

Rapid Communication**First record of *Limnobium laevigatum* (Humb. & Bonpl. ex Willd.) Heine (Hydrocharitaceae) and *Pontederia crassipes* Mart. (Pontederiaceae) in Poland**

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OPEN ACCESS**Abstract**

Invasive aquatic plants can spread rapidly causing many negative effects on both the structure and functioning of aquatic ecosystems. They can also hinder navigation, fishing, water tourism, and recreation. Early detection and rapid response to invasive aquatic plants can prevent their further spread and negative impacts. In this study, we present the first record of two invasive alien aquatic plants *Limnobium laevigatum* and *Pontederia crassipes* in Poland. The plants were found in an artificial pond in the eastern part of the city of Kraków, southern Poland, on 16 September 2020. The pond was also occupied by *Pistia stratiotes*, another invasive alien aquatic plant that has been recently recorded in Poland. The locality is mapped using the ATPOL cartogram method, photographic documentation of the habitat and species is provided and the status of *L. laevigatum* and *P. crassipes* in the Polish flora is discussed.

Key words: aquatic plants, biological recording, Central Europe, invasive alien species, weeds

Introduction

Biological recording contributes to a better understanding of the mechanisms of introduction, naturalization, and invasion of alien species (Roy et al. 2015; Lozano et al. 2017). Early detection and rapid response to invasive alien species (IAS) can prevent their further spread and negative impacts (Reaser et al. 2020). Alien aquatic plants are attractive for many gardeners and aquarists; however, their introduction by the aquatic nursery trade may lead to invasion (Strecker et al. 2011; Peres et al. 2018). Alien aquatic plants can spontaneously escape from places of their cultivation or can be released to natural habitats by human carelessness (EPPO 2014; Hrivnák et al. 2019; Hill et al. 2020; Pergl et al. 2020). Invasive aquatic plants can spread rapidly causing many negative effects on both the structure and functioning of aquatic ecosystems. For example, they can transform the ecosystem by trapping sediments, they can restructure food webs and communities of aquatic plants, animals, and microorganisms, they can decrease native biodiversity by forming dense monotypic mats and reducing

light and oxygen in the water. Moreover, they can hinder navigation, fishing, water tourism, and recreation (Havel et al. 2015 and references therein).

Limnobium laevigatum (Humb. & Bonpl. ex Willd.) Heine, a free-floating to rooted perennial freshwater plant of the Hydrocharitaceae family, is native to tropical areas of Central and South America. It usually occurs in rivers, lakes, swamps, canals, and ponds (Cook and Urmi-König 1983). Juvenile plants have a spongy aerenchyma tissue upon the abaxial surface of the leaf and they form leaf rosettes that lie flat on the water surface. Mature plants grow up to 50 cm tall having emergent leaves and solitary or paired white, unisexual flowers. It reproduces sexually by seeds and vegetatively by fragmentation of stolons (Cook and Urmi-König 1983; DiTomaso 2010; Howard et al. 2016). It was introduced to North America, Europe, Asia, Africa, and Australia, where is often used as an ornamental plant in aquaria and artificial ponds (Kadono 2004; DiTomaso 2010; Howard et al. 2016; Randall 2017). The naturalization and invasion of *L. laevigatum* have been confirmed in some parts of North America, South America, Asia, Australia, and Africa (Howard et al. 2016; Randall 2017; Lozano and Brundu 2018). In Europe, it has been recorded only in Belgium and Hungary so far, being treated as a casual alien (Verloove 2013; Riezing 2019). It grows fast forming dense mats on the water surface (Howard et al. 2016). It can reduce the biomass and diversity of native aquatic plants and animals by limiting light and oxygen in the water. Moreover, it can hamper navigation and water flow in rivers and canals (DiTomaso 2010; Riezing 2019).

Pontederia crassipes Mart. [= *Eichhornia crassipes* (Mart.) Solms], a free-floating perennial freshwater plant of the Pontederiaceae family, is native to tropical areas of South America. It occurs in rivers, lakes, swamps, and artificial aquatic habitats (Coetzee et al. 2017; Pellegrini et al. 2018). It forms shiny green leaves arranged in a basal rosette, borne on bulbous or elongate petioles, up to 1 m tall, and pale blue to mauve flowers arranged in a raceme. It reproduces sexually by seeds and vegetatively by fragmentation of stolons (Coetzee et al. 2017; Pellegrini et al. 2018). It was introduced to North America, Europe, Africa, Asia, and Australia (Kadono 2004; Coetzee et al. 2017; Randall 2017). It is known as the world's worst aquatic weed with numerous negative ecological and socio-economic impacts. Dense mats of *P. crassipes* promote detrital production and siltation, reduce light to submerged plants, decrease oxygen content in water, and reduce biomass and diversity of phytoplankton and benthic invertebrates. Moreover, *P. crassipes* restricts access to water, negatively impacting fisheries and recreational activities, the effectiveness of irrigation canals and hydroelectric stations, navigation, water transport, and tourism (Hansen et al. 1971; Kadono 2004; Coetzee et al. 2017). In Europe, *P. crassipes* is treated as an invasive plant in Portugal, Spain, France, and Italy. In many other European countries, it is treated as a naturalized species with no invasive capacity or a casual alien

(Hussner 2012; Kaplan et al. 2016; Coetzee et al. 2017; Randall 2017; Hrivnák et al. 2019). Moreover, in the EU, *P. crassipes* has been included in the list of invasive alien species of Union concern (Regulation (EU) No. 1143/2014 of the European Parliament and of the Council of 22 October 2014). Also, this species is regulated by current Italian legislation (Brundu et al. 2020). In this paper, we present the first record of *L. laevigatum* and *P. crassipes* in Poland.

Materials and methods

Field surveys were conducted in the city of Kraków, Lesser Poland Province, southern Poland, in September 2020. The study aimed to check the occurrence of alien vascular plants in urban water bodies. The area of Kraków is situated in the temperate climate zone. In the city center, the average annual air temperature is 9.3 °C, whereas the average annual precipitation is 730 mm (Matuszko and Piotrowicz 2015).

Identification of *Limnobium laevigatum*, *Pistia stratiotes*, and *Pontederia crassipes* was based on morphological features provided by Cook and Urmi-König (1983), EPPO (2017), and Pellegrini et al. (2018), respectively. Herbarium specimens were deposited at the Herbarium of the Institute of Botany of the Jagiellonian University in Kraków (*L. laevigatum*: KRA 0557636, 0557637, 0557638; *P. stratiotes*: KRA 0557633, 0557634; *P. crassipes*: KRA 0557635, *leg.* Artur Pliszko and Artur Górecki). The map with the first locality of *L. laevigatum* and *P. crassipes* in Poland was prepared using the ATPOL cartogram method, where the basic cartogram unit is a 10 × 10 km square (Zajac 1978).

Results and discussion

Limnobium laevigatum and *P. crassipes* were found in an artificial pond (~ 1000 m²) located near Agatowa Street (GPS coordinates: 50°01.306'N; 20°02.544'E; elevation: 201 m a.s.l.), in the Bieżanów-Prokocim district, the eastern part of Kraków, on 16 September 2020. This stand lies within the unit EF70 of the ATPOL cartogram grid (Figure 1). The pond is connected to a ditch and serves as a small reservoir. It has no recreational value (swimming is not allowed) and is not used by anglers. Moreover, the pond is located between a busy street and railway track and it seems to be neglected since there are dense shrubs and trees in its surroundings, and the fence on the street side of the pond is damaged. *Limnobium laevigatum* and *P. crassipes* were associated with native aquatic plants such as *Ceratophyllum demersum* L., *Lemna minor* L., *Persicaria amphibia* (L.) Delarbre, *Phragmites australis* (Cav.) Trin. ex Steud and *Spirodela polyrhiza* (L.) Schleid. Additionally, the invasive alien species *Pistia stratiotes* L. (Araceae) was also found in the pond. This is the first record of *P. stratiotes* in Kraków and Lesser Poland Province. Previously, it has been recorded as

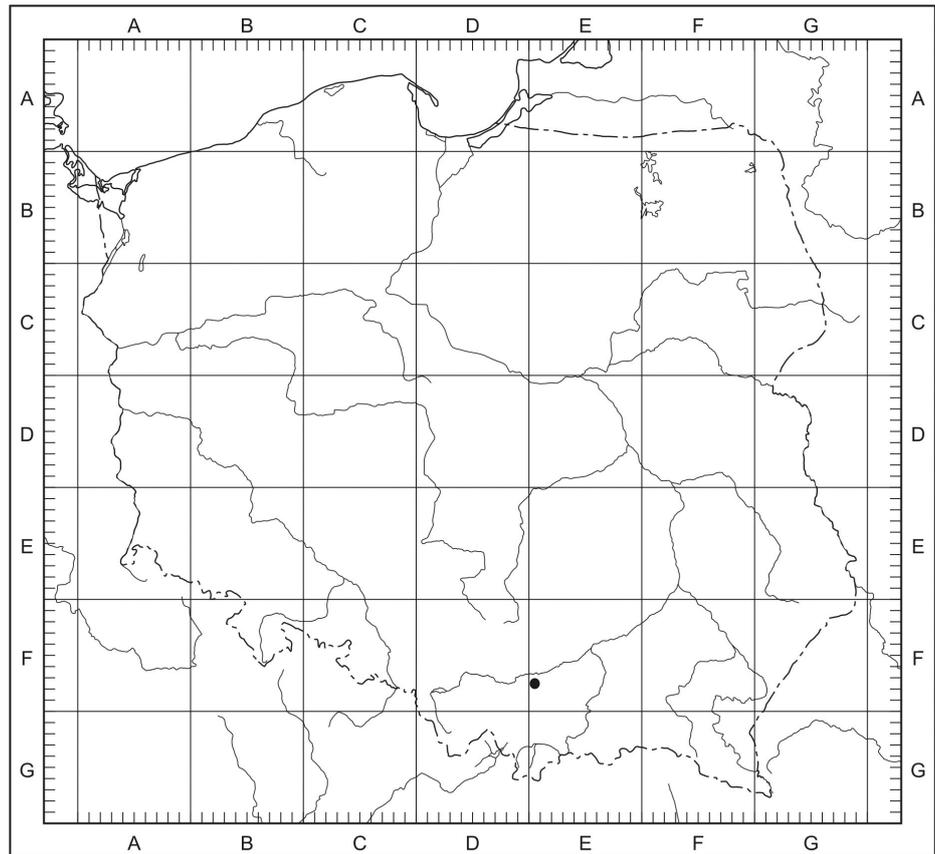


Figure 1. Locality of *Limnobium laevigatum* and *Pontederia crassipes* in Poland within the ATPOL cartogram grid.

an ephemerophyte in southern Poland (Silesia Province, Krajewski 2013). *Pistia stratiotes* is native to South America, where it is commonly used as an ornamental plant in the aquatic nursery trade. It was introduced to North and Central America, Europe, Africa, Asia, Australia, and Oceania and is considered invasive in many countries (Kadono 2004; Kaplan et al. 2016; EPPO 2017).

Limnobium laevigatum was dispersed quite regularly (except the central part of the pond), covering about 35% of the water surface of the pond (Figure 2a). *Pontederia crassipes* and *P. stratiotes* were dispersed irregularly, reaching less than 5% of the water surface of the pond (Figure 2b, c). Moreover, a few specimens of *L. laevigatum* and *P. stratiotes* were also found in a ditch connected to the pond (along with a distance of 5 m from the western bank of the pond). The population of *L. laevigatum* consisted of juvenile specimens with rosettes of floating leaves and mature specimens with rosettes of emergent leaves (Figure 2d). Mature specimens of *L. laevigatum* formed two dense clusters covering about 30 m² of the water surface in the southern part of the pond and a few small loose clusters covering about 2 m² of the water surface in the eastern part of the pond. However, flowers of *L. laevigatum* have not been observed. Particularly, *P. crassipes* and *P. stratiotes* were in the vegetative stage.

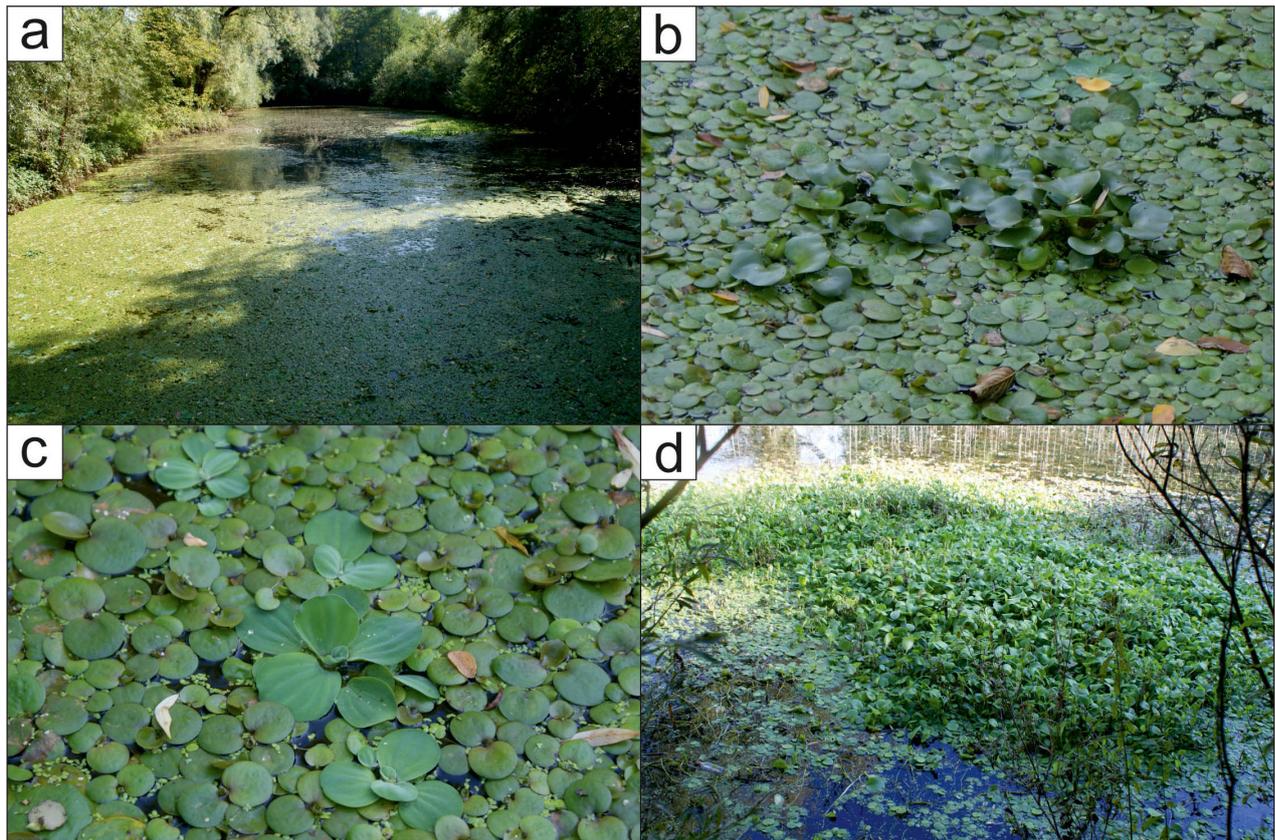


Figure 2. The figure shows: a – the artificial pond containing the alien species: *Limnobium laevigatum*, *Pistia stratiotes* and *Pontederia crassipes* in Kraków, southern Poland; b – rosettes of *P. crassipes* between juvenile *L. laevigatum* and *P. stratiotes* rosettes; c – rosettes of *P. stratiotes* between juvenile *L. laevigatum* rosettes; d – mature rosettes of *L. laevigatum*. All photographed by Artur Pliszko, 16–19 September 2020.

Alien plants are often intentionally introduced through direct release to nature, or spontaneously escape from areas of their cultivation (Pergl et al. 2020). The main pathway of introduction of *L. laevigatum* and *P. crassipes* is aquatic nursery plant trade. They can be also introduced by water birds or as hitchhikers on boats and ships (Howard et al. 2016; Coetzee et al. 2017). It is still uncertain how *L. laevigatum*, *P. crassipes*, and *P. stratiotes* were introduced to one pond. Most likely they were released by some aquarist, but it is not known how often they are grown in private aquaria. Unfortunately, they are easy to buy in various pet stores. We did not find any site with outdoor cultivation of these plants in the study area. Although, *L. laevigatum*, *P. stratiotes*, and *P. crassipes* are cultivated in the greenhouses of the Botanic Garden of the Jagiellonian University in Kraków, their escape is not likely. It cannot be excluded that *L. laevigatum*, which had the highest abundance, was introduced to the pond earlier than the other two alien species. According to Art. 120 of the Act of 16 April 2004 on nature protection in Poland, it is banned to introduce into the natural environment and to move in this environment alien species. Considering the criteria proposed by Pyšek et al. (2004), currently, *L. laevigatum* and *P. crassipes* should be treated as casual alien species in Poland. The geographical distribution of *P. stratiotes* and *P. crassipes* is limited by cold

winter temperatures and their naturalization in Poland is not likely (Cordeiro et al. 2020; Lozano 2021). On the other hand, due to the warming climate and the fact that the cities are heat islands (McCarthy et al. 2010), there is a probability that *L. laevigatum*, *P. stratiotes*, and *P. crassipes* will survive the following winters in Kraków. It is also worth mentioning that localities of naturalized populations of *P. stratiotes* and *P. crassipes* in Slovakia (Hrivnák et al. 2019) are situated relatively close to Poland. Furthermore, these invasive alien species have been known to occupy thermal or artificially heated water bodies, indicating that low air temperatures do not always prevent the naturalization of tropical aquatic plants. In Hungary, *L. laevigatum* has been recorded in streams fed by hot-water springs (Riezing 2019). Similarly, *P. stratiotes* has been found in thermal water in Slovakia (Hrivnák et al. 2019). In the pond near Agatowa Street in Kraków, the water temperature is not regulated by technical devices and no hot spring water flows into the pond either. In December 2020, we observed that the entire surface of the pond was frozen. Nevertheless, the stand of *L. laevigatum*, *P. stratiotes*, and *P. crassipes* in Kraków needs to be monitored, and appropriate control methods should be applied if the plants survive the winter. There is a risk that the plants may be transferred by water birds to other water bodies.

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