A City as a Source of Introduction for Tropical Alien Species (*Egeria Densa* Planch., *Pistia Stratiotes* L. & *Eichornia Crassipes* (Mart.) Solms) in Natural Ecosystems with a Temperate Climate

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Abstract

This paper is concerned with the study of ecology and invasive behaviour of southern tropical invaders (*Egeria densa*, *Pistia stratiotes, Eichornia crassipes)* in the setting of urban landscape water bodies with a temperate climate (the case of Kyiv, Ukraine). The article explores the role of a city as a source of invasions. It shows that escape from aquaculture (aquariums or decorative ponds) or deliberate release into natural water bodies are the main settlement solution. A brief historical background of these species found in water bodies of Ukraine has been presented. Favourable treatment for modern invasions of pantropical species has been analysed. Phytocoenotic special aspects of the communities formed by these species and ways and possibilities of naturalization of species in natural water bodies have been explored. Production indicators are being analysed.

Introduction

The European strategy for invasive alien species developed by the Berne Convention involves the current activity of the species that are away from their natural range is sharply increasing due to the product availability as a result of globalization (Butchart et al. 2010). It gives vectors and pathways for living organisms (plants, animals) to cross those biogeographic barriers that normally blocked their movement and spread (T-PVS-Inf 2016). Megalopolises with an ample quantity of pantropical alien species in the hands controlled by both professionals and amateurs are crucial here. Escape from aquaculture (aquariums or decorative ponds) or deliberate release into natural water bodies are the main settlement solution.

Significant changes in the main climate references are also an important factor when considering the current acceleration of the invasion of alien species. They are a reason of numerous indirect changes in aquatic ecosystems. The combined stresses that come with them mostly affect native hydrobiont species, but they are particularly influential to macrophytes (Reitsema et al. 2020).

Against the background of climate changes, the transformation of native macrophyte communities is intensifying due to anthropogenic transformation of aquatic habitats and anthropogenic eutrophication of waters. This results in a number of released ecological niches being suitable for new emigrants to settle in. Thus, over the past 15-20 years, the number of alien macrophyte species has increased by several times in Ukraine (Zub 2020). And if until recently the majority of alien macrophytes in the region were North American species (*Elodea sanadensis*, *Elodea nuttalli*, *Azolla caroliniana*, at the present stage there is an active penetration of species of more southern origin (*Egeria densa*, *Pistia stratiotes, Eichornia crassipes*). These species respond positively to the gradual increase in average annual water temperatures, as can be seen in the countries with temperate climate due to global climate change.

Like most macrophytes, these species have rapid growth, high productivity, wide ecological plasticity and the property to migrate over considerable distances. All these features determine the dynamics of the invasion. They form dense underwater (*Egeria densa*) or floating (*Pistia stratiotes*, *Eichornia crassipes*) thicket that can capture entire water bodies over a short period of time. These properties make them potentially dangerous alien species. In 2004, *Egeria* densa was added to the EPPO List of invasive alien plants. In 2008, the European and Mediterranean Plant Protection Organization included *Eichornia crassipes* to the A2 list where it recommended the species for regulation as a quarantine pest, and added Pistia stratiotes to the same list in 2017.

Waterways are excellent corridors for both the invasion and further spread of alien species. Expansions by waterways are usually rapid: the most striking examples of botanical "water" invasions include global water hyacinth infestation (*Eichhornia crassipes* (Mart.) Solms), which is a Brazilian native that has spread over the past century through tropical, reclamation, irrigation, and other navigational water bodies around the world – Africa, Australia, the United States, Indonesia, etc. In Europe, *Eichornia crassipes* spread across the river basins of France, Italy, Portugal and Spain, the species is recorded as random in several European countries with temperate climates – Belgium, Romania, the Netherlands, the United Kingdom and the Czech Republic (IAS 2017; EAA 2012) This species is now regarded as a serious weed in 52 countries around the world, causing significant damage and having a huge impact on aquatic ecosystems and water quality (De Groote et al. 2003; Golovanov et al. 2016).

The complex European Inland Waterway Network attributed to the spread of another tropical species with high invasive potential – *Egeria densa* Planch. (Cabi 2019). The South American, Brazilian, Argentinian, and Uruguayan bodies of water are the natural habitat for the species (Cook 1984). The plant was first found in the United States in 1893 (Mill Neck, Long Island) and put up for sale as a good oxygenator. This species was first discovered in Europe in a canal in the city of Leipzig (Germany) in 1910. This species was also found in Belgium, France, Hungary, Italy, the Netherlands, Spain, Switzerland, England, and Russia. It became an invasive species in six countries (Cabi 2019).

Another dangerous species, *Pistia stratiotes* L., is native in tropical and subtropical areas of Africa, Asia and South America. It is known that it was found in Europe in the second half of the 20th century, namely, in the Netherlands, Denmark, Germany, France, Spain, and Italy (EPPO 2021). At the onset of the 21st century, the species was discovered in the waters of Slovenia, Russia, and Ukraine.

The extension of a large city is accompanied by a radical transformation of the ecosystem (Marques et al. 2020). The temperature regime under urban conditions is milder, less extreme. This contributes to the introduction and spread of tropical alien species. Consequentially, urban ecosystems contain a large number of alien species, which was the outcome of human actions (Lososová et al. 2016; Richardson et al. 2011Furthermore, small plant phytocoenoses, which are mainly communities of macrophytes in urban hydroecosystems, are a convenient arena for the aggressor to spread. Therefore, this can lead to a complete transformation of the natural structure of the plant formation. The end result of such settlement is the formation of new viable populations with the required level of productivity and their "eviction" outside the urban landscape and naturalization in native ecosystems. And the modern enhanced anthropogenic transformation of natural aquatic biotopes (eutrophication of reservoirs, reduction of species diversity and changes in the structure of hydrobiocoenoses) and a significant number of newly created man-made reservoirs contributes to the activation of the processes of colonization of alien species to them.

This paper is concerned with the study of ecology and invasive behaviour of southern invasive species in the setting of urban landscape water bodies.

Material And Methods

The objects of research were local populations of Egeria densa, Pistia stratiotes, Eichhornia crassipes common in Kyiv and its suburbs. Kyiv is located in the midstream of the Dnipro, which flows through Ukraine from north to south for 1,100 km and is part of the Central European invasion corridor (Bij et al. 2002). The Kyiv area has a well-developed floodplain hydraulic network which transformed significantly with the development of the city. 2 expansion locations — *Egeria densa*, 6 – *Pistia stratiotes*, 3 – *Eichhornia crassipes* – were examined thoroughly (Fig. 1).

The study was conducted during the growing seasons May — October 2013 — 2021 using general hydrobotanical methods (Fasset 1969; Wood 1975). Traditional hydrobiological and hydrobotanic methods were used: field surveys (by route and semi-stationary methods), marking of test sites, monitoring sites, ecological-coenotic profiles, hydrobotanical mapping of reservoirs; population studies, coenotic, and production surveys, studies of trophic characteristics of biotope of anthropogenic eutrophication). Vegetation descriptions were carried out on sites with homogeneous conditions. For each place of growth the geographical location, type of reservoir, depth, presence and speed of flow, nature of sediments, and water temperature were indicated. Samples of phytomass were selected during the period when species reached maximum expansion and local populations – maximum density and phytomass (September – October). Slopes were selected at all research sites from the 0.1 m2 sample areas with the highest thicket density. Total soil cover (TSC) percentage in each description site as well as particular soil cover (PSC) percentage for each plant species were estimated. TSC and PSC were transleted into points accepted at the Braun-Blanquet School. Scientific names of family species are used in accordance with International Plant Names Index (IPNI 2021).

Brief Literature Review Of Species Invasions In Ukraine

All species got into the Ukrainian bodies of water and waterways precisely because of the intentional release: they were deliberately introduced into the decorative bodies of water of a city (mainly at private facilities, where there was no appropriate control of their expansion). What concerns *Edegia densa*, it most likely came from the aquarium cultivation. The invasion was facilitated by the average annual air temperature, which has increased by more than 2.5°C in Ukraine over the past 100 years (according to the data from the official portal of the Ministry of Environmental Protection and Natural Resources of Ukraine (MEPNRU 2021).

It is worth mentioning that the thermophilic species — *Egeria densa*— appeared in Eastern Europe within the climatic optimum of the secondary area: in Russia, Abkhazia, the Caucasus, and in the Far East (Kozhevnikov et al. 2009), and continental regions (Kapitonova et al. 2012). First findings of *Edegia densa* were also confirmed in the south in Ukraine – in the Crimea (Byalt et al. 2003). Three years later, in 2004, this plant was discovered more than 1,000 km to the north – in the canal remnants of the floodplain system of the Dnipro in the vicinity of Kyiv. This gives grounds to talk about two separate sources of the species' expansion in Ukraine.

The first finding in the midstream of the Dnipro (Left Bank of the Dnieper, southern outskirts of Kyiv) dates back to 2004; during 2005-2006, the species was recorded in the upper reaches of the Kaniv Reservoir (Bagatska 2007). According to T. S. Bagatska, in a year, the species was found 3 km downstream where its concentrations were recorded during 2005–2006. Ten years later, this species was recorded 600 km downstream of the Dnieper – in the Gulf of Sula of the Kremenchuk Reservoir (Starovoytova 2012). Rapidly spreading more than 100 km upstream along the Sula, its tributaries (marked for small rivers Sulitsa, Sliporod, Orzhytsia, Loknia, Byshkyn, Olava) and reclamation canals, *Egeria densa* it showed high coenotic activity, usually acting as a dominant communities of macrophytes. In 2016, our study could not confirm the expension of the species in the upper reaches of the Sula.

Pistia stratiotes were detected in Ukraine back in the 80s of the last century, however, they did not pose a particular threat because they freezing in winter (Dubyna et al. (2017). The development of local populations of the species was observed from time to time in decorative urban bodies of water (Odessa – 2005, Kyiv – 2009 (Lushpa 2009), they successfully overwintered and spread the following year. However, then they disappeared in these bodies of water, but were recorded on other ponds and decorative water bodies of a city (Prokopuk 2020). In 2011, *Pistia stratiotes* was reported in the canal of a thermal power plant on the Siverskyi Donets, near the urban village of Eskhar (south and east of Ukraine, Kharkiv Region) (Kazarinova et al. 2014). In 2013, thickets of the species are noted on the quarry bodies of water of Kryvyi Rih, which were formed in the depressions of the abandoned quarries of the lake) (Fedonenko et al. 2013).

Eichornia crassipes has not been recorded in Ukraine. In 2020, we first noticed a single specimen on one of the ponds in Kyiv.

Results

The *Egeria densa* communities were found in only two bodies of water of the city in late summer 2013 and 2015 (see Fig. 1): in the oxbow lake Zoloche (south border of Kyiv, Vyshenky Village) and in 2015 under the bank of the 1st lock of the drainage canal on the southern border of the city (the canal of Bortychi-Vyshenky). It should be noted that the population of the species did not go beyond the localities indicated in the sources for the first findings in the region in 2004. Individual specimens of the species were also found en masse in coastal macrophyte sediments. This gives grounds to assert the spread of

Egeria densa in other shallow sections of the canal and shallow waters of the Dnipro the canal joins with. The species vegetation began quite late in the conditions of the region studied. Mass thicket extension was observed in late August – early September, when the water warmed up above 20°C.

Egeria densa formed fragmentary spotted, usually monodominant tapetum thicket with a plant cover (PC) of up to 80-90% in sandy coastal shallow waters with a depth of 0.3-1.0 M (Table 1). It was mostly found in the areas with good water exchange (settlements with a weak current). It formed dense thicket, which completely covered shallow places. It can act as both a monodominant (80-90% PC) and a subdominant (20-30% PC) in the phytocoenosis respectively, forming communities of *Egerietun densa* and *Egerieto-Ceratophylletum demersi*. *Lemna minor* and *Spirodela polyrhiza* were singly observed in the phytocoenosis. In the setting of the localities studied, *Egeria densa* formed coenopopulations with phytomass indicators of 0.225-0.450 kg/m².

The 2020-2021observations showed only isolated *Egeria densa* in these localities, and they did not form individual plant communities, while a different species – *Pistia stratiotes* – reached massive expansion in these years in these sites.

Table 1
Phytocoenotic community characteristics involving Egeria densa

Description number*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
TPC, %	100	90	20	100	20	50	100	60	100	70
Depth, m	0.3	0.3	0.4	0.2	0.5	0.2	0.5	0.4	0.3	0.2
Soil type**	ds	ds	ds	s	s	s	s	s	s	s
Number of types	3	3	3	5	2	4	3	4	4	3
Egeria densa (Planch.) Casp.	5	4	1	2	1	2	3	2	r	r
Ceratophyllum demersum L.	2	.	+	4	1	3	3	3	5	r
Najas marina L.	.	.	.	r	.	.	.	.	1	.
Spirodela polyrhiza (L.)Schleiden	.	1	.	.	.	.	.	.	.	.
Lemna minor L.	r	1	.	r	.		r	r	r	.
Potamogeton perfoliatus L.	.	.	.	1	.	.	.	r	.	.
Typha angustifolia L.	.	.	1	.	.	.	.	.	.	.
Butomus umbellatus	.	.	.	.	.	r	.	.	.	.

Localization and date of description: 1-3-drainage canal of Bortnychi-Vyshenky Station (1st water gate) (Kyiv, 10.09.15); 4-10 – oxbow lake Zoloche (Kyiv Region, Boryspil District, the village of Vyshenky, 23.09.16);

** hereafter referred to as TPC– total projective cover in the plant community; *** s – sand, ds – silty sand

By 2020, *Pistia stratiotes* occasionally occurs on various decorative bodies of water of a city. These were weakly flowing eutrophic ponds with slightly silty sandy sediments. *Pistia stratiotes* usually created small spotted thickets, which disappeared the following year. Only during the study which took place in the autumn of 2016, the *Pistia stratiotes* concentration in the big pond (Sviatoshyn pond № 15), has achieved significant development, forming a separate belt of free-floating macrophytes along the thickets of helophytes. The formation of phytocoenoses involving the species in this location occurred in an unusually low temperature setting – the pond water temperature for this period was + 9 ° C. An interesting feature was that during the formation of the coenoses, the floral composition of macrophytes of the body of water was somewhat depleted – 8 species occurred (as a comparison, in the summer of 2015, we registered 15 species in the body of water). *Spirodela polyrhiza* (L.) Schleiden, *Potamogeton crispus* L., *Stuckenia pectinate* (L.) Borner, *Batrachium circinatum* (Sibth.) Spach, *Schoenoplectus lacustris* (L.) Palla, *Iris pseudoacorus* L., *Persicaria amphibia* (HL.) Delarbre were not detected as familiar components of the macrophyte flora of the city's body of water.

When the water level fell and the coastal shallow waters dried up, the formation of *Pistia stratiotes*, an amphibious ecomorph, was observed when the plant formed dense leathery rosettes on the mudbank.

At the end of summer of 2020, *Pistia stratiotes* gave a massive outbreak of development: most of the city's canals and floodplain bodies of water on the Left Bank of the Dnipro on the south-eastern border of Kyiv was overgrown with formed coenoses of the species. Thickets occupied the entire surface of water bodies (Fig. 2).

Pistia stratiotes created low-species monodominant coenoses (table. 3), in which duckweed only occasionally occurred (mainly *Spirodela polyrhiza).* The population of the species successfully overwintered and in the summer of 2021, fragmental mosaic thickets occurred once again in last year's locations. However, we did not observe such a large-scale development as it was in 2020 (see Fig. 2). The *Pistia stratiotes* production indicators research that lasted two years which occurred at the end of the growing period show that in 2021, raw phytomass was formed 6 times less in the same localities than in the same period of 2020 (Fig. 3). A pronounced variation in the production parameters of individual samples *Pistia stratiotes* within the same locality (Fig. 4).

Table 2
Phytocoenotic community characteristics involving *Pistia stratiotes*

Description number*	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
TPC**, %	90	100		100	100	100	70	100	60	40
Depth, m	0.4	0.5	0.2	0.4	0.2	0.4	0.5	0.4	0.3	0.3
Soil type***	ds	ds	s	ds	ds	ds	ds	s	s	s
Number of types	6	2	3	1	1	6	2	6	2	4
Pistia stratiotes L.	4	5	4	5	5	5	4	5	4	3
Egeria densa (Planch.) Casp.	.		r	.	.	.	.	r	r	r
Ceratophyllum demersum L.	r	1	.	.	.	.	.	.	.	
Elodea canadensis Michx.	.	.	.	.	.	.	.	.	.	r
Elodea nuttallii Planch.	.	.	.	.	.	r	.	.	.	
Najas marina L.	r		.	.	.			r	.	r
Nuphor lutea(L.) J.E.	.	.	.	.	.	r	2	.	.	.
Spirodela polyrhiza (L.) Schleiden	1		.	.	.	.	.	.	.	.
Lemna minor L.	r	.	.	.	.	r	.	.	.	.
Potamogeton crispus L.	r	.	.	.	.	.	.	.	.	.
Typha angustifolia L.	.	.	.	.	.	.	.	1	.	.
Sparganium erectum L.	.	.	1		.	r	.		.	.
Phragmites australis (Cav.) Trin. ex Steud.	.	.	.	.	.	1	.	1	.	.
Glyceria maxima (C.Hartm.) Holmb.	.	.	.	.	.	.	.	1	.	.

Localization and date of description: 11-12 – Sviatosyn Pond № 15 (Kyiv, 23 September 2016), 13 – drainage canal of Bortnychi-Vyshenky Station (1st water gate) (20.08.20); 14 – drainage canal of Bortnychi-Vyshenky Station (2nd water gate) (20.08.20); 15 – drainage canal of Bortnychi-Vyshenky Station (2nd water gate) (20.08.20); 16 – drainage canal of Bortnychi-Vyshenky Station (3rd water gate) (20.08.20); 17 – drainage canal of Bortnychi-Vyshenky Station (3rd water gate) (21.09.21); 18 – oxbow Zoloche (13.10.20); 19 – drainage canal of Bortnychi-Vyshenky Station (2nd water gate) (21.09.21); 20 – oxbow Zoloche (21.09.21).

A scale of values is plotted on the radius, and the ordinal number of samples is plotted around a circle.

First single *Eichornia crassipes* findings were recorded in 2020 in one of the park ponds in Kyiv. The plant has not reached the flowering stage and has not overwintered.

In 2021, widespread outbreaks of *Eichornia crassipes* in the drainage canals of the Osokorky suburban area and the Dnipro straits outside Kyiv. Here, a fragmentary belt of thickets was formed everywhere involving the species under the helophyte belt. *Eichornia crassipes* formed subdominant coenoses with sinusia of free-floating plants (*Lemna minor, Salvinia natans, Stratiotes aloides)* or monodominant thickets that sometimes occupied water areas that were not overgrown with helophytes (Table 3).

Table 3
Phytocoenotic community characteristics involving *Eichornia crassipes*

Description number*	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
TPC**, %	100	100	100	100	100	100	100	100	90	100
Depth, m	0.3	0.4	0.4	0.4	0.3	0.5	0.1	0.4	0.4	0.5
Soil type***	s	s	s	s	s	s	s	s	ds	ds
Number of types	7	2	6	4	4	1	1	1	2	3
Eichornia crassipes (Mart.) *Solms.*	4	3	+	5	4	5	5	4	3	1
Ceratophyllum demersum L.	r	2	.	.	.	.	.	.	.	.
Lemna minor L.	3	.	4	3	2	.	.	.	.	.
Stratiotes aloides L.	r	.	r	+	1	.	.	.	.	r
Salvinia natans (L.) Allioni	r	.	3	r	1		.	.	.	4
Sparganium erectum L.	.	.	r	.	.	.	.	.	.	.
Phragmites australis (Cav.) Trin. ex Steud.	+	.		.	.	.	.	.	.	.
Zizania latifolia L.	1	.		.	.	.	.	.	1	.
Glyceria maxima (C.Hartm.) Holmb.	.	.	r	.	.	.	.	.	.	.
* Localization and date of description: 21-28 the Dnipro (6.10.21); 29-30 – drainage canal of Bortnychi-Vyshenky Station (4water gate) (25.10.21).										

The *Eichornia crassipes* plants bloomed and formed phytomass reserves in a raw weight of 2.67-13.11 kg/m². As in *Pistia stratiotes*, a variation of individual samples within the local population was observed in the phytomass values (Fig. 5)

A scale of values is plotted on the radius, and the ordinal number of slopes is plotted around a circle.

Discussion

Long-term studies looking into regional features of the tropical alien species behaviour in urban bodies of water have shown its ephemeral character: the mass and rapid development of communities is usually replaced by development subsiding, sometimes to complete elimination. This process is accompanied by a change in the phytocoenotic composition of shallow water habitats (Table 4): with the outbreak of alien development, native species (primarily hydrophytes) are just as rapidly falling out of plant aggregations. For example, the *Pistia stratiotes* massive development in the drainage canal in 2020, 12 native species disappeared from shallow waters. Formation of coenoses *Egeria densa* in the Zoloche floodplain bodies of water was accompanied by the disappearance of mesotrophic species, such as *Nuphor lutea* (L.) J.E., *Trapa natans* L. and *Caulinia minor* (All.) Coss.) J.E., expended here in 2014 (see Table 4). According to G. Kazarina (Kazarinova 2014), due to the development of the *Pistia stratiotes* populations in the Siverskyi Donets in 2014, when about 70% of the area of bodies of water was covered with a continuous layer of specimen of the species, there were changes in the degree of trophic water from mesoeutophic to eutrophic. The non-flowing hydraulic systems changed its flow to hyperevtrophic. The *Pistia stratiotes* phytomass transition in detritus, the restoration of natural trophic activity was delayed for several years.

An extensive system of floodplain bodies of water and drainage canals within the city, their direct connection with the Dnieper makes it logical for these species to go beyond the urban landscape to the Dnipro Hydroelectric Station (as confirmed by an *Eichornia crassipes* outbreak in the branches of the Dnipro below the suburban areas of a city). When A. Afanasiev (Afanasev et al. 2016) first noted the Pistia stratiotes finding in the Dnipro in 2005 (upper sections of the Kaniv Reservoir), plants were massively fused by the current, the width of the strip was 30-50 m. According to the author, the species found there extended there but did not overwinter. In 2008, 2010, and 2011, single specimen of *Pistia stratiotes* dumped on the sandy beaches of the Dnieper of Kyiv were detected.

Table 4
Dynamics of the phytocoenotic composition of the biotopes under study

	drainage canal			**oxbow Zoloche**			**Dnipro River**	
Phytocoenotic description №	2015	2016	2020	2014	2016	2020	2015	2021
Total number of types	16	6	4	9	6	8	12	9
Egeria densa (Planch.) Casp.	II^{r}	IV^{4-5}	IV^{r}	-	V^{r-3}	II^{r}	-	-
Pistia stratiotes L.	-	-	V^{r-5}	-	-	V^{4-5}	-	-
Eichornia crassipes (Mart.) Solms.	-	-	-	-	-	-	-	V^{r-5}
Elodea nuttallii (Planch.) H. St. John		IV^{1}					II^{2-3}	
Ceratophyllum demersum L.		IV^{2}		II^{r-+}	V^{r-4}	II^{r}	II^{r}	II^{r-2}
Myriophyllum spicatum L.	II^{r-1}	II^{r-1}					II^{r-1}	
Najas marina L.	II^{r-1}				III^{r}	II^{r}	III^{r}	
Potamogeton perfoliatus L.	II^{r}			II^{1}	II^{1}		II^{1}	
Potamogeton crispus L.	II^{r-1}							
Stuckenia pectinata (L.) Borner	II^{r}			II^{1}			II^{1}	
Caulinia minor (All.) Coss.	I^{r}			I^{1}				
Hydrocharis morsus-ranae L.	II^{r-+}						II^{r-+}	
Nuphor lutea (L.) J.E.	IV^{r-2}			II^{r}		II^{+}		
Trapa natans L.	III^{1-3}			II^{r}			I^{1-3}	
Stratiotes aloides L.	II^{r-1}	II^{r-1}					III^{r-1}	IV^{r-1}
Spirodela polyrhiza (L.)Schleiden	III^{1-3}			II^{+}			II^{+}	
Salvinia natans (L.)Allioni							III^{r-4}	IV^{r-4}
Lemna minor L.	II^{r-+}	III^{r-1}			IV^{r}	IV^{+}	II^{r-+}	III^{2-4}
Typha angustifolia L.				II^{+-1}		II^{r}		

I – type is given in less than 5% of descriptions, II – 5-25%, III – 25-50%, IV – 50-75% and V – 75-100%.

	drainage canal			oxbow Zoloche			Dnipro River	
Typha latifolia L.			I^{1}					
Butomus umbellatus L.					II^{r}			
Phragmites australis (Cav.) Trin. ex Steud.						I^{1}		I^{+}
Zizania latifolia L.								I^{1}
Glyceria maxima (C.Hartm.) Holmb.	I^{1}					I^{1}		I^{r}
Eleocharis palustris L.				II^{r}				
Sparganium erectum L.							II^{1}	II^{1}
Sagittaria sagittifolia L.	II^{+-1}						II^{+-1}	
I – type is given in less than 5% of descriptions, II – 5-25%, III – 25-50%, IV – 50-75% and V – 75-100%.								

The formation of stable local populations in the conditions of natural watercourses and floodplain bodies of water can be expected, since this has already been observed in the *Egeria densa* reproduction in the conditions of the hydraulic network of the Stugna in 2013) (Starovoytova 2012).

This is also facilitated by the fact of flowering and fruiting that we have noted *Pistia stratiotes* and *Eichornia crassipes.* The possibility of generative reproduction in temperate climates has already been considered for other European countries (Neuenschwander et al. 2009; Buzgo 2015). However, in most case *Pistia stratiotes* reproduces vegetatively. It forms small colonies with daughter plants attached to the mother plant by stolons that develop in the axils of lower leaves. The expansion is enhanced by the separation of daughter plants that form new colonies. Allelopathic interaction with species of the local aquatic flora is believed to be one of the mechanisms of invasive species dominance in aquatic plant community (Aliotta et al. 1991).

The severity of variations in production parameters in the middle of local populations of these species indicates their plasticity in the conditions of the research region, which is usually characteristic of species that are at the first stages of invasion. The first large-scale infestations of tropical alien species, which covered the natural Ukrainian biotopes and caused serious environmental damage, occurred in the Siverskyi Donets mentioned earlier in 2014 due to a massive outbreak of *Pistia stratiotes* (Kazarinova et al. 2014; Mosyakin et al. 2014). General trends towards its further invasive spread on the territory of Ukraine are outlined (Mosyakin et al. 2014).

Phytoinvasions of thermophilic species in natural bodies of water are facilitated by the high concentration of industry-related facilities with an open water cycle in the region (Dubyna et al. 2017).

Another feature of these species is their ability to withstand anthropogenic pollution of water bodies: they can grow in reservoirs with a low content of CO_2 in water, low light, withstand high levels of phosphorus or inorganic nitrogen (Zub 2020; Williamson 1996).

The high competitiveness of species, the ability to reproduce vegetatively and spread over considerable distances over a short period of time is considered as the basis for attribution *Egeria densa*, *Pistia stratiotes*, *Eichornia crassipes* to species with a CR strategy.

Conclusion

Due to the widespread and uncontrolled use of tropical alien species, cities are the source of their penetration into urban and natural hydroecosystems. High competitiveness and eurythopicity of popular species in urban aquaculture – *Egeria densa, Pistia stratiotes*, *Eichornia crassipes* – gives grounds for us to consider them as types of violet ecological and phytocoenotic strategy (CR-strategists), capable of further invasive distribution by the drainage system of Ukraine. The formation of stable local populations in the conditions of natural watercourses and floodplain bodies of water may be expected. If the climate softens, which is observed in temperate latitudes, they are able not only to naturalize in the natural hydraulic systems of Ukraine, but also to prove themselves as Transformers. The severity of variations in production parameters in the middle of local populations of these species indicates their plasticity in the conditions of the research region and the first stages of their invasion.

Declarations

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Consent for publication All authors give their consent for publication.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Mariana Prokopuk, Lesya Zub and Yuliia Bereznichenko. The first draft of the manuscript was written by Mariana Prokopuk and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

Distribution map of tropical invasive species in the bodies of water of Kyiv and its suburbs (2013-2021)

Figure 2

General view of the overgrowth of oxbow lake of Zoloche with the Pistia stratiotes coenoses

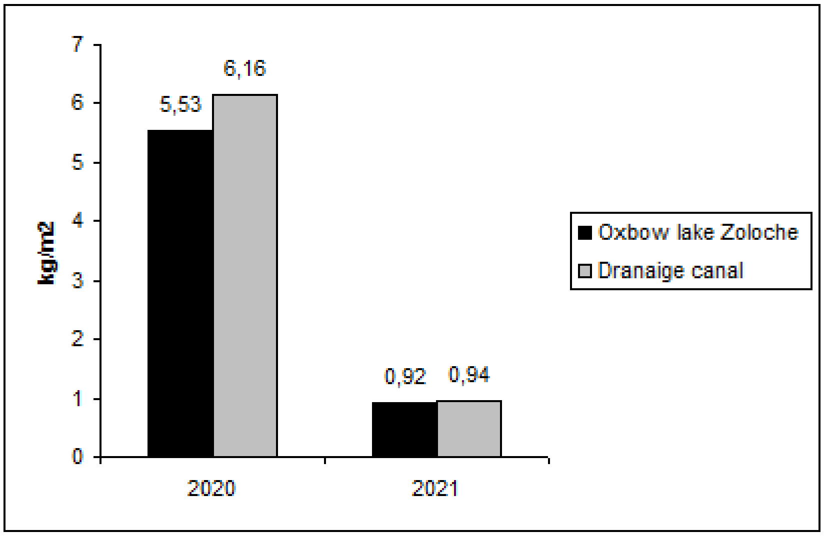

Figure 3

Pistia stratiotes phytomass dynamics in model localities

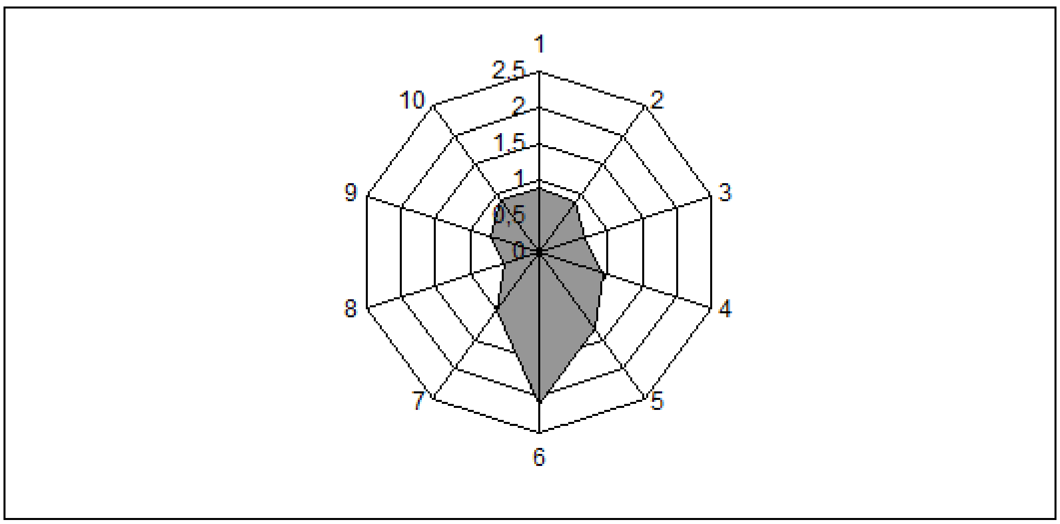

Figure 4

Variation of the Pistia stratiotes phytomass value (raw phytomass, kg/m²) in the local population.

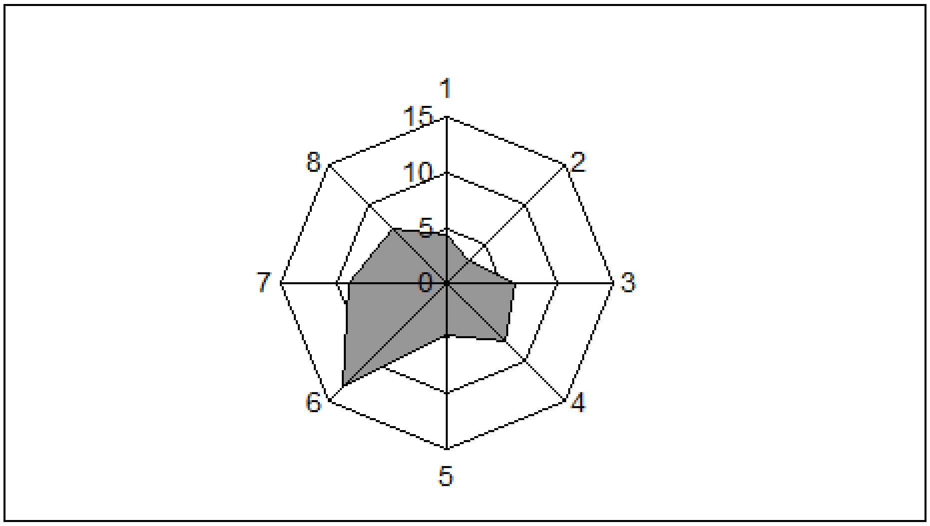

Figure 5

Variation of the Eichornia crassipes phytomass value (raw phytomass, kg/m²) in the local population.