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Original article

Impatiens glandulifera (Balsaminaceae) in Ukraine: its current distribution, ecological and coenotic features

Serhii M. Koniakin*, Liubov M. Gubar, Vasyl V. Budzhak

National Academy of Sciences of Ukraine, Institute for Evolutionary Ecology, Lebedeva 37 Str., 03143 Kyiv, Ukraine
E–mail address (corresponding author): ser681@ukr.net*
ORCID iD: Serhii M. Koniakin: https://orcid.org/0000-0002-6715-5707; Liubov M. Gubar: https://orcid.org/0000-0003-4904-1092; Vasyl V. Budzhak: https://orcid.org/0000-0002-7754-6437

ABSTRACT

Data on the spontaneous distribution (529 sites) of *Impatiens glandulifera* in the territory of Ukraine have been collected and studied comprehensively. *I. glandulifera* invades plant communities of the *Phragmito-Magnocaricetea* class (1 alliance), *Salicetea purpureae* (1 association), *Alnetea glutinosae* (1 association), *Robinietea* (2 associations), and *Epilobietea angustifolii* (2 associations). The species phytoindicative assessment, which considered 12 ecological factors, revealed that in its secondary distribution range *I. glandulifera* shows characterics of a stenotopic hygromesophyte, subacidophile and is a semi-eutrophic species. In the studied areas, the environmental niche of *I. glandulifera* is limited mainly by soil water response (Hd) and saline (Sl) regimes, and soil carbonate content. A thermal regime (Tm) response of the species to an increase in the average annual air temperature by 1, 2, and 3^{0}C has been predicted. A temperature increase of 2^{0}C could, lead to a critical shift in the values of soil acidity (Rc) and salinity regimes (Sl) that might cause a decline of the species' potential niches in the studied area. The obtained data have the potential to be useful in limiting the spread of *I. glandulifera* into new territories and reducing its transforming effect in plant communities of river valley corridors.

KEY WORDS: econiches, invasive alien species, plant communities, riverine habitat

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1. Introduction

Biological invasion is one of the most significant ecological threats to biodiversity, which can change the functioning of ecosystems and the provision of ecosystem services (Wilcove et al., 1998; Biological invasions, 2012; European Strategy, 2015; European Commission, 2017). In new habitats, alien plant species usually grow locally but human activity and environmental changes, can provoke them to spread spontaneously and cause "invasions" (McNeely et al., 2001; Rai & Singh, 2020). Invasive alien species (IAS) have a great and lasting impact on the functioning of ecosystems. Sometimes IAS populations grow spontaneously and expand their secondary range (Korpelainen, 2021), triggering irreversible environmental changes, and consequently threatening public health (Roiloa et al., 2020). In addition, IAS not only supersede native species, but also cause serious socio-economic loss when they invade aboriginal species communities (McGeoch et al., 2010; Kim et al., 2021).

Impatiens glandulifera Royle (Balsaminaceae) is an ergasiophyte, and a self-pollinating annual plant, which is spreading throughout Europe due to its being highly decorative, and having significant seed production and rapid growth (Lambdon et al., 2008; Helsen et al., 2021). Also, the invasions of the species are observed in certain provinces of Canada, the USA, New Zealand, and Japan (Beerling & Perrins, 1993; Cockel & Tanner, 2012; Perrins et al., 1993; Weber, 2003). *I. glandulifera* is a strong competitor with a high plastic reaction, which is

capable of creating dense monocultures (HULME & BREMNER, 2006; PERRINS ET AL., 1993; SKALOVA ET AL., 2012), and threatening the local biota (TANNER & GANGE, 2020). Regarding the high ecological and socioeconomic consequences of *I. glandulifera* invasion, we performed a spatial data collection from a large area in Ukraine, which is included in the species' secondary distribution range in Europe, and undertook a comprehensive analysis of the species' ecological niche and ecological factors limiting its spread to new areas.

2. Material and methods

The study of *I. glandulifera* is based on a detailed analysis of herbaria materials, scientific publications (PROTOPOPOVA ET AL., 2015; TARASEVICH & ORLOV, 2013; PROTOPOPOVA & SHEVERA, 1998; TOKARYUK ET AL., 2018; ZAVIALOVA, 2017; HRYTSYNA & LYUBYNETS, 2015; LYUBINSKA & MATVIEIEV, 2021) and materials from our own field descriptions.

For the species' current distribution in the territory of Ukraine, we used materials from herbarium collections of M.H. Kholodnyi Institute of botany, NAS of Ukraine (*KW*), M. M. Hryshko National Botanical Garden of the National Academy of Sciences of Ukraine (*KWHA*), Institute of Ecology of the Carpathians of the National Academy of Sciences of Ukraine (*LWKS*), Taras Shevchenko National University of Kyiv (*KWU*), Uzhhorod National University (*UU*), Yuriy Fedkovych Chernivtsi National University (*CHER*), Kherson National University (*KHER*); Pavlo Tychyna Uman State Pedagogical University (*UPU*), V. N. Karazin Kharkiv National University (*CWU*), National University "T.H. Shevchenko Chernihiv collegium" (*CHU*). We also used data from, on-line resources, i.e. UkrBIN (https://ukrbin.com), INaturalist (https://www.inaturalist.org), GBif (https://www.gbif.org), Encyclopedia of Life (https://eol.org), Catalogue of Life (http://www.catalogueoflife.org), and Plants of the World Online (https://powo.science.kew.org).

Distribution maps of *I. glandulifera* were made using MapInfo Professional 7.5 software[1] and the network mapping method in accordance with ATLAS FLORAE EUROPAEAE (1972) methodology adapted to the territory of the studied region.

The syntaxonomic scheme of vegetation with the participation of *I. glandulifera* was created using our geobotanical descriptions carried out during field research in 2021–2022 and supplemented with geobotanical descriptions from open sources (TOKARYUK ET AL., 2018). The total data array included 58 geobotanical descriptions involving *I. glandulifera.*

Database formation and merging of geobotanical descriptions were carried out via Turboveg for Windows v. 2.142a (HENNEKENS & SCHAMINÉE, 2001) with subsequent export to Juice 7.1 (TICHY, 2002). Since the used databases, such as the nomenclature standard, use the "Russia" species list, which is based on S.K. Cherepanov's nomenclature summary (CHEREPANOV, 1995), the list of species has been checked and brought into line with the Internet resource known as "The Euro+Med PlantBase" (https://europlusmed.org/).

The names of syntaxa and the classification scheme of vegetation have been compiled in accordance with "Prodrome of Vegetation of Ukraine" (DUBYNA ET AL., 2019) with additions to the EuroVegBrowser (MUCINA ET AL., 2016) reference system.

The ecological characteristics of the species were assessed by calculation of quantitative phytosociological indicators of 12 leading ecological factors according to the corresponding scales of Ya.P. Didukh and P.H. Pliuta (DIDUKH & PLIUTA, 1994; DIDUKH ET AL., 2000) via JUICE software (TICHY, 2002).

To build a cyclogram of the distribution of quantitative indicators of the leading ecofactors and to establish the ecological valence of the species, we used our own software for automating the process of calculating point indicators of ecological factors (DIDUKH & BUDZHAK, 2020).

The impact of climate change on *I. glandulifera* distribution has been assessed according to the results of calculating the values of 12 indicators of leading ecofactors based on Ya.P. Didukh's scales and methods (DIDUKH, 2011, 2021).

3. Results

According to general data, 529 localities of *I. glandulifera* were identified in Ukraine, which are shown on the map of Ukraine (Fig. 1). The localities marked on the map correspond to a time interval of about 25 years.

Analysis of the dynamics of the detection of *I. glandulifera* sites (Figs. 1, 2) in the last 30 years shows its exponential nature, which is facilitated by the presence of many potential places for its existence. This gives us reason to classify *I. glandulifera* as a species which is actively spreading in certain areas. At the same time, an increase in the number of new sites of *I. glandulifera* have been observed, mainly along valleys and floodplains, on wet roadsides and in anthropogenic ecotopes.

[1]Product – 20MIRU750WP Serial Number–MIPWRS0750400147

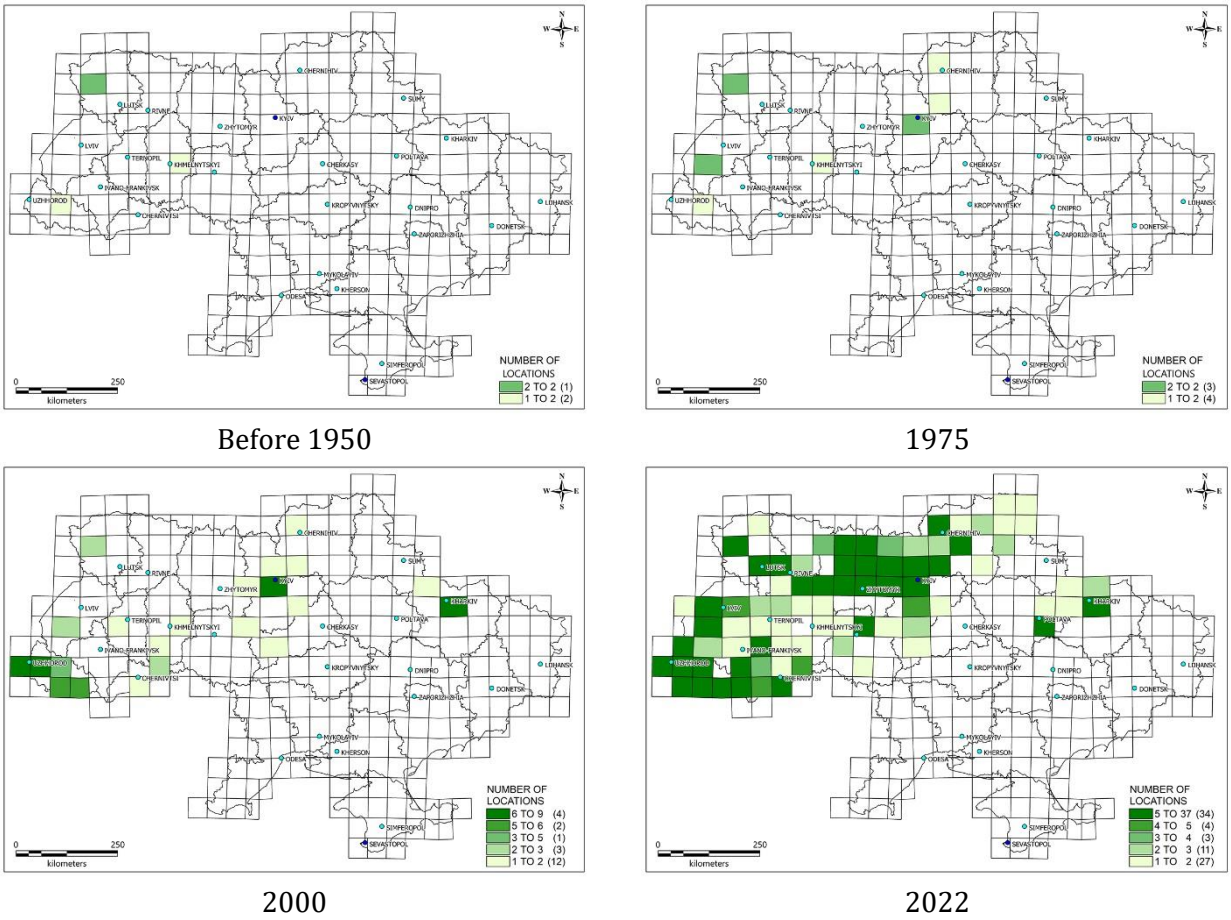


Fig. 1. *Impatiens glandulifera* Royle distribution in Ukraine

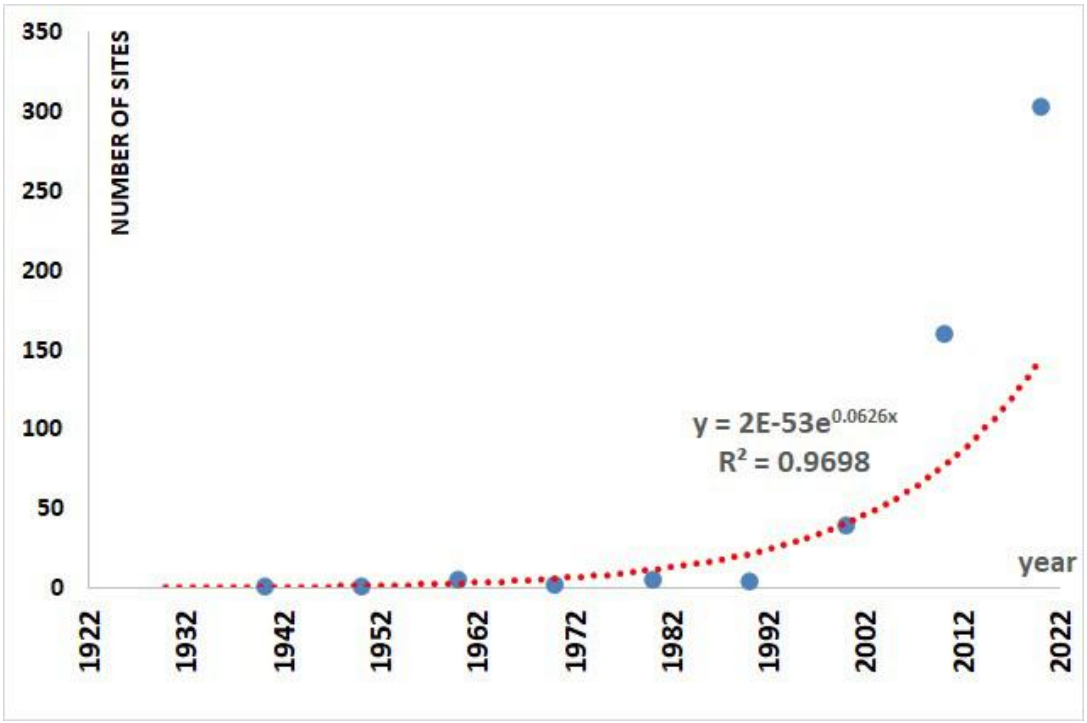


Fig. 2. Dynamics of the detection of *Impatiens glandulifera* Royle sites in the territory of Ukraine

Species and coenotic composition of phyto-coenoses with the participation *Impatiens glandulifera* in Ukraine have been studied and covered fragmentarily. We compiled a syntaxonomic scheme of the vegetation in the territory of Ukraine which included *I. glandulifera*: (see Table 1):

Cl. *EPILOBIETEA ANGUSTIFOLII* Tx. et Preising ex von Rochow 1951
Ord. *Circaeo lutetianae-Stachyetalia sylvaticae* Passarge 1967
All. *Aegopodion podagrariae* Tx. 1967
Ass. *Reynoutrietum japonicae* Görs 1974 corr. Hilbig 1995
Ord. *Convolvuletalia sepium* Tx. ex Moor 1958
All. *Senecionion fluviatilis* Tüxen ex Moor 1958
Ass. *Calystegio sepium-Impatientetum glanduliferae* Hilbig 1972
Cl. *SALICETEA PURPUREAE* MOOR 1958
Ord. *Salicetalia purpureae* Moor 1958
All. *Salicion albae* Soó 1951
Ass. *Populetum nigro-albae* Slavnić 1952
Cl. *ROBINIETEA* JURKO EX HADAČ ET SOFRON 1980
Ord. *Chelidonio-Robinietalia pseudoacaciae* Jurko ex Hadač et Sofron 1980
All. *Chelidonio-Acerion negundi* L. Ishbirdina et A. Ishbirdin 1991
Ass. *Chelidonio-Aceretum negundi* L. Ishbirdina et A. Ishbirdin 1991
All. *Chelidonio majoris-Robinion pseudoacaciae* Hadač et Sofron ex Vítková in Chytry 2013
Ass. Elytrigio repentis-Robinietum pseudoacaciae Smetana 2002
Cl. *PHRAGMITO-MAGNOCARICETEA* KLIKA IN KLIKA ET NOVÁK 1941
Ord. *Nasturtio-Glycerietalia* Pignatti 1953
All. Phalaridion arundinaceae Kopecký 1961
Cl. *ALNETEA GLUTINOSAE* BR.-BL. ET TX. EX WESTHOFF ET AL. 1946
Ord. *Alnetalia glutinosae* Tx. 1937
All. Alnion glutinosae Malcuit 1929
Ass. *Carici elongatae-Alnetum* Schwickerath 1933

Communities of the association *Calystegio sepium-Impatientetum glanduliferae* (Fig. 3), which are formed on floodplains, along streams and communication routes, were noticed in Bukovyna Cis-Carpathian Region, Volyn and Kyiv Polissias. The vegetation cover (total projected cover 90–100%) is dominated by *I. glandulifera;* and *Urtica dioica, Artemisia vulgaris, Solidago canadensis* co-dominate. The number of species in the coenoses varies from 9 to 30. In the floristic composition of the association communities, 89 species were found, among which were several invasive plant species – *Solidago canadensis*, *Acer negundo*, *Impatiens parviflora*, *Erigeron annuus*, *Erigeron canadensis, Echinocystis lobata* and *Geranium sibiricum* (Table 1, cluster 1).

As part of the communities of the association *Populetum nigro-albae*, which is formed on elevated areas with turf-sand and meadow-swamp soils under conditions of periodic flooding, *I. glandulifera* was found in the floodplain forests of Podillia (the Southern Bug River) and Kyiv Polissia. In these communities, the species occurs both as single specimens and forms small groups (up to 40% of the projected cover). *Salix alba* and *Populus alba* dominate in the tree layer, where canopy layer closure does not exceed 35–40%. Species diversity is represented by 88 species. The grass cover is co-dominated by *Urtica dioica* and *Calystegia sepium* (Table 1, cluster 2). *Parthenocissus inserta* and *Humulus lupulus* vines have a high percentage projected cover.

In the territory of the Eastern Carpathian Foothills, Podillia and Polissia, *I. glandulifera* also penetrates the *Chelidonio-Aceretum negundi* community, which is formed mostly on dense substrates under conditions of sufficient moisture (Table 1, cluster 3). The tree layer is dominated by *Acer negundo* with a minor admixture of *Salix alba* and *Populus alba*. The species composition of the communities is represented by 112 species of higher vascular plants. *Chelidonium majus, Elytrigia repens* and *Urtica dioica* predominate in the grass layer. A well-defined spring efemeroid sinusia is dominated by *Galium aparine*. In some sites, the participation of *I. glandulifera* in the projected cover can reach 30%. The penetration of this species into artificial plantations of the class *Robinietea* (association *Elytrigio repentis-Robinietum pseudoacaciae*) on eroded chernozem-like or loamy soils was also noted, the community is represented by 54 species of higher vascular plants. The coverage of *I. glandulifera* in some localities reaches 25% (Table 1, cluster 4).

Quite often, *I. glandulifera* is a component of hygrophytic and mesohygrophytic communities of coastal areas of water bodies with sandy and loamy soils that are sometimes flooded (alliance *Phalaridion arundinaceae*) (Table 1, cluster 5) (Fig. 4).



Fig. 3. Community of the association *Calystegio sepium-Impatientetum glanduliferae*
(Boiarka, Kyiv region. Photo by S. Koniakin)



Fig. 4. *I. glandulifera* in communities of the alliance *Phalaridion arundinaceae*
(Vinnytsia, Vinnytsia region. Photo by S. Koniakin)

Table 1. Phytocoenotic characteristics of communities with the participation of *Impatiens glandulifera*

Impatiens glandulifera_58_releves_one releves 3.wc

Number of releves: 58
Number of group: **1111111111122222222222223333333333333333333333344444445555**

Number of releves: 444144 1344 22 22221 24555 554553314123213 31253533 1131
30726583112135987230186497562388414944057758931602260496 57

***D.s. Ass. Calystegio sepium-Impatientetum glanduliferae* Hilbig 1972**

Calystegia sepium 1+12+221.+.2313..1..+.....+.....

***D.s. Ass. Асоціація Populetum nigro-albae* Slavnić 1952**

Phragmites australis .....444332...+.....
Salix alba .....1....12.2.223211+...1.....+..1.....+..1....
Populus alba .....+.....2...+.....+....

***D.s. Ass. Chelidonio-Aceretum negundi L.* Ishbirdina et A. Ishbirdin 1991**

Acer negundo ....12+.....+..1..+3333322222221+1++++1++2++++.....
Chelidonium majus .....2.+...1.11+..31..1..22.....3+++.2.11.....

***D.s. Ass. Elytrigio repentis-Robinietum pseudoacaciae* Smetana 2002**

Elytrigia repens 1+....2.2+..+++.3..3.....112.2..+12...1..2....333.1114....
Galium aparine .....1.....1..1.3222..+13232.12321....221.3+..2444+.1112.
Ballota nigra ..+.111.....1.+3+.....++..+..

***D.s. All. Phalaridion arundinaceae* Kopecký 1961**

Poa trivialis .....+..+..11112.2.....+.11.+....2+.....2+1+4542

***D.s. Cl. EPILOBIETEA ANGUSTIFOLII* Tx. et Preising ex von Rochow 1951**

Glechoma hederacea 22+3.....2.....+.....++1...+....2.....
Solidago canadensis 343.22+..+2..+..1..+.....1.3..3.....+..
Erigeron annuus 22+.12...1...2.....+.....+2.....
Lapsana communis 2...+.....+.....2.....
Chaerophyllum aromaticum .2.....2.....1.+.....3.....
Urtica dioica 2+352243.232.123.41.3+112++.+.3+2..2422442+.2.41113.+13+1.
Petasites hybridus ....21.....+.....
Sonchus arvensis ...1+.....1.....
Calamagrostis epigeios .....+.....2..1.....3.....
Lamium album 1.....+.....
Lamium maculatum 2.....+.....
Eupatorium cannabinum ....2+.....+.....+....
Geum urbanum 1...+....+++.....+.+...++.....+.1..13....2...+...1+3.
Impatiens parviflora 2..1.....+2.+.....+...1.+2..+....1...2.....1..2...+
Asperugo procumbens .....+.....++.....
Alliaria petiolata .....++...+.....1.1
Impatiens glandulifera **42434333555312444+33+11323322234+42+3442343422223423433433**
Helianthus tuberosus .....1.....2.....

***D.s. Cl. ROBINIETEA* Jurko ex Hadač et Sofron 1980**

Aegopodium podagraria	3....1..........1.......111..+.+.1.21.2.........11.....3
Parthenocissus inserta	......1..........22+31..2..15..213....1.1.23.2...1..+.....
Humulus lupulus	...+2......++1+.+1....+..2.+.1+.+.2...1+1..+1.+..++2..+.+.
Robinia pseudoacacia	1...++....+.........+..............2.....
Rubus caesius	.2+.3+...+.............+12+......1........1........2....
Rubus idaeus	.1...1.....
Salix caprea	....................1...................1..............
Sambucus nigra	..........1......++.1..++..........+1.........+..........+
***D.s. Cl. PHRAGMITO-MAGNOCARICETEA* Klika in Klika et Novák 1941**	
Glyceria fluitans	........2..............2.................................+..
Glyceria maxima	.......2...+..............3..............................
Typha latifolia	........3.......1.......................+...............
Other species	
Acer platanoides	+....1+.............................+.+.....................
Acer pseudoplatanus	.+.....................+...+..............................
Ajuga reptans	1....1..................................1.....................
Alnus glutinosa	......................+2+..........3...................+...
Alopecurus geniculatus	...2...2..............................3...1..............
Alopecurus pratensis	........+...1..
Ambrosia artemisiifolia	......+.....................21......+..........3..........
Angelica archangelica	............1.............................3...........+.+
Arctium lappa	1...2..1....+..+....+....++......++..+...+.....+.+..+...+.
Arctium tomentosum	1.....2.............................1.....................
Argentina anserina	1.....2...1.....
Armoracia rusticana	1.........................+..............................
Arrhenatherum elatius	.+.+...............3.................................+...
Artemisia vulgaris	13+.21....2..+.............12+.....+.11....................
Bidens frondosa	.............1..2...........+3.+..........................
Bromus carinatus	........................+........2.....+.1.....+.......+..
Bromus tectorum	...........+.....................................+..........
Capsella bursa-pastoris	....1.........2..
Carex hirta	....1..1..............
Carex pseudocyperus	...........2....2......................................
Carex sp.	.......+........+.....................................+....
Chaerophyllum hirsutum	....1.....+.......................2.....................
Chenopodium album	...........+.+..+.........2.4.........1.....3..+..........
Cirsium arvense	.2+....+..
Cirsium oleraceum	......................+1+..............................
Convolvulus arvensis	..........+.........................+..+..................
Dactylis glomerata	........++.........1...+..+....1...+...+++....++......12.+
Daucus carota	+.....................................+................
Echinochloa crus-galli	................1.....................+...................
Equisetum arvense	........+.......+.....................................1.....
Echinocystis lobata	.....+.......2..........+.++.+..............1..+1+.......
Elytrigia intermedia	1.....................................+.1.......3...1........
Erigeron canadensis	.....+.......+.....................................+.....
Fraxinus excelsior	............................+........+..+.......+..........
Geranium pratense	1...........+.....................................2.
Geranium sibiricum	1........1......+..............+...1+.............+.......
Heracleum mantegazzianum	...................+.............2..........................
Heracleum sosnowskyi	.......1.........4..2..................+...................
Juglans regia	+.........+.+.....................+..................+....
Lactuca serriola	.................+..........+2..............................
Lolium perenne	........................+...........+.....................
Lysimachia nummularia	++...................+..............1.....................
Myosotis sparsiflora	.....................................+...........+..
Pastinaca sativa	..............+.....+..............1.....................
Persicaria hydropiper	..3.......1.....................................+.............+.
Persicaria maculosa	.................1............2.....................2..
Plantago major	..+.11...+......+...................+......................
Poa annua	......................+..............+......1...........2..
Poa pratensis	...............2.....................+................
Polygonum aviculare	......1.....................+................+............
Ranunculus repens	.+..2....+2....2.....+..+.......+.......++.......+..2.++..
Rumex obtusifolius	........................+1.................................++.
Salix acutifolia	.....................................+........+.+......
Salix cinerea	......................2.2..................+...........+...
Sambucus ebulus	1.................................+.1....................
Scirpus sylvaticus	........1............23......+.....................1....+.
Solidago gigantea	..................................+.......+.1....+...+.....
Sonchus asper	..............+..............+..........................
Sonchus oleraceus	...............+............+1.............................+..
Sonchus palustris	........+.......3.................................+.....
Stellaria media	...............+.....................................+.2
Taraxacum officinale	......+..++...+.............................+.+....+...11+

```
Thelypteris palustris           ..............+.......+..............................
Thladiantha dubia               ........................3......2...........2.............
Torilis japonica                .......+....1............++.............+......1....+....
Tripleurospermum inodorum       ............................+.............+..+......+..
Tussilago farfara               .1..11.......3.....................+.+...................
```

Species that occur in one description: *Anthriscus sylvestris* 45: 1; *Galeopsis speciosa* 42: +; *Stachys sylvatica* 41: +; *Heracleum sphondylium* 41: +; *Conium maculatum* 50: +; *Epilobium parviflorum* 10: +; *Verbascum thapsus* 14: +; *Salix triandra* 1: 2; *Ulmus laevis* 56: +; *Veronica beccabunga* 19: 1; *Carex acuta* 18: 4; *Calla palustris* 36: 1; *Carex vulpina* 34: +; *Lycopus europaeus* 23: +; *Phalaris arundinacea* 53: 1; *Achillea millefolium* 39: +; *Agrostis canina* 5: +; *Artemisia annua* 47: +; *Atriplex sagitatta* 2: +; *Atriplex tatarica* 2: +; *Berteroa incana* 1: +; *Betula pendula* 2: +; *Bidens tripartita* 47: +; *Brachypodium sylvaticum* 46: +; *Bromus catharticus* 51: +; *Bromus japonicus* 55: +; *Calamagrostis arundinacea* 43: +; *Cannabis sativa* 26: 2; *Cardamine amara* 17: 3; *Cardamine impatiens* 16: 1; *Carduus crispus* 14: +; *Carex lasiocarpa* 30: +; *Carpinus betulus* 18: +; *Chenopodium rubrum* 47: +; *Corylus avellana* 34: +; *Deschampsia caespitosa* 47: +; *Descurainia sophia* 50: +; *Echium vulgare* 1: 1; *Epipactis helleborine* 4: +; *Filipendula ulmaria* 4: +; *Fragaria vesca* 41: +; *Galeopsis tetrahit* 47: +; *Galium odoratum* 17: +; *Geranium pusillum* 50: +; *Geum rivale* 19: +; *Heracleum sibiricum* 30: +; *Hordeum murinuâ* 18: +; *Impatiens noli-tangere* 18: 2; *Leonurus villosus* 54: +; *Lolium giganteum* 44: 1; *Malus domestica* 10: +; *Medicago sativa* 39: +; *Mentha longifolia* 40: +; *Morus alba* 50: +; *Oenothera biennis* 10: +; *Oxalis stricta* 5: 2; *Persicaria amphibia* 16: +; *Phleum pratense* 43: 1; *Physocarpus opulifolius* 39: +; *Phytolacca acinosa* 49: +; *Plantago lanceolata* 45: 1; *Poa compressa* 17: +; *Portulaca oleracea* 1: +; *Potentilla reptans* 40: +; *Prunus divaricata* 48: 1; *Reynoutria × bohemica* 16: 1; *Reynoutria japonica* 39: 5; *Ribes nigrum* 18: +; *Rorippa amphibia* 24: +; *Rosa sp.* 3: +; *Rumex confertus* 45: 1; *Rumex sylvestris* 46: +; *Salix acuta* 36: +; *Salix pentandra* 16: +; *Saponaria officinalis* 34: +; *Setaria glauca* 10: +; *Stachys annua* 39: 1; *Stachys palustris* 4: +; *Stellaria nemorum* 46: +; *Swida sanguinea* 1: +; *Syringa vulgaris* 14: +; *Tilia cordata* 45: +; *Torilis arvensis* 39: +; *Veronica arvensis* 16: +; *Vitis vinifera* 10: 1;

Descriptions were made:
1. Vinnytsia city, the South Bug River coastal strip, 24.07.2021, S. Koniakin, L. Gubar;
2. Vinnytsia city, the ruderal area of the stream, 24.07.2021, S. Koniakin, L. Gubar;
3. Vinnytsia city, the South Bug River bank, 25.07.2021, S. Koniakin, L. Gubar;
4. Vinnytsia city, the South Bug River bank, 26.07.2021, S. Koniakin, L. Gubar;
5. Khotiv village, Kyiv region, the Vita stream coastal strip, 16.08.2021, S. Koniakin, L. Gubar;
6. Kyiv city, along the Syretsky stream, 16.08.2021, S. Koniakin;
7. Boyarka town, Kyiv region, Ivan Franko str., along the stream of the Prytvarka River, 16.08.2021, S. Koniakin;
8. Boyarka town, Ivan Franko str., the coastal strip of the stream of the Prytvarka River, 16.08.2021, S. Koniakin;
9. Chernihiv city, 22 Persha Naberezhna str., Banya "Mali Riky", overmoistened area, 9.09.2021, S. Koniakin;
10. Lutsk city, overmoistened area of an abandoned orchard along the road, 22.09.2021, S. Koniakin, L. Gubar;
11. Lutsk city, overmoistened area, the beginning of storm sewers, along the road, 23.09.2021, S. Koniakin, L. Gubar;
12. Lutsk city, waterlogged area of the Styr River floodplain, Naberezhna str., 23.09.2021, S. Koniakin, L. Gubar;
13. Lutsk city, overmoistened area of the floodplain of the Styr River, Naberezhna str., 23.09.2021, S. Koniakin, L. Gubar;
14. Pylky village, Shepetivskyi district, Khmelnytskyi region, coastal strip of a stream, 28.08.2021, L. Gubar;
15. Bila Tserkva town, Kyiv region, coastal strip of the Protoka River, under the highway bridge, 9.10.2021, S. Koniakin, L. Gubar;
16. Kyiv city, along the Syretsky stream, Mahistral'na str., 2.06.2022, S. Koniakin, L. Gubar;
17. Kyiv city, along the Syretsky stream, near Kupeli area, 2.06.2022, S. Koniakin, L. Gubar;
18. Kyiv city, floodplain forests of the Syretsky stream, 2.06.2022, S. Koniakin, L. Gubar;
19. Kyiv city, the Syretsky stream bank, 2.06.2022, S. Koniakin, L. Gubar;
20. Kyiv city, the coastal strip of the Syretsky stream, "Syretsky Gai" forest, 2.06.2022, S. Koniakin, L. Gubar;
21. Kyiv city, Kurenivka district, ruderal area, "Syretskyi Gai" forest, 2.06.2022, S. Koniakin, L. Gubar;
22. Kyiv city, transformed area of the Syretsky stream, 2.06.2022, S. Koniakin, L. Gubar;
23. Kyiv city, ruderal area, "Syretskyi Gai" forest, 2.06.2022, S. Koniakin, L. Gubar;
24. Kyiv city, floodplain forests of the Syretsky stream, 2.06.2022, C S. Koniakin, L. Gubar;
25. Kyiv city, the Syretsky stream bank, 2.06.2022, S. Koniakin, L. Gubar;
26. Boyarka town, overmoistened area, Ivan Franko str., 06.06.2022, S. Koniakin, L. Gubar;
27. Boyarka town, ruderal area along the stream of the Prytvarka River, 06.06.2022, S. Koniakin, L. Gubar;
28. Boyarka town, ruderal area along the stream of the Prytvarka River, Ivan Franko str., 15, 06.06.2022, S. Koniakin, L. Gubar;
29. Boyarka town, coastal strip of the Prytvarka River stream, Ivan Franko str., 17, 06.06.2022, S. Koniakin, L. Gubar;
30. Boyarka town, coastal strip of the Prytvarka River stream, Ivan Franko str., 13, 06.06.2022, S. Koniakin, L. Gubar;
31. Boyarka town, the Prytvarka River coastal strip, Zelena str., 06.06.2022, S. Koniakin, L. Gubar;
32. Boyarka town, ruderal area of the Prytvarka river, Zelena str., 06.06.2022, S. Koniakin, L. Gubar;
33. Boyarka town, along the Zelena str.,06.06.2022, S. Koniakin, L. Gubar;
34. Boyarka town, floodplain forests of the Prytvarka River, Zelena str., 06.06.2022, S. Koniakin, L. Gubar;
35. Boyarka town, the Pritvarka River bank, Zelena str., 15, 06.06.2022, S. Koniakin, L. Gubar;
36. Boyarka town, the Prytvarka River coastal strip, Ivan Franko str.,108, 06.06.2022, S. Koniakin, L. Gubar;
37. Boyarka town, ruderal area, Samielenko str., 06.06.2022, S. Koniakin, L. Gubar;
38. Boyarka town, overmoistened area, Samiylenko str., 16 m from the railway, 06.06.2022, S. Koniakin, L. Gubar;
39. Chernivtsi city, the Molnytsia River bank, 31.07.2008, A. Tokaryuk, K. Korzhan (Tokaryuk et al., 2018);
40-41. Chernivtsi city, Sadky tract, 08.08.2008, A. Tokaryuk, O. Bucha (Tokaryuk et al., 2018);
42. Chernivtsi city, Kalinivska str., along the road, 31.07.2008, A A. Tokaryuk, K. Korzhan (Tokaryuk et al., 2018);
43-44. Chernivtsi city, Kalinivska str., forest plantation along the road, 18.07.2008, K. Korzhan (Tokaryuk et al., 2018);
45. Chernivtsi city, Moskovs'koyi Olimpiady str., forest plantation along the road, 18.07.2008, K. Korzhan (Tokaryuk et al., 2018);
46. Chernivtsi city, forest strip between Kalinivska str. and Moskovs'koyi Olimpiady str., along the road,31.07.08, A. Tokaryuk, K. Korzhan (Tokaryuk et al., 2018);

47. Chernivtsi city, Kovelska str., 11.09.2007, A. Tokaryuk, K. Korzhan (Tokaryuk et al., 2018);
48. Zhytomyr city , area of the downspout, 4th Chudnivskyi lane, 9.06.2022, S. Koniakin, L. Gubar;
49. Zhytomyr city, ruderal area, 4th Chudnivskyi lane, 9.06.2022, S. Koniakin, L. Gubar;
50. Zhytomyr city, area with organic waste remnants, 4th Chudnivskyi lane, 9.06.2022, S. Koniakin, L. Gubar;
51. Zhytomyr city, ruderal area, 4th Chudnivskyi lane, 9.06.2022, S. Koniakin, L. Gubar;
52. Zhytomyr, city ruderal area under construction waste near the Kamyanka River, 9.06.2022, S. Koniakin, L. Gubar;
53. Zhytomyr city, the Kamianka River bank, 9.06.2022, S. Koniakin, L. Gubar;
54. Zhytomyr city, ruderal area, 4th Chudnivskyi lane, 9.06.2022, S. Koniakin, L. Gubar;
55. Nizhyn town, Chernihiv Region, ruderal area of the Oster River floodplain, 12.06.2022, S. Koniakin, L. Gubar;
56. Nizhyn town, the Oster River bank, 12.06.2022, S. Koniakin, L. Gubar;
57-58. Nizhyn town, ruderal area of the Oster River floodplain, 12.06.2022, S. Koniakin, L. Gubar

According to the results of the phytoindicative assessment based on the values of 12 ecological factors (Table 2), it was established that in the conditions of Ukraine, *I. glandulifera* is a stenotopic hygromesophyte, subacidophile and semi-eutrophic species. Thus, indicators of water (Hd) and saline (Sl) regimes of the soil, thermal regime (Tm) and the content of carbonates in the soil (Ca) are limiting factors for the ecological niche of *I. glandulifera* (Fig. 5) in the conditions of the secondary areas of the species. Regarding climatope factors (Table 2), *I. glandulifera* is a stenotopic submesotherm, subaridophyte, hemicontinental and subcryophyte.

We predicted the reaction of the species to an increase in the average annual air temperature from +1 to +3°C. In particular, the relationship between a possible increase in temperature by 1, 2 and 3°C and the corresponding changes in the indicators of each of the 12 ecofactors has been analyzed. The analysis determined which of these factors can limit (values that exceed the tolerance range) the existence of *I. glandulifera* (Fig. 6).

The degree of change of each of the factors with increasing temperature in relation to the existing amplitude of growth conditions was estimated. If the amplitudes overlap by more than a half, it is considered there are no threats to the existence of the species; at 25-50% overlap there are threats of reduction, and at 0-25% – a threat of extinction (DIDUKH, 2021).

As can be seen from the resulting diagram, a temperature increase of 1^{0}C is not critical for the studied species, since the change in the values of the leading ecofactors does not exceed the values of the tolerance limits of the species and does not go beyond its ecological niche, (or the overlap of the tolerance zones exceeds 50%). However, an increase in temperature of 2^{0}C will lead to a shift in the acidity and salinity of the soil, which will probably cause a reduction in the area colonized by *I. glandulifera* and the rate of its spread in the area under research. A further increase in the average annual air temperature by 3^{0}C will most likely cause a reduction in the secondary area of the species.

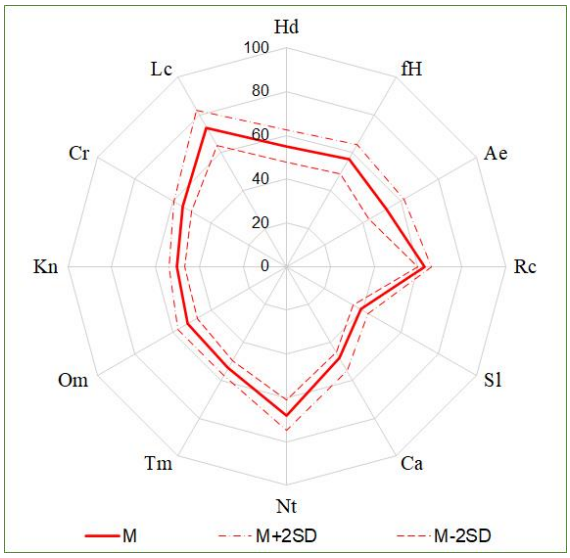


Fig. 5. Potential and realistic econiches of *I. glandulifera* Royle in the study region

Note: M - arithmetic mean; SD - standard deviation; Hd - soil humidity; fH- variability of damping; Ae - aeration of soil; Rc - acidity; Sl - total salt regime; Ca - carbonate content in soil; Nt - nitrogen content; Tm - thermal climate; Om – humidity; Kn - continental climate; Cr – cryoclimate; Lc - light in community

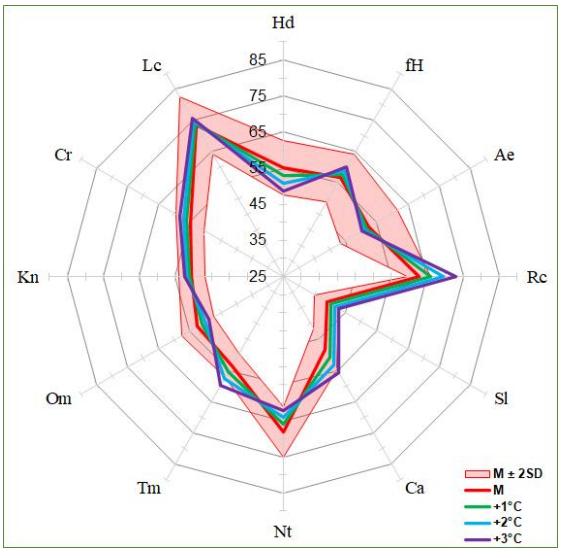


Fig. 6. Cyclogram of changes in ecological indicators of *I. glandulifera* Royle when the average annual temperature increases by +1, +2, +3°C

Table 2. Phytoindicative assessment of *I. glandulifera* Royle in the study area

EDAPHOTOPE																											
Soil water regime (hydromorph)				Moistening variability				Soil aeration				Soil acid regime				Salt regime				The content of carbonates in the soil				The content of absorbable forms of nitrogen			
Hd				fH				Ae				Rc				Sl				Ca				Nt			
M	min	max	SD	M	min	max	SD	M	min	max	SD	M	min	max	SD	M	min	max	SD	M	min	max	SD	M	min	max	SD
12.67	11.00	14.67	0.87	6.22	5.17	7.21	0.42	7.86	6.73	9.61	0.69	8.17	7.69	8.75	0.21	7.41	6.50	8.19	0.37	6.28	5.13	7.18	0.43	7.49	6.66	8.38	0.38
stenotope				hemistenotope				hemistenotope				stenotope				stenotope				hemistenotope				hemistenotope			
hygromesophyte				hemihydrocontrastophile				hemiaerophobe				subacidophile				semieutroph				acarbonatophile				nitrophile			

CLIMATOPE																			
Thermoclimate (thermomode)				Climate humidity (humidity)				Climate continentality (contrast regime)				Severity of winters (cryo regime)				Lighting			
Tm				Om				Kn				Cr				Lc			
M	min	Max	SD	M	min	max	SD	M	min	max	SD	M	min	max	SD	M	min	max	SD
9.10	8.39	10.07	0.33	12.07	10.21	13.35	0.60	8.57	8.10	9.42	0.30	8.23	7.10	9.00	0.34	6.60	5.58	7.47	0.42
stenotope				stenotope				stenotope				stenotope				hemistenotope			
submesotherm				subaridophyte				hemicontinental				subcryophyte				subheliophyte			

4. Discussion

The natural range of *I. glandulifera* covers the foothills of the western Himalayas: northeastern Pakistan, northwestern India (Jammu and Kashmir, Himachal Pradesh, and Uttarakhand) and western Nepal (GBIF, 2022, STACE, 2019). Here, the species is distributed over an area of about 40,000 km^2 (TANNER, 2008) in the altitude range 1,600 – 4,300 m a.s.l. (HAGENBLAD ET AL., 2015). *I. glandulifera* was first introduced to Great Britain in 1838 as a garden ornamental, and as early as 1855 it was registered in England as an" escaped plant" (LAMBDON ET AL., 2008). Over the next decade, the species was also introduced to other European countries, to Sweden in 1842, Austria in 1845, and the Czech Republic in 1846 (ČUDA ET AL., 2020). In the USA, in 1883, *I. glandulifera* was first recorded in Norwich (Connecticut). In 1901, the growth of Himalayan balsam was confirmed in Ottawa (Canada). About 40 years later, *I. glandulifera* was naturalized in many countries and began to spread further in Europe and North America (ČUDA ET AL., 2020; NAGY & KORPELAINEN, 2015). *I. glandulifera* is currently found in 35 European countries (GBIF, 2022). It also grows in the Balkans and the Caucasus (FAYVUSH & TAMANYAN, 2011; GBIF, 2022; PACANOSKI & SALIJI, 2014). *I. glandulifera* is naturalized in Russia (European part, Far East, Altai Republic), China (Hunan), Japan, New Zealand, Argentina, as well as in the western and eastern parts of Canada and the USA (SKALOVA ET AL., 2012; GBIF, 2022; ČUDA ET AL., 2020; VINOGRADOVA ET AL., 2020). Some researchers believe that the main way *I. glandulifera* entered the American continent was as cargo in sea vessels from Europe (MILLS ET AL., 1993; TABAK & VON WETTBERG, 2008). Information about the Chronology of dates of the discovery of *Impatiens glandulifera* in Ukraine is given in Appendix 1.

One of the important factors in the spread of alien species is climate change, which leads to an increase in the average annual air temperature and aridification (DIDUKH, 2009; HULME, 2017). This causes the migration, adaptation, or disappearance of certain elements of the biota. Thus, according to the United Nations, the world is currently approaching warming at the level of 3.2°C by 2100 (UNITED NATIONS ENVIRONMENT PROGRAM, 2019). BEERLING & PERRINS (1993) noted that the limiting factors for the spread of *I. glandulifera* are moisture deficiency and low temperatures. In Ukraine, *I. glandulifera* is spreading in coastal water, floodplain forests, and ruderal biotopes. According to our study and the works of other scientists, *I. glandulifera* prefers moist places, and river systems are favourable for its intensive distribution and naturalization (PROTS & DRESCHER, 2010; HELSEN ET AL., 2021). This species forms quite dense and numerous populations, displacing native plant species from phytocoenoses. It should be noted that in its natural range, *I. glandulifera* is widespread in tall grass meadows and shrubs, as well as in pastures of the zone of *Cedrus deodara* mixed forests (Roxb. ex D. Don) G. Don (BALOGH, 2008). Here, the species may be less numerous than in Europe and form small populations of 30–60 individuals that grow in natural communities (TANNER ET AL., 2014). A number of European researchers cite different classes of phytocoenoses into which the studied species penetrates (BEERLING & PERRINS, 1993; ADAMOWSKI ET AL., 2018; DRESCHER & PROTS, 1996; DAJDOK ET AL., 2003; TYLER ET AL., 2021). In Central Europe, *I. glandulifera* occurs as part of natural vegetation (*Betulo-Adenostyletea, Phragmito-Magnocaricetea, Salicetea purpureae, Alnetea glutinosae* classes), ruderal – *Epilobietea angustifolii, Artemisietea vulgaris* (DRESCHER & PROTS, 1996; KLOTZ ET AL., 2002; TOKARSKA-GUZIK ET AL., 2012). Besides, this species penetrates communities of *Alnetea glutinosae* classes (GUBAR, 2004*;* TARASEVICH & ORLOV, 2013), and rarely into *Molinio-Arrhenatheretea* and *Bidentetea* (LYUBINSKA & MATVIEIEV, 2021). In Poland, an association dominated by *I. glandulifera* was isolated under the name *Impatienti-Calystegietum* (DAJDOK ET AL., 2003). The species also occurred in foothill meadows and roadsides in communities of *Molinio-Arrhenatheretea* class (KIEŁTYK & DELIMAT, 2019). In the UK, *I. glandulifera* occurs in four habitat types: riparian, partially flooded *Phragmites-Urtica* swamps, mesotrophic grasslands and various types of woodland, including *Alnus glutinosa-Urtica dioica* woodland (BEERLING & PERRINS, 1993; FITTER & PEAT, 1994). According to the results of our studies, in the syntaxonomic aspect, *I. glandulifera* was found in the communities of 4 associations, 5 alliances, and 4 classes (Table 1). It can be stated that for *I. glandulifera*, while maintaining modern climatic indicators, further expansion of the secondary range is characteristic due to its invasion into the species composition of forest, ruderal, wetland and meadow coenoses.

5. Conclusions

For the first time, the Southeast Asian species *I. glandulifera* has been studied in the territory of Ukraine. Its distribution has spread across three landscape zones, i.e Carpathian, forest, and forest-steppe. The syntaxonomic scheme of the vegetation with the participation of *I. glandulifera* covers the classes: *Phragmito-Magnocaricetea, Salicetea*

purpureae, Alnetea glutinosae, Robinietea and *Epilobietea angustifolii*. The species shows a tendency to spread spontaneously, and can change the composition and structure of phytocoenoses of river valley corridors. A phytoindicative assessment revealed, that in its secondary range in Ukraine, *I. glandulifera* shows features of a stenotopic hygromesophyte, subacidophile, and a semieutroph. According to climatope factors, the species is a stenotopic submesotherm, subaridophyte, hemicontinental and subcryophyte. In order to control further spread of *I. glandulifera* we propose the constant control of this species in coastal ecosystems and urban ecotopes; the implementation of monitoring studies at phytocoenotic and population levels; the development and implementation of control methods in order to reduce the areas of transformed coenoses of river valley corridors.

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Appendix 1. Chronology of distribution of *Impatiens glandulifera* in Ukraine

Date of discovery, years	Nature zone	Reference
1930-1938	Carpathians (Zakarpattia region)	Flora of the Ukrainian SSR, 1955
1939	Forest steppe (Khmelnytskyi region)	
1970	Carpathians (Zakarpattia region)	Fodor, 1974
1980	Mixed forest (Left Bank Polissia)	Protopopova et al., 2015
1994	Forest steppe (Kharkiv city)	Burda & Ryabokon, 1994
1998	Carpathians (Zakarpattia region, Tysa river basin)	Protopopova & Shevera, 1998
2004	Forest steppe (Small Polissya)	Gubar, 2004
2008	Mixed forest (Chernihiv region)	Lukash, 2008
2010	Carpathians (Zakarpattia region)	Prots & Drescher, 2010
2012	Carpathians (Ivano-Frankivsk region)	Sychak, 2012
2013	Mixed forest (Zhytomyr Polissia)	Tarasevich & Orlov, 2013
2015	Forest steppe (Kharkiv region)	Zvyagintseva, 2015
2016	Mixed forest (Volyn region)	Kotsun & Kuzmishyna, 2016
2017	Carpathians (NR: Gorgany); Steppe (NR: Dniprovsko-Orilskyi)	Zavialova, 2017
2018	Carpathians and Forest steppe (Bukovyna Cis-Carpathian Region)	Tokaryuk et al., 2018
2017-2021	Carpathians (NNP: Hutsulshchyna); Mixed forest (NNP: Hetman, Ichnyansky, Mezynsky); Forest steppe (NNP: Holosiivskyi, Desniansko-Starogutskyi, Podilski Tovtry	Zavialova, 2017; Hrytsyna & Lyubynets, 2015; Lyubinska & Matvieiev, 2021

Note: NNP - national nature park; NR - natural reserve