BioInvasions Records (2025) Volume 14, Issue 2: 361–374

Co-funded by the European Union

Rapid Communication

Invasive alien plant species of Union concern in the Lower Siret Floodplain Natura 2000 site (Romania)

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Citation: Patrascu LM, Melescanu GM, Stinga CA (2025) Invasive alien plant species of Union concern in the Lower Siret Floodplain Natura 2000 site (Romania). *BioInvasions Records* 14(2): 361–374, https://doi.org/10.3391/bir.2025.14.2.05

Received: 12 August 2024
Accepted: 4 March 2025
Published: 21 May 2025

Handling editor: Carla Lambertini
Thematic editor: Giuseppe Brundu

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Abstract

The increasingly negative impact of invasive alien species on ecosystem structure and function, biodiversity, health, and the economy has led to an intensification of efforts to control or eradicate these species. The growing threats from invasive alien species are well illustrated by the expansion of the List of invasive alien species of Union concern (EU Regulation 1143/2014), which has been updated three times since the initial list was adopted in 2016. The number of species included has risen from 37 in 2016 to 88 today. The most recent data from Romania indicate the presence of 10 of the 41 invasive alien plant species (IAPS) of Union concern in Romania. Among them, three species (i.e., *Baccharis halimifolia*, *Celastrus orbiculatus*, and *Heracleum mantegazzianum*) are records submitted through citizen science apps and not confirmed through peer-reviewed publications. To provide distribution data for IAPS of Union concern in an environmentally sensitive area, between 2022 and 2023, we sampled 166 terrestrial, aquatic and riparian plots from the Lower Siret Floodplain (Eastern Romania). We identified two IAPS Union concerns, namely *Ailanthus altissima* in 8 (5.63%) sample areas located predominantly on the left bank of the Siret River, in the sector between Movileni and Poiana (Galati), having the primary pathways of introduction Unaided (n = 4), Release in nature (n = 2) and Transport – Stowaway (n = 2), and *Elodea nuttallii* in one sample area near Movileni (Galati). We recommend further monitoring, focusing on areas already invaded or likely to be invaded, as well as the removal and replacement of IAPS species. Additionally, we suggest raising public awareness through educational campaigns, increasing the use of open data repositories by scientists, as well as advocacy for a more intense use of citizen science platforms for monitoring.

Key words: nature reserves, non-native plant species, protected areas, occurrence records, sampling, Siret River

Introduction

Invasive alien species are a subset of established alien species that spread and have a negative impact on the ecosystem to which they are introduced by altering ecosystem functioning, causing a reduction in the abundance or even extinction of native species, and having economic, social, health, or cultural impacts on human communities (Roy et al. 2023). The number of invasive alien species increased significantly after 1950 (Seebens et al. 2017; Groom et al. 2019) with substantial negative ecological, economic, and

social impacts (Peyton et al. 2020; Polce et al. 2023; Gallardo et al. 2024; Peller and Altermatt 2024). Worldwide, it is estimated that there are more than 3,500 invasive alien species known to have a negative impact, of which 1,061 (30.3%) are plants (IAPS) (Roy et al. 2023). In a recent review of inventories of alien plants in Europe, Kalusová et al. (2024) listed 740 alien plant species for Romania (excluding hybrids, cultivars, and species with uncertain alien status), of which 88 are considered invasive, 532 casual, 106 naturalised, and 14 with unknown status. Regarding the alien plant species pathways of introduction in Romania, Sîrbu et al. (2022) analysed 102 taxa, and identified "Unaided – by natural dispersal across borders" as the most important (31.3%), followed by "Escape from confinement – introduced for horticulture or ornamental purposes" (24.9%), "Transport – stowaway" (12.1%), "Transport – seed contaminant" (10.4%), "Escape from confinement – forestry" (9.8%), and "Escape from confinement – agriculture" (3.9%). Furthermore, the economic impact of invasive alien species in Europe is increasing. For example, a study of the costs incurred between 1960 and 2020 indicates a more than tenfold increase every decade, a total cost of $140.20 billion, of which $1.61 billion was reported for Romania (Haubrock et al. 2021).

At the EU level, EU Regulation 1143/2014 on invasive alien species and its list of invasive alien species of Union concern (i.e., invasive alien species are strictly regulated in all Member States) is the pillar of invasive species management. Since it entered into force in 2016 (Anastasiu et al. 2017), the list of species of Union concern has been regularly updated. In 2020, it included 66 species, of which 36 (54.5%) were invasive alien plant species. By 2023, the EU list included 88 species, of which 41 (46.6%) are invasive alien plant species (Anastasiu et al. 2024; European Commission 2024).

According to EU Regulation 1143/2014, Member States are required to monitor and manage the invasive alien species of Union concern and to provide reports to the EU every six years (Bara et al. 2022). So far, of the 41 invasive alien plant species of Union concern (European Commission 2022), 10 have been reported in Romania. Seven species (i.e. *Ailanthus altissima* (Mill.) Swingle, *Asclepias syriaca* L., *Elodea nuttallii* (Planch.) H.St.John, *Heracleum sosnowskyi* Manden., *Humulus scandens* (Lour.) Merr., *Impatiens glandulifera* Royle, and *Ludwigia peploides* (Kunth) P.H.Raven) were reported by the nationwide survey following the implementation of the EU Regulation on Invasive Alien Species (Sîrbu et al. 2021b; Anastasiu et al. 2024). In previous studies, two more species (*Cabomba caroliniana* A.Gray and *Myriophyllum aquaticum* (Vell.) Verdc.) were listed as present but not confirmed in the last few decades (Anastasiu et al. 2020, 2024; Sîrbu et al. 2021a). Three species were reported by citizen science groups (*Baccharis halimifolia* L. in Resita, Caras-Severin county, *Celastrus orbiculatus* Thunb. in Ciceu and Miercurea Ciuc, Harghita county, *Heracleum mantegazzianum* Sommier & Levier in Brasov, Sacele, Sinca Veche, Zarnesti, Brasov county, and Busteni, Prahova county) but not yet confirmed by peer-reviewed publications (iNaturalist 2022; Pl@ntNet 2022a, b).

Over the last two decades, the number of studies focusing on IAPS has started to rise, showing an increasing regional and national interest in the topic (Sîrbu and Oprea 2011; Ciocănea et al. 2018; Sîrbu and Şuşnia 2018; Şuşnia et al. 2020a, b; Sîrbu et al. 2021a, 2022, 2023; Anastasiu et al. 2024). However, most studies include occurrence reports and not an assessment of the entire plant community, which shows that there is a need for more studies on the impact on the plant communities. In the study area, between 1992 and 2000, Mohan (2001) collected occurrence data for 974 taxa from the Siret Floodplain, and Oprea (2021) studied the Tecuci Plain from 1992 to 1998, recording 1930 taxa. Regular surveys and monitoring of plant communities will contribute to better results in the pursuit of early detection, control, and eradication of alien species and offer valuable information regarding the impact on species composition and diversity, thus improving conservation strategies (Urziceanu et al. 2024). Early detection and regular monitoring are the most effective management methods, taking priority over direct control measures (Stănescu et al. 2020), and allow better knowledge of the effects of invasive alien species on biodiversity, health and the economy. To fill this gap, the aim of the study is to provide regional data on IAPS of Union concern to inform decision-making. The objectives were: (i) to identify and map IAPS of Union concern, (ii) to assess the pathways of introduction, (iii) to prioritise the invaded areas, and (iv) to provide specific management measures by sampling 166 terrestrial, riparian, and aquatic areas from the Lower Siret Floodplain Natura 2000 area and overlapping nature reserves.

Materials and methods

Study area

The study was carried out in the Natura 2000 site ROSPA0071 Lower Siret Floodplain and overlapped protected areas (ROSCI0162 Lower Siret Floodplain, ROSCI0072 Dunele de Nisip de la Hanul Conachi, RONPA0844 Lunca Siretului Nature Reserve, RONPA0428 Balta Potcoava Nature Reserve, RONPA0429 Balta Talabasca Nature Reserve, RONPA0419 Dunele de Nisip de la Hanul Conachi Nature Reserve, and RONPA0964 Padurea Merisor – Cotul Zatuanului Nature Reserve), to which a 100 m buffer was added (Figure 1A) (Ministerul Mediului Apelor și Pădurilor 2016, European Environment Agency 2022). The study area, located in south-eastern Romania, overlaps Bacau, Braila, Galati, and Vrancea counties and covers 417 km^2 (Figure 1B).

The area is located on the Siret River, the main watercourse flowing through, with a mean annual flow of 250 m^3/s (35 m^3/s min, 4,650 m^3/s max) at the Siret – Danube confluence, and part of the Siret River Basin, the largest in Romania (42,900 km^2) (Iojă et al. 2013; Salit et al. 2015). Specifically for the Lower Siret Floodplain, flat surfaces with low fragmentation

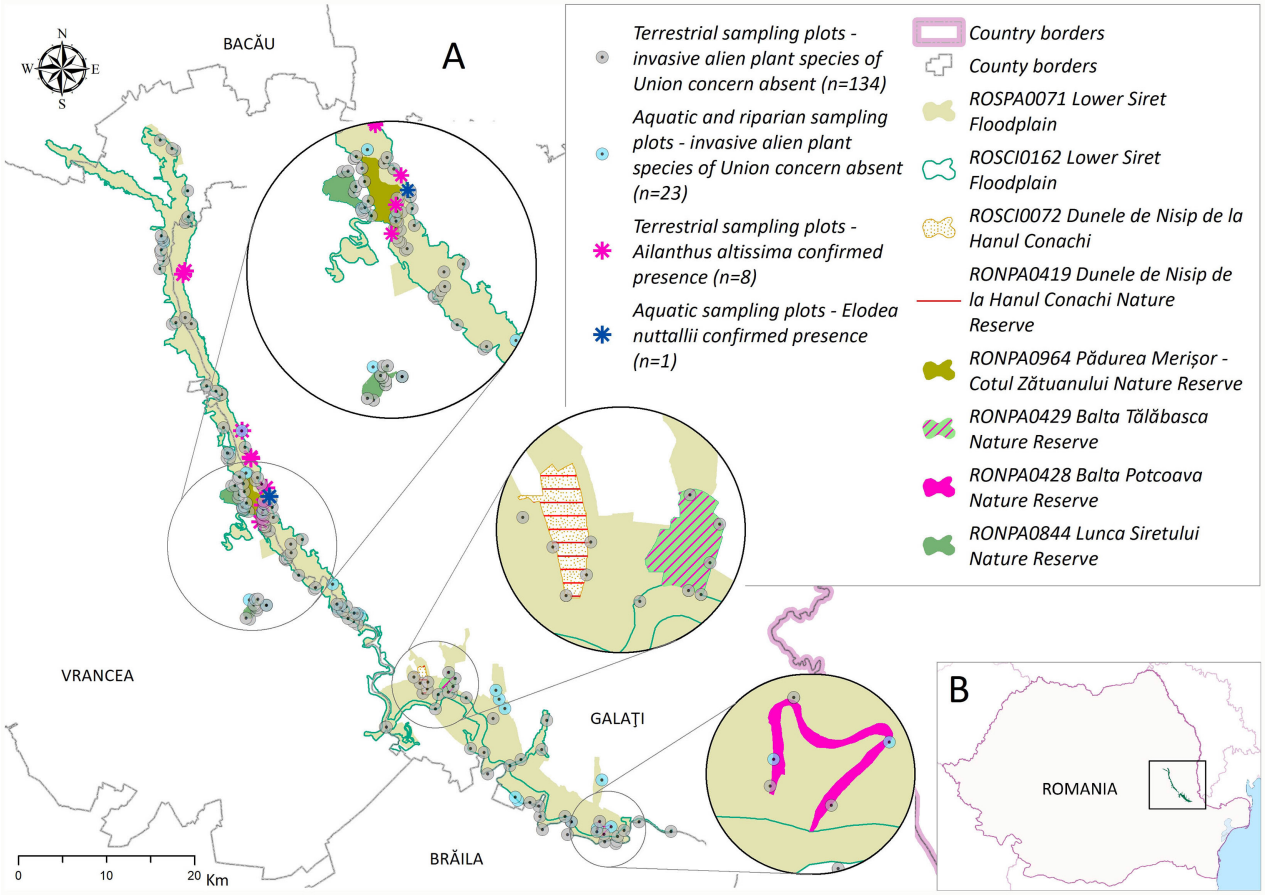


Figure 1. Locations of the sampled terrestrial, riparian and aquatic plots from the Lower Siret Floodplain Natura 2000 site (A) within Romania (B)

have facilitated the development of transportation infrastructure, leading to increased land use intensity and the development of potential pathways for invasive alien species (Harrower et al. 2020; Bara et al. 2022; Sîrbu et al. 2022).

The predominant soils are the unevolved soils of the Protisols class (85%), distributed along the Siret River, and on much smaller areas, Cernisols (9.9%), Hydrosols (2.6%), Salsodisols (1%), and Luvisols (0.4%) soil classes. The climatic characteristics are given by average annual temperatures ranging from 9.3 °C in the north to 11.1 °C in the south and annual rainfall ranging from 533–465 mm from north to south (Iojă et al. 2013).

Given the developed infrastructure and favourable environmental conditions, agriculture plays the main role in the local economy (Ministerul Mediului Apelor și Pădurilor 2016).

Occurrence sampling

We followed the sampling protocol used by Anastasiu et al. (2019), i.e., a total of 166 sampling plots (8 of 100 m^2, 41 of 150 m^2, 33 of 200 m^2, 35 of 250 m^2, 42 of 300 m^2, 3 of 350 m^2, and 4 of 400 m^2) relevant to the study area were purposely chosen in areas likely to be invaded, such as riverbanks, road and railway embankments, road intersections, illegal dump sites, undesignated campsites, grazing grounds near sheepfolds and forest edges.

These were divided into two categories: terrestrial sampling plots (142 sampling plots) and riparian and aquatic sampling plots (24 sampling plots). Due to limited resources (availability of personnel and vehicles), each plot was sampled once between December 2022 and May 2023, rather than during the typical period of June to October (Figure 1A). The terrestrial plots were sampled in December (n = 12), March (n = 44), April (n = 26), and May (n = 60) and the aquatic and riparian plots were sampled in December (n = 3), March (n = 4), April (n = 3), and May (n = 14).

The morphological characteristics of the identified species were compared with description sheets, which included identification keys (Pioarcă-Ciocănea et al. 2020a, b, c, d, e, f, g, h), literature (Tutin et al. 1968, 1972, 1976, 1980, 1993; Stace 2010; Sârbu et al. 2013), and World Flora Online (WFO 2022).

Survey data were collected in an electronic form adapted after the one recommended in the intensive sampling and mapping of hotspots and possible priority entry routes of alien species protocol (Anastasiu et al. 2019). The form was transposed onto the KoboToolbox platform and deployed for use during fieldwork with KoboCollect, an Android-based application that is free for nonprofit organisations to gather data in electronic forms (KoBo Toolbox 2023). The use of a standard form facilitated consistent data gathering, including the date of sampling, plot description, plot area, GPS coordinates, altitude, species, population size, plant phenology, type of dispersal, introduction pathways, and the presence of other species in each plot. The local pathways of introduction were identified based on the classification provided Harrower et al. (2020) and Arianoutsou et al. (2021).

Results

Of the 10 species of Union concern reported from Romania, only two were confirmed to be present in the Lower Siret Floodplain, namely *Ailanthus altissima* (Mill.) Swingle, and *Elodea nuttallii* (Planch.) H.St.John.

Ailanthus altissima was identified in eight (5.63%) of the 142 terrestrial plots sampled (Figure 1A, Supplementary material Table S1), where the main pathway of introduction was Unaided: natural dispersal (n = 4, all located close to Movileni, Cosmesti and Poiana villages in Galati county), followed by Release in nature: stabilisation and barriers (two sampling plots also on the left bank of the Siret River, at Cosmesti and Poiana villages in Galati county) and Transport – Stowaway: land vehicles (two sampling points, both in Vrancea county, near Biliesti and Vanatori villages). In seven out of eight sampling plots where *Ailanthus altissima* was observed, the population size was small (11–50 individuals), and only in one plot, near Radulesti village, in Vrancea county, *Ailanthus altissima* was very small (1–10 individuals).

During fieldwork, *Ailanthus altissima* was identified incidentally outside the sample areas, along secondary roads, on the outskirts of localities, inside abandoned or unkept households and in areas of uncontrolled waste disposal.

Table 1. Observable morphological characteristics of the 10 invasive alien plant species of Union concern reported in Romania outside of Spring–Autumn period.

Species	Plant type	Observable morphological characteristics		Observations
		Winter	Spring	–
Ailanthus altissima	tree	bark and fruits	bark and leaves	–
Asclepias syriaca	herbaceous plant	stems stouts and fruits	leaves	–
Baccharis halimifolia	shrub	stems and fruits	leaves	–
Celastrus orbiculatus	vine	vines and fruits	leaves	–
Elodea nuttallii	aquatic plant	–	stems and leaves	difficult to identify due to unfavourable timing of the study period
Heracleum mantegazzianum	herbaceous plant	stems stouts	leaves	–
Heracleum sosnowskyi	herbaceous plant	stems stouts	leaves	–
Humulus scandens	vine	–	leaves	difficult to identify due to unfavourable timing of the study period
Impatiens glandulifera	herbaceous plant	–	leaves	difficult to identify due to unfavourable timing of the study period
Ludwigia peploides	aquatic plant	stems and leaves	stems and leaves	difficult to identify due to unfavourable timing of the study period

Additionally, the species was observed in high abundance on the embankment of the railway line between Tudor Vladimirescu – Piscu (Galati county) and at the edge of the old cemetery in Piscu, Galati county.

Elodea nuttallii was identified in one sample area (Movileni, Galati county) out of 24 sampled (Figure 1A, Table S2).

All observations were submitted to the iNaturalist citizen science project and published on the Global Biodiversity Information Facility platform (GBIF) after confirmation as research-grade observations.

Discussion

Sampling of invasive alien plant species is usually carried out between June and October, but ours took place between December and May due to limited resources. Given the mild climate during the sampling period, with the exception of aquatic species, most alien plants of Union concern can be identified outside of Spring–Autumn period. Detecting *Humulus scandens* and *Impatiens glandulifera* during the winter months may have been hindered by the absence of observable morphological characteristics (Table 1).

Following the comprehensive investigation of the ROSPA0071 Lower Siret Floodplain Natura 2000 site between December 2022 and May 2023, we detected two out of 10 invasive alien plant species of Union concern reported from Romania, namely *Ailanthus altissima* and *Elodea nuttallii*, with only *Ailanthus altissima* in higher abundance.

The observed pathways introduction were Unaided: natural dispersal, Release in nature: stabilisation and barriers and Transport – Stowaway: land vehicles. Unaided: natural dispersal is a category that includes species dispersed naturally, without human intervention, from an area where they were introduced to an area where they were not present before. Release in nature: stabilisation and barriers is a pathway that includes species cultivated for their rapid growth in areas where wind reduction is needed for the protection of soil, agricultural products, or properties. Finally, Transport –

Stowaway: land vehicles was the category in which species were unintentionally transported by cars, trucks, or agricultural machinery to areas where they were not previously present.

Recent articles and reports provided regional occurrence data for *Ailanthus altissima* in Iron Gates Natural Park, Maramures Mountains Natural Park, Danube Delta Biosphere Reserve, Vacaresti Natural Park, Snagov Natural Protected Area, Lower Siret Floodplain, Macin Mountains Natural Park, Canaraua Fetii Natural Reserve, Gradistea Muncelului – Cioclovina Natural Park and for *Elodea nuttallii* along the River Danube, in the Danube Delta, Vacaresti Natural Park, Iron Gates Natural Park, Danube Borcea Arm, Brates Lake on Prut River and Prut at Vladesti – Frumusita Floodplain (Sîrbu et al. 2021a, 2022).

Sampling and data collection for terrestrial herbaceous species, trees and shrubs

Given the flat terrain, low fragmentation, and well-developed transport infrastructure in our study area, the sampled terrestrial plots were located in sites with high visibility. These characteristics were beneficial when recording terrestrial plant species.

On the right bank of the Siret River, an area where land is used for agricultural activities and mineral aggregate extraction, *Ailanthus altissima* was identified in sample areas near Biliesti village in low abundance, having been introduced unintentionally, through various anthropogenic and natural vectors. The highly developed road network in the area contributes to its high degree of anthropisation. The roads are heavily used, especially in the warm season, by amateur fishermen and tourists and for accessing natural resources. The sample areas near Biliesti village are located in habitats fragmented by roads, where changes in environmental characteristics are observed due to the edge effect (Primack et al. 2008). Thus, the introduction pathway of *Ailanthus altissima* observed in these plots was considered to be Transport – Stowaway: land vehicles.

In the Vadu Rosca (Vrancea county) – Cotu Mihalea (Braila county) Siret River sector, there is a clear functional separation between the boundaries of the localities and the protected area due to the presence of embankments and barriers. *Ailanthus altissima* was not identified in the sampled plots of this sector but at the edge of villages, planted on the boundaries of households. In this area, the embankments can limit the transport of invasive species both by blocking traffic where there are barriers (Gallardo et al. 2017) and by altering the local microclimate or if maintenance works are carried out (e.g. removal of vegetation from embankments).

On the left bank of the Siret River, *Ailanthus altissima* was identified in sample plots located between Movileni and Poiana (Table S1, Figure 1A).

However, the species is present in high abundance throughout the area, particularly at the edges of villages (Movileni, Furcenii Noi, Furcenii Vechi, Poiana) and within households, where it serves as a property boundary or as windbreaks on the limits of agricultural land. In this context, the pathway of introduction was Release in nature: stabilisation and barriers. In this area, the settlements are located on the Siret River terrace and border the Lower Siret Floodplain protected natural area at the terrace's edge. Sporadically, but present in the entire sector, the inhabitants use the top of the terrace, which is also the boundary between the localities and the protected area, to dump household and construction waste, thus creating the image of an unmanaged area with a high invasion risk.

The fact that the species is cultivated or tolerated in the localities bordering the protected area in this sector, combined with its ability to disperse samaras through anemochory, facilitates its dispersal. Additionally, the area's exposure to winds and its well-drained, sunny soils enable the species to spread from nearby settlements to the protected area (Enescu et al. 2016; USDA 2017). The species' dispersal is favoured in areas with a high wind gradient, with documented movement of the samaras over a 200 m distance over a pasture (Brundu 2017). The introduction pathway of *Ailanthus altissima* in these plots was classified as Unaided: natural dispersal. In the absence of management measures to eliminate *Ailanthus altissima*, additional populations may quickly develop, favouring the establishment of other invasive species and making habitats in the protected area vulnerable (Gallardo et al. 2017).

In sample plots close to water bodies (near Movileni, Furcenii Noi and Furcenii Vechi, Galati county), *Ailanthus altissima* can be dispersed via hydrochory. Studies have documented the dispersal of samaras over 20 days or over a distance of 1,200 m in three hours (Kowarik and Säumel 2008; Brundu 2017). Reproduction of the species can be sexual as well as vegetative, by vegetative sprouting (Anastasiu et al. 2019). The dispersal of stem fragments can also occur via hydrochory (Kowarik and Säumel 2008), making habitats in flood-prone areas vulnerable to invasions.

The sample areas in which *Ailanthus altissima* was identified do not overlap with habitats of Community interest (i.e. protected by the Habitats Directive). Still, the species is present less than 100 m from *Salix alba* and *Populus alba* galleries (92A0 Natura 2000 code, northeast of Radulesti, Vrancea county).

In terms of land use, we compared and validated the Corine Land Cover 2018 data (Copernicus Land Monitoring Service 2022) with the sampled plots. *Ailanthus altissima* was observed in pastures (37.5% of sample plots), followed by transitional woodland-shrub areas (25%), beaches, dunes, sands (25%) and non-irrigated arable land (12.5%). The eight plots do not overlap with areas where land use change was recorded between 1990 and 2018 (Copernicus Land Monitoring Service 2022).

Sampling and data collection for riparian and aquatic plant species

Elodea nuttallii was observed in a single sample area (Table S2) near Movileni (Galati), with an incidental observation of *Elodea canadensis*. During the study, we sampled areas from the central and southern parts of the study area (Figure 1A) due to logistical and accessibility constraints. Furthermore, the sampling of riparian and aquatic plant species in our study was impacted by the unfavourable timing of the study period (December 2022 to May 2023), which may result in an underestimation of the distribution of this species in the Lower Siret Floodplain. To obtain a better overview of the distribution, it is recommended that the aquatic sample plots be supplemented mainly in the north and south of the study area and resampled annually between June and November. Data can be complemented by consulting recreational fishermen and stakeholders who are often knowledgeable about the area and aquatic invasive alien species.

It is recommended that the species *Ailanthus altissima* be removed and replaced with native ones specific to the habitats of the Lower Siret Floodplain. To achieve good results, it is advised to use an integrated control strategy, that aims to apply effective eradication measures, monitors the effectiveness of the measures, and adapts them according to the results obtained, as well as carrying out awareness campaigns in all the localities bordering the protected area. Management measures should prioritise the removal of large trees to limit the dispersal of samaras to non-invaded areas (USDA 2017), application of EU-approved herbicides in non-sensitive areas, and include actions to limit disturbance in habitats likely to be invaded (EPPO 2019).

Awareness campaigns play a very important role because they can be the most effective and cheapest way of limiting the distribution of the species. Considering the large surface area of the study site, early detection and monitoring of alien plant species could be greatly aided by engaging weekend tourists, fishermen, residents of nearby localities, ecologists, and biologists in the use of citizen science platforms, such as iNaturalist (Groom et al. 2019; Meeus et al. 2023; Pernat et al. 2024), requiring much fewer human and financial resources.

Monitoring can be done with standard methods, such as sampling and mapping with reduced data collection effort or intensive sampling and mapping for assessing the impact of species (Anastasiu et al. 2019). It can also integrate UAV platforms and plant identification applications using machine learning methods (Brundu 2017; Hart et al. 2023; Naharki et al. 2024). The use of UAV platforms could yield very good results in the sector between Movileni and Poiana and the railway section between Tudor Vladimirescu and Piscu because the populations of *Ailanthus altissima* are large, compact and sometimes located in hard-to-reach areas. Areas like the ones we sampled are highly suitable for pre-planned UAV surveying missions of terrestrial plots, as they allow consistency of measurements between visits when assessing land changes, presence, and invaded surfaces.

Conclusions

Between December 2022 and May 2023, we sampled 166 terrestrial, aquatic and riparian plots and identified only two of the 10 invasive alien plant species of Union concern reported in Romania, namely *Ailanthus altissima* and *Elodea nuttallii*. Out of the 142 terrestrial plots, we recorded *Ailanthus altissima* in eight (5.63%) of them. Most plots (n = 6) were located on the left bank of the Siret River, close to Movileni, Cosmesti, and Poiana in Galati County, while the other two plots were near Biliesti and Vanatori in Vrancea County. The identified pathways of introduction were Unaided: natural dispersal (n = 4), Release in nature: stabilisation and barriers (n = 2) and Transport – Stowaway: land vehicles (n = 2). Due to undersampling in some areas, technical difficulties, and the timing of the study, we identified *Elodea nuttallii* in only one plot, on the left bank of the Siret River, near Movileni (Galati county). It is recommended that an integrated control strategy aimed at implementing effective IAP eradication/control measures be implemented in the region, as well as regular surveys of the entire plant diversity, adaptation of the measures, and awareness campaigns.

Authors' contribution

LMP: research conceptualization, sample design and methodology, investigation and data collection, data analysis and interpretation, writing and review of the original draft, GMM: investigation and data collection, CAS: investigation and data collection.

Acknowledgements

The authors thank Laurentiu Rozylowicz, the journal editors Giuseppe Brundu and Carla Lambertini and anonymous reviewers for their valuable comments and suggestions, which greatly contributed to the improvement of the original manuscript.

Funding declaration

Publication of this study was partly supported by the European Union's Horizon Europe HORIZONCL6-2024-BIODIV-01 project "GuardIAS - Guarding European Waters from IAS", under grant agreement no. 101181413 (Katsanevakis et al. 2024).

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Supplementary material

The following supplementary material is available for this article:

Table S1. Results of sampled terrestrial plots from Lower Siret Floodplain Natura 2000 site.

Table S2. Results of sampled aquatic and riparian plots from Lower Siret Floodplain Natura 2000 site.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2025/Supplements/BIR_2025_Patrascu_etal_SupplementaryMaterial.xlsx