Ludwigia peploides* (Kunth) P.H. Raven, *Oenothera speciosa* Nutt., *Opuntia* sp., *Orobanche aegyptiaca* Pers., *Platanus* × *hispanica* Mill. ex Münchh., *Populus deltoides* subsp. *deltoides*, *Pteris multifida* Poir., *Pyracantha coccinea* M.Roem, *Symphoricarpos orbiculatus* Moench).

We emphasize that 34 taxa were not found in the study area during field surveys or when recent reports were reviewed (Anastasiu et al. 2024). These are species that have been cultivated mainly for ornamental (*Ilex aquifolium* L., *Tanacetum balsamita* L.) and food purposes (*Abelmoschus esculentus*, *Bunium bulbocastanum* L.), activities that have been abandoned over time and which have discontinued the presence of the species in the study area. Moreover, as they were no longer found in the field in recent decades, they were not included in the most recent floristic compendia (Ciocârlan 2009; Sîrbu and Oprea 2011; Sârbu et al. 2013). Therefore, we considered these taxa as vanished (*sensu* Aymerich and Sáez 2019) for the study area.

The analysis of the similarities in the presence/absence of the species, between the sectors within the study area, showed that the distribution of the taxa is very heterogeneous. Each of the three sectors of the LDRR has its particularities in terms of the degree of naturalness and the anthropogenic component, so that the distribution of APS varies as being more or less related to the site conditions and anthropogenic disturbances. Thus, the number of taxa is different in the three sectors (185 in BDTS, 157 in DTSC, 109 in CB). The first sector overlaps almost completely with the boundaries of the IGNP, and the presence of APS is directly related to the number of urban and rural settlements, tourism development and environmental interventions, in contrast to the other two sectors characterised by environmental interventions, where agriculture and forestry activities predominate. However, numerous taxa have been identified in natural habitats where human disturbance has favoured the invasion and spread of APS, such as *Ailanthus altissima*, *Erigeron annuus*, *Erigeron canadensis*, *Impatiens parviflora*, *Oxalis stricta*, *Phytolacca americana* L. or *Robinia pseudoacacia*.

In recent years, favourable climatic conditions and high levels of disturbance, as well as the current trends of increasing global warming (Walther et al. 2009), are causing new species to adapt outside of human-controlled frameworks. Thermophilic (e.g. tropical and subtropical) introduced species, escape, spread and tend to naturalize in a temperate continental climate with Mediterranean influences (Maslo 2016; CABI 2024). Some of these species are cultivated as ornamentals in Romania, but we have observed signs of escape of *Delosperma cooperi* and *Opuntia* sp. in small populations in IGNP (Caraş-Severin County). These records are new reportings for the LDRR area, together with *Impatiens balfourii*, *Impatiens parviflora* (found in a single point along Mraconia Valley, but in large numbers of individuals along the Mala Valley, Mehedinți County) and *Ambrosia trifida* (found in populations of dozens of individuals on the high banks of the Danube, near Lake Suhaia, Teleorman County).

Regarding the relative abundance of IAPS along the LDRR, 16 species are highlighted, among which the most abundant are *Ailanthus altissima*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Amorpha fruticosa*, *Erigeron annuus*, *Portulaca oleracea* L., *Robinia pseudoacacia*, *Xanthium orientale*. The species are found in both natural and anthropogenic habitats, inside and outside PAs.

At national level, the number of reported species of EU concern (EC 2025) is currently 13, of which nine species have also been identified along the LDRR: *Ailanthus altissima*, *Asclepias syriaca* L., *Elodea nuttallii* (Planch.) H.St. John, *Impatiens glandulifera* Royle, *Humulus scandens* (Lour.) Merr. and *Ludwigia peploides* (Anastasiu et al. 2017, 2024). *Humulus scandens* and *Ludwigia peploides* are recent additions to the alien flora of the LDRR (Sîrbu et al. 2021; Urziceanu et al. 2022) and, similar to *Asclepias syriaca* and *Elodea nuttallii*, have locally abundant populations, restricted to a few localities. Distinctively, *Ailanthus altissima* is a widespread species on the national territory (Anastasiu et al. 2024) and throughout the LDRR, while *Impatiens glandulifera* is frequent in the colder regions of the country (Sîrbu and Oprea 2011; Anastasiu et al. 2023a) and has only one location along the LDRR (Anastasiu et al. 2023a).

A distinctive feature of the taxa on our list is the conservation status assigned to several species. Some taxa, despite being alien, were considered rare by specialists, probably because of their low abundance and frequency on the national territory, which "determined" their classification in a category of vulnerability (e.g. rare, vulnerable, endangered, critically endangered): *Ammannia verticillata* (Ard.) Lam., *Azolla filiculoides* Lam., *Bryonia cretica* subsp. *dioica* (Jacq.) Tutin, *Glinus lotoides* L., *Polycarpon tetraphyllum* (L.) L. (Oltean et al. 1994; Dihoru and Negrean 2009). Moreover, one species (*Ilex aquifolium*) has been declared a natural monument (Ciocârlan 2009; Sârbu et al. 2013). These taxa are species reported mainly from natural habitats, but also from anthropogenic

habitats (Sîrbu and Oprea 2011). Only two species (*Azolla filiculoides* and *Glinus lotoides*) were still observed during field surveys along the LDRR, the rest of the taxa have not been reported in recent years in the study area.

Conclusions

This is the updated list of alien plant species identified along the Lower Danube River in Romania, a "fertile" territory for the establishment of new taxa, being an economically important area, in some parts in full rural development, with tourism and transport, which will entail the invasion and spread of (new) alien taxa (species already present or "expected" in Romania).

Our results make an important contribution to the knowledge gap of the diversity and distribution of alien plant species along the Lower Danube River in Romania. Such initiatives can be considered as a step forward in the early detection of new introductions, providing valuable information for both researchers and stakeholders regarding nature conservation and alien species management projects.

We further appreciate that an analysis of the characteristics of the alien flora in the study area is necessary to understand the mechanisms of dispersal and naturalization, in order to identify the most appropriate ways to reduce plant invasions along the Danube. We also emphasise the importance of continuing this specific research, as biological invasions represent a constant pressure and threat to aquatic and riparian ecosystems.

Authors' contribution

IMS: research conceptualization; sample design and methodology; investigation and data collection; data analysis and interpretation; ethics approval: not applicable; roles/writing – original draft; writing – review and editing. PA: research conceptualization; sample design and methodology; investigation and data collection; ethics approval: not applicable; funding provision: not applicable; writing – review and editing. TEȘ: research conceptualization; writing – review and editing.

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Ethics and permits

Permis cercetări (Research Permit), Regia Naţională a Pădurilor – Romsilva, Administraţia Parcului Natural Porţile de Fier R.A. (Administration of Iron Gates National Park), 000182.

Data availability

Species georeferenced records are available at the European Alien Species Information Network: https://easin.jrc.ec.europa.eu/easin/RJD/Download/97a49e58-fd25-48b9-8994-dc9026a001c3.

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Supplementary material

The following supplementary material is available for this article:

Table S1. List of the alien plant species distributed along the Lower Danube River in Romania, on the left bank of the river.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2026/Supplements/BIR_2026_Sirbu_etal_SupplementaryMaterial.xlsx