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Short communication

First record of *Pistia stratiotes* L. (Araceae) in Croatia, with the consideration of possible introduction pathways

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Abstract

Background and Purpose: *The species* Pistia stratiotes *L. (Araceae) is South American (or pan-tropical) free-floating, aquatic macrophyte, present on all continents, except Antarctica, today. In Europe it occurs occasionally and casually in many countries, but it is established only in thermally abnormal waters in Slovenia, France and Germany. Although it was found in different European countries, even in Slovenia, it has never been recorded in Croatia.*

Materials and Methods: *Floristic research in the Sava-Strmec Special reserve (Zagreb County) was carried out during autumn (September and November) of 2017. Position of investigated localities was recorded with GPS Receiver.*

Results: *The species* Pistia stratiotes *was firstly recorded on 9th September 2017 on one locality in the Sava-Strmec Special reserve (Zagreb County). On 24th and 27th November 2017 several other localities in the vicinity were found. On each locality a small colony of plants was found. Although exact introduction pathway is not known, several possible pathways were taken into consideration and discussed.*

Conclusion: *A first record of the macrophyte* Pistia stratiotes *for Croatia is reported here. For now, it should be treated as a casual alien species.*

INTRODUCTION

Pistia stratiotes L. belongs to the monospecific genus within the Araceae family. It is a free-floating, aquatic macrophyte with leaves in rosettes. Leaves are sessile, obovate to spatulate, and short-haired, with a light green upper side, and an almost white underside. Roots are numerous and feathery (1).

It is a stoloniferous plant that reproduces vegetatively via stolons which are formed in the axils of bottom leaves. In this way small colonies consisting of the mother plant with attached daughter plants are formed. Daughter plants can detach from the mother plant, and form new stolons with their own daughter plants (2). Besides vegetative reproduction, *P. stratiotes* also reproduces sexually (by seeds). It mostly occurs only in tropical and subtropical regions, although viable seed production was also observed in Europe (e.g. Slovenia; 3).

P. stratiotes occurs in different freshwater habitats, such as lakes, ponds, reservoirs, stagnant watercourses (streams, rivers and canals) and wetlands (1).

It is assumed that *P. stratiotes* is native to South America, although its native distribution is also suspected to be pan-tropical (1). Today it is present on all continents, except Antarctica. It was introduced and established in Africa, Asia, Australia, Europe and North America, and in many countries it is considered invasive (1; 4). In Europe it occurs occasionally and casually in many countries: Austria, Belgium, the Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Norway, Portugal, Romania, Russia, Serbia, Slovenia, Spain, the United Kingdom (1, 5, 6). As it is sensitive to frost, which hinders its establishment in continental Europe, established populations in Europe were discovered only in thermally abnormal waters in Slovenia in the Topla stream (3), in France in a canal along the Rhône (1) and in Germany in thermal sections of the Erft river (7).

In 2007 *P. stratiotes* was included on the EPPO Alert List, while in 2012 it was transferred to the EPPO List of Alien Invasive Plants (1). It is being considered for inclusion on the list of invasive alien species of Union concern under the Regulation (EU) No 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species (OJ L 317, 4.11.2014, p. 35).

MATERIAL AND METHODS

Fieldwork in the Sava-Strmec Special reserve was carried out on 9th September, on 24th and 27th November 2017. During the second visit to the reserve, plants were collected and subsequently herbarized. Coordinates of localities were recorded by Garmin GPSMAP 60CSx GPS Receiver in the national HTRS96 coordinate system (8). A distribution map was prepared in ESRI GIS ArcMap 10.1 software using maps from State Geodetic Administration (Digital orthophoto 2018 – WMS).

Study area

The Sava-Strmec Special reserve is an ornithological reserve covering an area of 269.92 hectares, situated northwest of the City of Zagreb, in Zagreb County (9). It was declared protected in 1971 when the Sava river in this area still had characteristics of a natural river, with numerous, anastomosing sidearms and meanders, the dynamic process of deposition of gravel bars and regular flooding of the areas along the river (9, 10). However, the reserve looks quite different today, after the building of an embankment in the middle of the Sava-Strmec Special reserve on the right Sava river bank, which left most of the lakes of

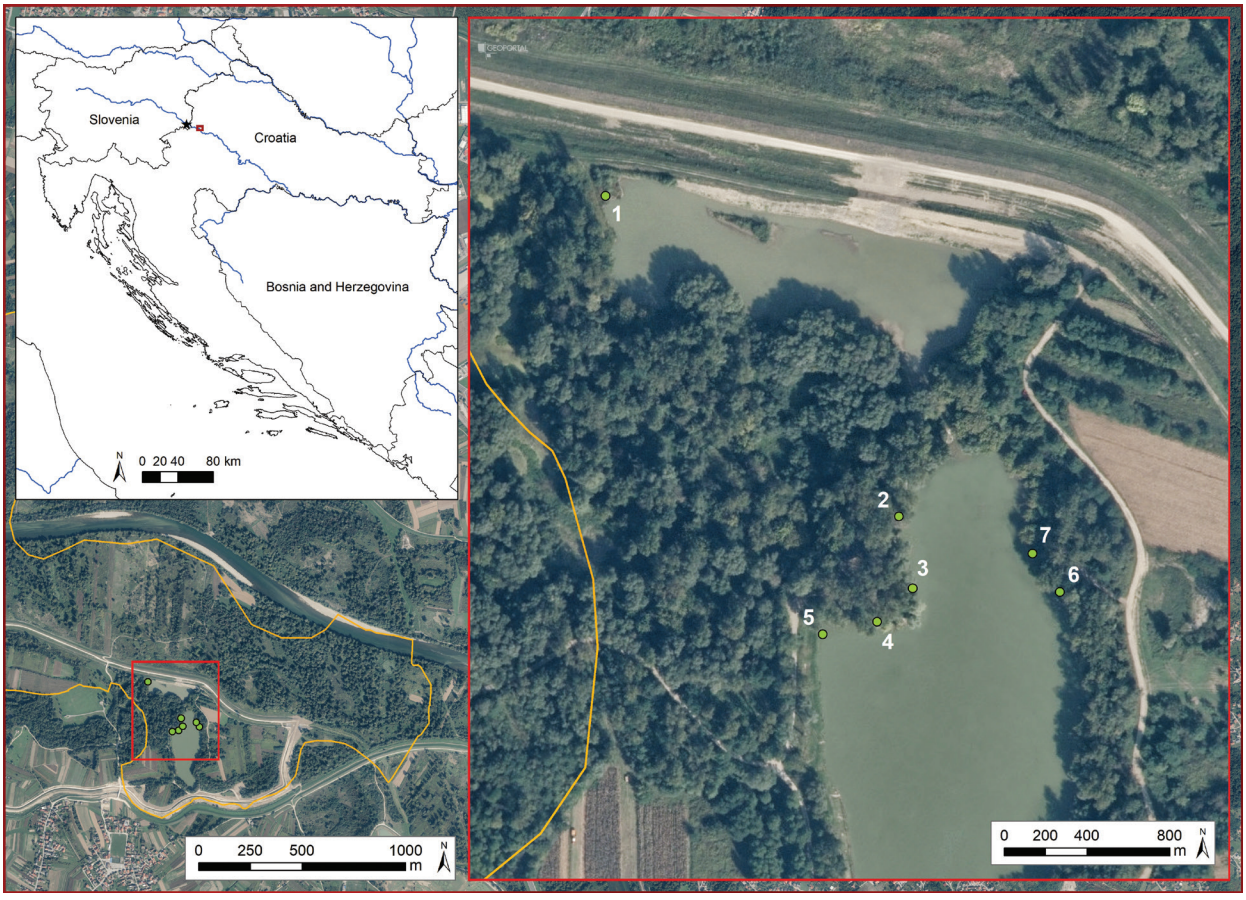

Figure 1. *Recorded localities of Pistia stratiotes in the Sava-Strmec Special reserve (orange line; Zagreb County). The upper left map shows its position in Croatia (red rectangle) and the Slovenian locality (black star).*

Table 1. *Localities of Pistia stratiotes in the Special reserve Sava-Strmec (Zagreb County) recorded in September and November 2017 with coordinates in HTRS96 coordinate system.*

Locality	X coordinate	Y coordinate
1	445499	5076744
2	445660	5076568
3	445667	5076529
4	445648	5076511
5	445618	5076504
6	445748	5076527
7	445733	5076548

the reserve outside of the flooding zone, and thus without direct contact with the Sava river (11). As part of a migration route, this area allows nesting, wintering as well as a safe rest area for passage bird species. In this area a total of 157 bird species have been recorded (10).

RESULTS AND DISCUSSION

Although it was found on numerous localities in different European countries (1) and in some of them it has even been naturalized, like in Germany (7) or in the neighbouring Slovenia where it has been present since 2001 (3), *Pistia stratiotes* has never been recorded in Croatia (cf. 12). Therefore, the first record of this species in Croatia is reported here.

Pistia stratiotes was discovered by the second author during the fieldwork in the Sava-Strmec Special reserve (Zagreb County) on 9th September 2017 (locality 1 on the map; Figure 1, Tab. 1). Approximately thirty colonies of *P. stratiotes*, with the biggest plants of about 12 cm in the diameter, were recorded rather than separate individuals (Figure 2). During the second visit to the reserve on 24th November 2017 the species was not confirmed on the locality where it had previously been found. However, several other localities of the species were found in the vicinity, on the Lake 1 (localities 2-5 on the map; Figure 1, Tab. 1). On these localities altogether seven small colonies of plants were found (Figure 2). On 27th November 2017 two other localities on Lake 1 were found (localities 6-7 on the map; Figure 1, Tab. 1) with three small colonies in total (Figure 2). It might be possible that the plants noticed during the first visit to the reserve drifted away to Lake 1 and were recorded during the second and third visit. However, given that all colonies consisted of a moth-

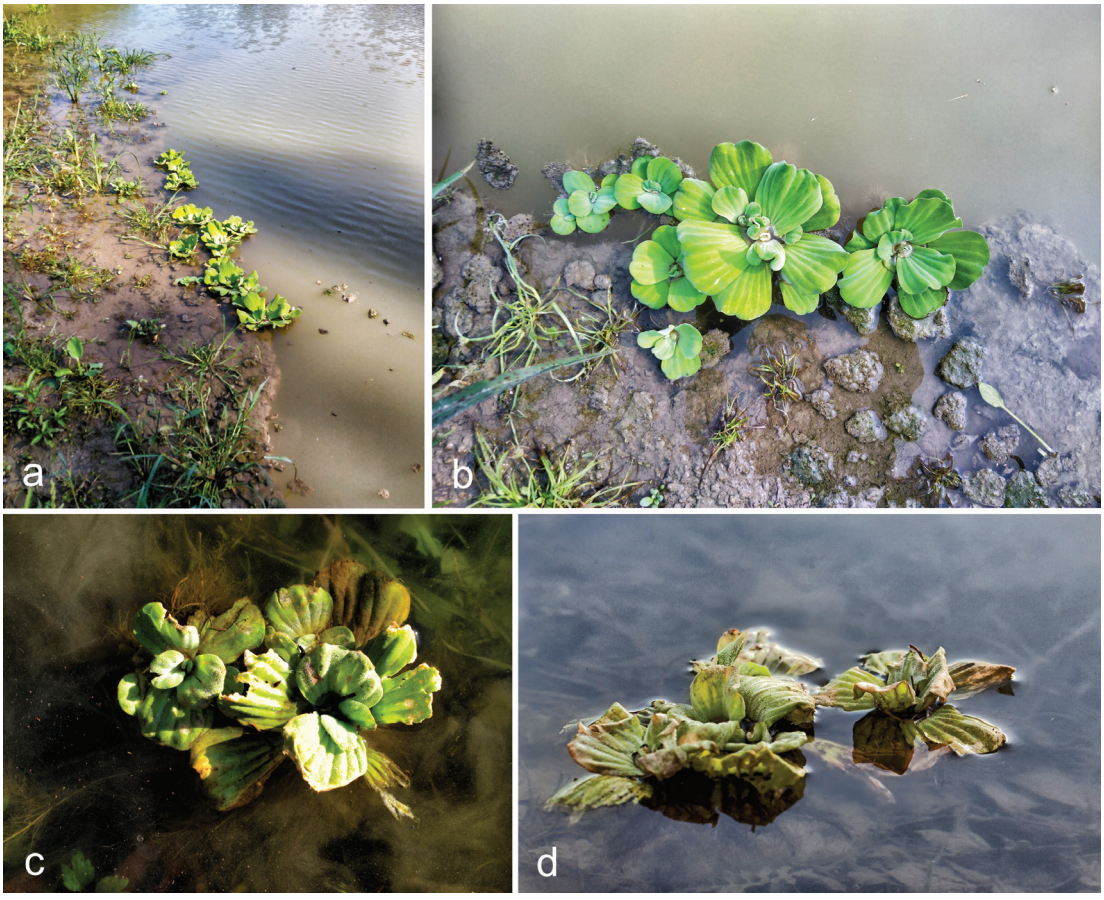

Figure 2. *Species Pistia stratiotes on locality 1 on 9th September 2017 (a and b), on locality 2 on 24th November 2017 (c) and on locality 6 on 27th November 2017 (d) (Photos: T. Rubinić)*

er plant with attached daughter plants of different sizes, we believe that the species was vegetatively reproducing on the site during the season.

There are no exact water temperature data for the Sava-Strmec Special reserve but this area is less than a 10 km straight-line distance from the Jarun Recreational and Sports Centre, which is situated in the south-western part of the city of Zagreb. The Jarun lake has the average annual water temperature of 14.3 °C, with the lowest average winter temperature of 3.9 °C in January (13). As the lakes in the Sava-Strmec Special reserve are significantly smaller and shallower than Jarun lake, they would have even lower average winter temperature. MacIsaac et al. (14) showed that *P. stratiotes* is sensitive to low temperatures and frost, which cause decline in condition and dying of plants. Thus, it is assumed that plants will fail to survive winter conditions in this area. Already during the second and especially the third visit to the Sava-Strmec Special reserve it was observed that the state of the plants had deteriorated compared to the state of the individuals found during the first visit. Furthermore, the plants on the first locality were not subsequently found.

The exact way of introduction of *P. stratiotes* to the Sava-Strmec Special reserve is not known, but several introduction pathways were considered and discussed hereinafter.

According to the Act on Prevention and Management of the Introduction and Spread of Alien and Invasive Alien Species (Official Gazette 15/2018) it is forbidden to introduce alien species into the nature and/or ecosystems which they do not inhabit naturally, to breed/cultivate them and to place them on the market without a permit from the competent authority (namely the Ministry of Economy and Sustainable Development). The permit can be issued only for the species not posing a threat to biodiversity, ecosystem services and/or human health, also taking into consideration their possible adverse impact on economy as an aggravating factor. Up to now there have been no formal requests to import *P. stratiotes* to Croatia. However, a simple Internet search showed that *Pistia stratiotes* is illegally offered and sold online for aquaria and fishponds, even in Zagreb County. Therefore, it is possible that it was either deliberately introduced into the nature or accidentally "released" through the disposal of individuals grown in aquaria.

Another possible introduction pathway might be through waterbirds. *P. stratiotes* was recorded in the Topla stream in the neighbouring Slovenia (3), which is less than a 15 km straight-line distance from the Croatian locality. Although not specified as vectors for *P. stratiotes* (cf. 4, 15), waterbirds could act in this way since they have been demonstrated to be the dispersal means for some other alien plant species for which they had not been mentioned as vectors (16). However, it has been proven that the species reproduces by seeds in Slovenia and seeds were found in the sediment seed bank of the Topla stream, which is considered to be "a potential source for further vegetative and sexual spread" of the species (3). As it was stated by Green (16): "Spread of alien species by birds is one of the so-called unaided pathways by which aliens can undergo natural spread into new, neighbouring biogeographical or political regions.". The Sava-Strmec Special reserve is an ornithological reserve which hosts numerous nesting, wintering and resting bird species. Therefore, it is speculated that propagules of *P. stratiotes* might have been transferred either on waterbirds (ectozoochory), or they might have been dispersed by endozoochory or secondary endozoochory (i.e. seeds ingested by fish which are then eaten by piscivorous waterbirds; 16) from an adjacent Slovenian locality.

An unintentional introduction of *P. stratiotes* by fishermen might also be considered as a possible pathway, because propagules of *P. stratiotes* (i.e. seeds and seedlings) might be spread by fishing gear (15). Although it is not known whether fishermen from the Štuka – Strmec Sport fishing association have been to the Topla stream, fishermen from other fishing associations (e.g. the Zagorje Fishing Club) have been fishing Nile tilapia (*Oreochromis niloticus*) there (17). However, at present this pathway is not recognized as significant (15).

One of the potential pathways of introduction might also be a drift of plants from the Topla stream to the Sava river, and then to the Sava-Strmec Special reserve during a flood. In Germany it was calculated that from June to October cca 6000 plants drift daily from the Erft river into the Rhine (7). However, we do not consider this pathway possible because there were no floods in this area in the last two years, since the building of an embankment in the middle of the Sava-Strmec Special reserve.

According to the proposal for Croatian standards and criteria for treating alien flora (18), *P. stratiotes* should be treated as a casual alien in Croatia for now. Further investigations over the next years should show whether this really was just an ephemeral occurrence of *Pistia stratiotes* in Croatia or it will start occurring regularly due to repeated (un)intentional introductions.

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