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The water caltrop (*Trapa natans* L.) in Ukraine: new areas of expansion in the north of the country and contradictions in concepts of its protection and population management

Igor Merzlikin[1,2], Oleksandr Savitsky[3]

[1] Sumy State Pedagogical University (Sumy, Ukraine)
[2] Mikhailivska Tsilyna Natural Reserve (Sumy, Ukraine)
[3] Lower Sula National Nature Park (Orzhytsia, Ukraine)

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correspondence to
Igor Merzlikin; Sumy State Pedagogical University; 87 Romenska Street, Sumy, 40000 Ukraine;
Email: mirdaodzi@gmail.com;
orcid: 0000-0001-8209-9144

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abstract

This paper reviews data on the distribution of the water caltrop *Trapa natans* L. in Ukraine. This relict species (listed in the Red Data Book of Ukraine) had strongly declined in the early 1979s, but has now locally recovered and even excessively spread in the upper reaches of the Kaniv and Kyiv reservoirs on the Dnipro River. Therefore, both protection and regulation of its local abundance are on the agenda today in the country. Work is currently underway to monitor the population of the species and search for new habitats. Previously the presence of the water caltrop in Sumy Oblast has been documented only in floodplain waterbodies of the Desna River. On 18 June 2017, we found four new record localities of *Trapa natans* in the Psel River within the city boundaries of Sumy (north-eastern Ukraine). All of them were located along the right bank of the river. The four groups of plants were comprised of 8, 70, 2, and 100 individual plants, respectively, growing at a depth of 0.5–3.2 m and about 5–15 m far from the riverbank. A second visit to the location on 15 August 2017 revealed a total of 591 rosettes. Three years later (visited on 28 August 2021), the number of individual caltrop plants in this location increased as many as eight times (total of 4766). The plant spread 3 km further downstream and its mats (variable in size) could be found at both banks of the river. The transformation of the Psel River from one of the fastest tributaries of the Dnipro into a cascade of numerous channel reservoirs led to a slowdown in water flow and the continuous siltation of the bottom created favourable conditions for the water caltrop. Most likely, seeds of this plant were artificially introduced into the river (possibly by aquaculture enthusiasts) a few years prior to the first finding and the plant spread downstream. This was facilitated by the spring flood, which carried the fruit down the river. In summer, the current carries plants that were uprooted by vacationers. Leaves of the water caltrop were seen consumed by the mallard *Anas platyrhynchos* L., whereas seeds of the plant were eaten by the European water vole *Arvicola amphibius.* The newly discovered occurrence spot of the water caltrop is currently the only one on the Psel River and it complements the information on the current distribution of this rare plant species. It is located about 145 km south-east from the closest population on the Desna River, which described the presence of this species in Sumy Oblast.

Водяний горіх (*Trapa natans* L.) в Україні: нові райони експансії на півночі країни та протиріччя в концепціях його охорони і регуляції чисельності

Ігор Мерзлікін, Олександр Савицький

Резюме. У статті розглядається ситуація в Україні із червонокнижним реліктовим видом водяний горіх плаваючий *Trapa natans* L., який на початку 1970-их років значно скоротив свою чисельність. Зараз спостерігається надмірне розростання рослини у верхів'ях Канівського і Київського водосховищ. Тому нагальним є питання розробки концепції його охорони і регуляції чисельності. Наразі продовжуються роботи з моніторингу популяції виду і пошуку нових місцезростань. У Сумській області місця зростання водяного горіха були відомі тільки для заплавних водойм річки Десни. Авторами 18.06 2017 знайдено чотири локалітети водяного горіха плаваючого в річці Псел в межах міста Суми (північно-східна Україна). Всі вони розташовувалися біля правого берега. Перша група рослин нараховувала 8 особин, друга — близько 70, третя — 2 особини і четверта — 100 особин. Вони розташовувалися в 5–15 м від берега на глибині 0,5–3,15 м. Повторне обстеження місця зростання 15.08.2017 показало, що загальна чисельність чиліму складала приблизно 591 розетку, а 28.08.2021 їх кількість збільшилася у 8 разів і досягала приблизно 4766 екз. За цей час водяний горіх поширився майже на 3 км нижче за течією і його куртини різних розмірів зустрічаються біля обох берегів річки. Перетворення р. Псел з однієї із найбільш швидких приток Дніпра на каскад чисельних руслових водосховищ призвело до помітного уповільнення течії води і суцільного замулення дна створило сприятливі умов для мешкання водяного горіху. Вірогідно плоди *T. natans* були кимось вкинуті у воду декілька років тому назад і рослина поширилася вниз за течією. Цьому сприяла течія річки під час весняної повені, яка переносила плоди чиліму вниз по річищу. Влітку течія переносить рослини, які вирвали відпочивальники. Зареєстроване споживання молодого листя водяного горіха крижнем (*Anas platyrhynchos* L.) і його плодів — щуром водяним (*Arvicola amphibius* L). Виявлене місцезростання *T. natans* є поки що єдиним відомим на р. Псел і доповнює відомості щодо сучасного поширення цього рідкісного виду. Воно розташоване приблизно в 145 км на південний схід від водойм на р. Десна, де було описано перебування цього виду на Сумщині.

Ключові слова: річка Псел, моніторинг, екологічний менеджмент, водні макрофіти, управління чисельністю, Червона книга України, розширення ареалу, експансія.

Адреса для зв'язку: Ігор Мерзлікін; Сумський державний педагогічний університет ім. А. С. Макаренка; вул. Роменська 87, Суми, 40000 Україна; e-mail: mirdaodzi@gmail.com; orcid: 0000-0001-8209-9144

Introduction

Modern approaches to the protection and conservation of biological and landscape diversity require significant improvement and practical changes. They are especially relevant for the components of our freshwater ecosystems, which have been particularly vulnerable to modern climate change and the subsequent transformation of natural landscapes. One such component is rare and endangered species of animals and plants. A well-known practice of protection of various species of plants and animals in our country is to include them into the Red Data Book of Ukraine. The situation with the water caltrop (*Trapa natans* L. s. l.) was unique because its abundance in the 1970s had significantly declined due to human economic activity, in fact, to critical values. This led to the species' inclusion into the Red Book of Ukraine. Since, it has been considered a rare species of aquatic vascular plants.

But in the early 2000s, for various reasons, its population in the upper part of the Kyiv and Kaniv reservoirs began to grow rapidly. And now it became a real problem for many human activities and natural processes in the water (recreation, fishing, fish farming, and fish spawning) (Savitsky *et al*. 2005; Savitsky 2007). For more than 15 years, various management groups have been discussing solutions for the problem and eventually it was excluded from the Red Book of Ukraine in 2021. Now this will allow the application and implementation of large-scale melioration measures to clean reservoirs from plant biomass. But we all know that *Trapa natans* is a complex species and therefore it is necessary that along with measures to clean reservoirs a complete inventory of the species should be carried out as well, as the situation with the complete extinction of the species may be repeated.

Meanwhile, such discussions are underway; any information on the distribution of the species and features of new habitats is interesting and useful for science.

The aim of the research was to determine and find new places of occurrence of the water caltrop in the north of Ukraine, particularly in Sumy Oblast, and to discuss the strategy of its protection and conservation in the territory of Ukraine.

Material and Methods

The article is based in data collected during expeditions to the rivers near the borders of Sumy Oblast in 1990–2021. Material was collected by inspecting rivers and floodplain lakes by boat, as well as visiting the riverbanks. Were researched the following rivers and floodplain lakes: Desna River (from the village of Novovasylivka to the village of Ochkyne, Seredyna-Buda Raion), Desenka River (near the village of Ochkyne, Seredyna-Buda Raion), Seym River (from the village of Tyotkino, Kurskaya Oblast, Russia, to the village of Lysogubivka, Konotop Raion, Sumy Oblast, Ukraine), Jezuch River (from Konotop to the confluence with the Seym River near Lyzogubivka, Konotop Raion), Sula River (1–2 km upstream and downstream from Romny), Psel River (from the village of Myropillia to Sumy), Vorskla River (1991–2021, from the town of Velyka Pysarivka, Velyko-Pysarivka Raion, to the village of Kuzemen, Okhtyrka Raion), and some lakes and waterbodies in various parts of Sumy Oblast.

Common methods of floristic and geobotanic research of vascular plant formations were used, including the study of the floristic composition of the plant cover of waterbodies, establishment of the specifics of the plant cover in different parts of the waterbodies. Water macrophytes flora is considered after V. M. Katanskaya (1956, 1981). The Latin names of plants follow the key handbook 'Checklist of Vascular Plants of Ukraine' (1987).

Materials were also collected during the expeditions by methods of ecological site and transect surveys. To determine the vegetation cover and the level of vascular plants' concentration on the water surface, the method of visual evaluation was used. Determination of water depth and bottom soil type under the plant cover followed the geobotanical descriptions (Romanenko *et al*. 2006).

Results and Discussion

The water caltrop (*Trapa natans* L. s. l.) is a relict polymorphic species with a disjunctive geographic range and is found in waterbodies of Central, Eastern, and Southern Europe, the Mediterranean, the Caucasus, Southern Siberia, the Far East, and Asia Minor. In Ukraine, it is found in river valleys of different geographical regions of 19 oblasts (Dubyna 1982). It was included into the third edition of the Red book of Ukraine in 2009 (Dubyna & Chorna 2009), but in 2021 it was decided to excluded from this edition.

Temperature increase and other ecological consequences of Global Climate Change (GCC) have a large influence on representatives of various species as well as on the ecosystem processes and interspecific relationships. Changes of range boundaries occur now quite rapidly and mainly randomly. The increasing annual mean temperature affects fluent transition between the seasons of the year, the temperature of different seasons, amount of precipitation, wind speed, and other environmental factors (Afanasyev & Savitsky 2016). The current trends in climate change are so radical that it they are discussed not only in the scientific community, but also is a subject of serious political debates.

Our complex long-term research (1996–2021) of aquatic vascular plants and its habitats in the territory of Ukraine demonstrate that modern trends in range dynamics and the appearance of new species is typical also for the territory of Ukraine. We note the following cases: appearance and ecological disasters related to the tropical plant *Pistia stratioides* L. in various waterbodies of Ukraine, uncontrolled overgrowth of the water caltrop *Trapa natans* L. s. l. in the upper parts of Kyiv and Kaniv reservoirs, range expansion of *Ceratophyllum tanaiticum* Sapjeg to the south, and changes in distribution of *Typha laxmannii*. In addition, the list of invasive species aquatic vascular plants includes up to 20 species.

Sumy Oblast is a region with a well-developed hydrological network. The Desna, Seym, Sula, Psel, and Vorskla are the largest rivers in the oblast (Demchenko 1947). *T. natans* in Sumy Oblast was a rare species and was known to occur only in floodplain waterbodies of the Desna River. Both local botanists (Karpenko & Kovtun 1996; Sklyar 1998; Karpenko *et al.* 2001) and experts from Kyiv (Dubina & Semenikhina 1978; Semenikhina 1979, 1982; Dubina 1982) wrote about it. Relatively recent studies have also confirmed this (Panchenko 2005; Savitsky *et al*. 2005; Dubina & Chorna 2009) (Fig. 1).

We have found the water caltrop only in some floodplain lakes of the Desna River and its tributary — the Desenka River, at the territory of Desnyansko-Starogutsky National Nature Park.

On 18 June 2017, we found two specimens of the species in the Psel River in the territory of Sumy City (Fig. 2). They were found on a small, abandoned, 10 m long beach on the right bank near the Central Park (Merzlikin & Savostyan 2020). Previously, in 2014–2016, the species was absent at this site. The plants grew two metres off the bank, where the river is 1.5 m deep. Respectively, 24 and 27 leaves were calculated, the largest of which was 37 mm long. Rosettes of floating leaves were 15 cm and 15×19 cm in diameter without flowers.

This beach is visited daily by vacationers, so the fear that these plants will not survive became true — on 29 June 2017, they disappeared. However, after the research of the right bank of the Psel upstream and downstream of the mentioned place, three localities of the water caltrop were found: two upstream and one downstream (Fig. 3).

There were eight plants in the first group (locality 1). The plants were located 6 m off further from the bank at a depth of 0.5–1.0 m and upstream from the pedestrian bridge across the Psel. The second group of plants (locality 2) was found 65 m downstream and consisted of nearly 70 plants. The plants grew at a 1.5–2.8 m depth and 15 m off and further from the bank (Fig. 4). The third group included two plants (locality 3) and was located 150 m downstream from the previous locality. The fourth group of plants (locality 4) was located 50 m downstream from the previous one and consisted of about 100 plants. The majority of plants grew at the depth of 1.5–3.2 m and 15 m off and further from the bank. But separate plants grew closer to the bank: 7 m off and at a depth of 1 m. The first and forth localities were situated on places of former sand beaches covered by wetland vegetation.

The second observation of the habitats on 15 August 2017 revealed that the number of water caltrop rosettes greatly increased. At the first locality, there were 25 rosettes (covering an area of nearly 50 m^2), and about 220 rosettes (covering 4200 m^2) at the second locality and 346 (nearly 4200 m^2) at the fourth. The plants had 2–5 rosettes. In some places, the density of rosettes was five plants per m^2. The maximum diameter of rosettes was 39 cm, the minimum — 12 cm. In the last case, the rosette had three formed fruits and all of its leaves were gnawed by molluscs. The total number of rosettes was nearly 591.

The habitat had a sandy bottom and slow stream, which create generally favourable conditions for this species (Dubina & Chorna 2009; Sklyar 2015). It is necessary to note that in all three localities there were well developed plants, which did not differ in size from the others but there were also yellow and clearly suppressed ones. They were about 25.9%, 5.5%, and 5.9%, respectively, in each locality of the total number of floating water caltrop rosettes.

The first case of flowering of *T. natans* was noted on 27 July. Mass flowering began on 11 August. The number of flowers in one rosette ranged from one to five, the average was about three. In the plant association also grew *Nuphar lutea* (L.) Smith, *Potamogeton pectinatus* L., *Myriophyllum spicatum* L., *Ceratophyllum demersum* L., *Lemna minor* L., *L. trisulca* L., *Spirodela polyrhiza* (L.) Schleid., *Hydroharis morsus-ranae* L., and *Elodea canadensis* Michx. At a depth of 2 m and more, *T. natans* was found mainly together with *N. lutea*. The main threat to the water caltrop at the fourth locality is posed by vacationers who uprooted it with the other aquatic plants growing on and near the beach (Fig. 5). There were more than 13 plants uprooted by the people. The first two localities were situated in places not visited by the people.

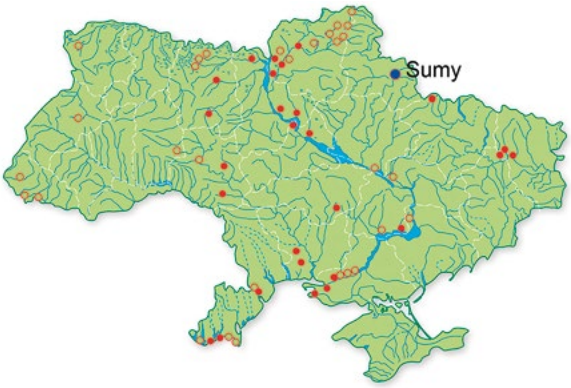

Fig. 1. Distribution of the water caltrop in Ukraine (after Dubyna & Chorna 2009) with additions. Designations: ○ — records before 1994; ● — records after 1994.

Рис. 1. Поширення водяного горіху в Україні (по: Dubyna & Chorna 2009) із доповненням. Позначення: ○ — місцевості, де вид зустрічався до 1994 р.; ● — після 1994 р.

Fig. 3. Record localities of *T. natans* in the Psel River in the central park of Sumy based on study results as of 2017.

Рис. 3. Місцезнаходження *T. natans* в р. Псел на території центрального парку м. Суми. Результати обліків 2017 р.

Additional survey of the Psel River was carried out within the city of Sumy: a section of 4.5 km upstream, starting from the city line of Sumy, was carefully inspected on an inflatable boat. It gave negative results, although there were quite a few places suitable for water caltrops and where other species of rooted hydrophytes were growing.

Fig. 2. *T. natans* in the Psel River in the territory of the Sumy Central Park.

Рис. 2. *T. natans* в річці Псел на території центрального парку м. Суми.

Fig. 4. Locality No. 3 of *T. natans* in the Psel River.

Рис. 4. Локалітет № 3. *T. natans* в річці Псел.

Fig. 5. Locality No. 4 of *T. natans* near a beach of the Psel River.

Рис. 5. Локалітет № 4. *T. natans* біля пляжу в р. Псел.

Fig. 6. Fruit of the water caltrop gnawed by the European water vole (*Arvicola amphibius*).

Рис. 6. Плід водяного горіху, розгризений щуром водяним (*Arvicola amphibius*).

It is necessary to mention that we have never recorded before this plant in the valley of the Psel within Sumy and in its outskirts. Other authors also did not note this species for the Psel River (Kovtun 1990; Karpenko *et al*. 2002; Ladur & Vacal 2017). Apparently, this is probably due to the fact that before the creation of numerous dams on its channel the Psel was considered one of the fastest-flowing tributaries of the Dnipro and had a clayey and sandy bottom (Demchenko 1947). Now the Psel has become a cascade of numerous channel-like waterbodies — only in Sumy Oblast, there are five of them. This has led to a remarkable slowdown in water flow and continuous siltation of the bottom, which created favourable conditions for the development of aquatic vegetation, including vascular plants.

Repeated observations of the water caltrop carried out on 28 August 2021 from a boat showed that over the past 4 years its number has increased in 8 times and accounted to approximately 4766 rosettes. The area occupied by these plants also increased. Individual clusters of plants were found along both banks and they spread almost 3 km downstream.

It is unknown how the seeds of the water caltrop appeared at this section of the Psel River. Considering that fruits of the plant are heavy and sink immediately after ripening (Dubyna & Chorna 2009; Didukh 2011), it is unlikely that they were brought here by currents or birds or mammals, especially since this finding is far from the only one known in the Psel River.

The most probable assumption is that the seeds were thrown into the water by the people a few years ago. This version is supported by the fact that the highest place of growth of the water caltrop is near the pedestrian bridge over the river, from which its seeds were scattered. With time, *T. natans* was distributed downstream.

Due to the good properties of this plant, its decorative and ecological-phytocoenotic significance, it seems quite real to grow it in other water bodies of Sumy. The plant is not very difficult in aquaculture, and the waterbodies of the city can be favourable habitats for its vital needs. Especially since this species grows in urban biotopes of such a large city as Kyiv (Ivanova *et al.* 2007; Savitsky 2007). In the autumn of 2018, we tried to sow the water caltrop in other waterbodies of the city. We gathered 90 seeds and planted them in 6 new places: in the Psel riverbed, 3 small ponds located in the city park (10–27 seeds in each of them) and 2 ponds in the village of Vakalishchyna located near the biological field lab of Sumy Pedagogical University (10 and 16 each). However, our efforts were unsuccessful. The plants sprouted only in two ponds located in the park (3 and 6 plants). In the other two ponds (in the city park and near the village of Vakalishchyna), they did not grow. In the backwater of the Psel, where the seeds were thrown, a pier for catamarans was built, and one of the ponds in Vakalivshchyna was drained and there was a playground with solar panels. Young water caltrop leaves, which germinated in two ponds of the park, were eaten by mallards, the broods of which lived in these ponds.

The specifics of *Trapa natans* is that it is a complex species, which includes several species that differ from each other mainly in the shape of their fruit (Key handbook of vascular plants of the Ukrainian SSR 1950). According to D. N. Dobrochaeva and co-authors (1987), the family Trapaceae includes a single genus and 25 species distributed in waters of almost the entire globe. The same authors have identified the following species in the territory of Ukraine: *Trapa natans* L., which grows in backwaters and rivers of Transcarpathia, Rostochya-Opillia, and western Polissya; *Trapa hungarica* Fler. Non Opiz, which grows in basins of the Southern Bug and Dniester within Odesa and Mykolaiv oblasts; *Trapa rossica* V. Vassil, which grows in rivers and lakes in western and Right-Bank Polissia, the eastern part of the Forest-Steppe and the northern part of the Steppe; *Trapa borysthenica* V. Vassil., which grows in the Dnipro basin from the Polissia to the Steppe; *Trapa maeotica* Woronow, which grows in backwaters and slow-flowing waters in the Steppe (lower part of the river Konka); *Trapa macrorhiza* Dobrocz, which grows in the Steppe (in the Dnieper and its tributaries); *Trapa ukrainica* V. Vassil, which grows in waterbodies in the Steppe, in backwaters of the Dnipro and its tributaries, Lake Zagynay, and other bodies of water; *Trapa pseudocolchica* V. Vassil., which grows in the Steppe, at the Danube Delta, and in other southern rivers; *Trapa danubialis* Dobroch, which grows in the Steppe and at the Danube Delta. At the same time, quite rare species were also noted: *Trapa maeotica*

Woronow, *Trapa macrorhiza* Dobrocz, *Trapa colchica* Albov, *Trapa cruciata* (Glück) V. N. Vassil, and *T. danubialis* Dobrocz. Mosyakin and Fedoronchuk (1999) also listed 10 water caltrop species.

Due to the excessive growth of this plant in some waterbodies of Ukraine, it is expected that there will be a problem of how to deal with the large amounf of green plant biomass in case of melioration measures to clean the area and eradicate the species. One way is to use the plant biomass for biogas production. In one of our recent works, we described the possibility of biomass utilization of other water plant species, such as the invasive *Pistia stratiotes* L. (Havryliuk *et al*. 2021).

In our opinion, methods of biological control due to the development of elements of ecosystems that suppress the plant population may be promising. Any biological methods of controlling a certain species of plants or animals are based on the presence of its enemies in natural ecosystems. In the case of the water caltrop, these are invertebrates or vertebrates that actively use the vegetative parts or fruits of this plant.

Some animal species of waterbodies of Ukraine could theoretically be natural limiters of aquatic vascular plants: *Gallerucella nymphaeae* L., *Cricotopus sylvestris* Fabr., *Endochironomus tendens* Fabr., *Paraponyx stratiolata* L., *Acentropus niveus* Ol., *Lymnaea auricularia* L., *Phopalosiphum nymphaeae* L., *Abramis brama* L., *Ctenopharyngodon idella* Val., *Anser anser* L., and *Myocastor coypus* Mol. A number of researchers have studied quite well the biology and ecology of populations of the above herbivores, which limit the spread of water caltrop thickets (Gaevskaya 1966; Egereva 1958; Smirnov 1959; Shilova 1976 *et al.*). We have recorded feeding on water caltrop by two animal species: the mallard (*Anas platyrhynchos* L.) and the European water vole (*Arvicola amphibius* L.). Mallards consumed young leaves of a water caltrop as soon as they appeared on the water surface. We also found mature plants gnawed by the European water vole (Fig. 6).

According to the experience of botanists and conservationists of neighbouring countries, such as the Czech Republic, Poland, Russia, Belarus, Moldova, and countries of Western Europe and according to the European Environmental Agency, the water caltrop is a protected species in most of these countries and is included into the lists of threatened and rare species of these countries (EEA Agency of the European Union). In particular, it has a threatened status in Western Europe and Near Threatened in the red lists of the International Union for Conservation of Nature (IUCN Red List).

At the same time, the analysis of international databases on invasive adventive species (IAS) of aquatic plants showed that in the United States, as well as in some other American countries, the water caltrop is also considered as IAS. In particular, reports from experts and lists from the US Ministry of Agriculture and USDA's Plants Database of the Centre for Invasive Species and Ecosystem Health of the US National Park Service confirm this (Marion & Paillisson 2003).

Conclusions

The issues of protection and regulation of the water caltrop is a complex issue and it can be solved through a comprehensive inter-institutional dialogue between all counterparts working in the field of conservation and exploitation of water resources. This work should be based on a detailed inventory of the species according to a multi-criteria approach to diagnosing the species at different levels of biological organization in order to gain new knowledge about the quantitative and qualitative composition of the species population in Ukraine.

The identified locality of *T. natans* is so far the only one known in the Psel River and complements the information on the current distribution of this species. It is located approximately 145 km southeast of the Desna River, where the presence of this species in the Sumy Oblast was described earlier. An increase in the number of plants as much as 8 times was observed over the past four years, as well as an increase in the area of distribution by almost 3 km downstream.

Permanent monitoring is necessary for the protection of the discovered localities of the water caltrop. Despite the exclusion of the species from the Red Book of Ukraine, it is necessary to continue monitoring its habitats and studying the composition of its associations.

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