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Method for Ecological Risk Assessment of the Invasive Alien Species *Impatiens Glandulifera* Royle in Bulgaria

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Abstract

The aim of the present study is based on the existing experience to apply methodology for environmental risk assessment of Hymalayan balsam (*Impatiens glandulifera*), which will be useful for management and control of the distribution and impact of this invasive alien species in Bulgaria. The adapted methodology for *Impatiens glandulifera*'s risk assessment is based on the "Methodology for risk assessment of invasive alien species" developed by the Bulgarian Executive Environment Agency and on "The South Australia's Weed Risk Management System protocol". The object of the risk assessment is an experimental section of the Iskar river gorge ("Gorge") close to the village of Kokalyane, Pancharevo municipality, Sofia-city district. The area of the Gorge is 3 km² and the study area represent approximately 3.3% of it or 0.1 km². Following the Methodology the assessment was done independently by 7 experts representatives of the scientific institutions, governmental and local organizations. The scores of the experts' evaluation based on the questionnaires completed by them are averaged and applied for the Final phase of Risk assessment - Determing priorities.

The risk assessment of the invasive alien species *Impatiens glandulifera* in the experimental area showed that at the present stage the level of risk of its spread and impact is medium and requires a set of measures, including information and publicity for the purpose of prevention, reduction of the population in case of predominant presence of the species or the strategic function of its localities and conducting regular monitoring to trace the changes in the invasiveness of the species.

Due to the significant distribution along the river of single individuals of the Hymalayan balsam, it is impossible to completely destroy the species at once. It is achievable as a immediate result in the studied area this exotic plant to be limited to an assectator, as it contributes to the enrichment of bee grazing in the area.
The methodology used in the Weed Risk Management Guide is largely applicable, easy and convenient for studies that are related to the risk assessment of invasive alien species.
Keywords: *Hymalayan balsam, risk, control, methodology, invasiveness, monitoring, riparian communities, habitats*

1. Introduction

Hymalayan balsam (*Impatiens glandulifera* Royale) is an invasive alien weed of river wetlands characterized by its rapid growth and an entertaining mode of explosive seed dispersal (Invasive Species Council of BC, 2020). Biological invasions of *I. glandulifera* affect biodiversity worldwide, and, consequently, the invaded ecosystems may experience significant losses in economic and cultural values (Pacanoski, Saliji, 2014). Hymalayan balsam possesses all important characteristics for the successful invasive alien species (Tanner, 2012) such are the ability to tolerate a variety of habitat conditions, rapid growth and reproduction potential (including dispersal mechanisms). *Impatiens glandulifera* is known to compete with and displace native plant species, reduce native plant diversity, and negatively impact habitat for wildlife (Global Invasive Species Database, 2021). This invasive alien species (IAS) forms dense stands which suppress the growth of native

plants (Newman, 2004). Kiełtyk & Delimat (2019) found that in species-rich tall herb communities, invasion by *I. glandulifera* causes a considerable change (especially after exceeding a 80% cover abundance) in plant species richness, diversity and evenness. Phytotxicity of *I. gladulifera* may also inhibit the germination and regeneration or recruitment of the neighbouring species in invaded habitats and may considerably reduce the species diversity (Baležentienė, 2018). The invasion of *I. glandulifera* into an already stressed river network increases the risk of flooding which in turn may have detrimental effects on the ecological functioning of the habitat (Tanner, 2012).

Up to now *I. glandulifera* spread throughout 26 countries of Europe between 45 and 60 N latitude, the Russian Far East, Japan and the USA (Drescher, Prots, 2003). According to Petrova at al. (2013) in Bulgaria the species was first recorded in 1978 and is distributed in the Forebalkan, Balkan Range (Central), Sofia Region, Vitosha Region, Znepole Region, Valley of River Struma, Valley of River Mesta, Rila Mts, Mt Sredna Gora, Rhodopi Mts, Thracian Lowland, up to about 1500 m a.s.l.

The species is included in a significant number of referencing world and Europe Database, operating in real time and all interconnected, such as Global Invasive Species Database (GISD, 2020), European Network on Invasive Species (NOBANIS, 2020), Invasive Species Compendium (2020) ESENIAS (2020), EASIN (2020), etc., where the information on invasive alien species is constantly updated with data from new observations and researches. There is a need for measures on controlling the *Impatiens glandulifera*'s populations – from the pathways of invasion to management on the negative consequences of its naturalization and key step to their adequate selection is the preparation of qualitative risk assessment of the species potential impact and spread. A risk assessment is required as Hymalayan balsam is listed as a "Non-native species subject to restrictions under Regulations 49 and 50" in the Third Schedule of the European Communities (Birds and Natural Habitats) Regulations 2011 (SI 477/2011). The procedure of risk assessment is in compliance with article 5, paragraph 1 of the Regulation (EU) No 1143/2014.

The risk of IAS is defined as "ecological" (Kil et al., 2004) and its assessment is considered with the following factors: harmful effects to animals or humans, ecological characteristics, invasion time, present state after invasion (dispersion), and availability of resources. There are many approaches to environmental risk assessment and impact of invasive alien species, which according to (Bartz, Kowarik, 2019) can generally be grouped into three groups: predictive systems, prioritisation tools and information tools. *Impatiens glandulifera* has been subject of small number but different kind of risk analysis including on a global level to assess the risks associated with this species in EU (Pisarczyk, Tokarska-Guzik, 2015) and on a national level - to assess the risks associated with this species in Ireland (Millane, Caffrey, 2014) and Netherlands (Matthews at. al., 2015). Unfortunately, only part of the methodology of these analyzes is applicable to the environmental and most of all socio-economic conditions of Bulgaria where at this stage an in-depth risk assessment of Hymalayan balsam has not been performed. The closest example is the Conservation Management Plan of Srebarna Nature Reserve (2016) where is mentioned that out of the 23 established IAS, *Impatiens glandulifera* is currently among the species with less impact, along with *Azolla filiculoides, Cannabis sativa* and *Phytolacca americana*. The authors' conclusion is that these species do not require measures to control on the territory of the nature reserve, but monitoring of the status of their populations and of other invasive species is required.

The New Modul for "Mapping and analysis on the impact of Invasive Alien Species", developed in 2017 and financed by the Financial Mechanism of European Economic Area (EEA) 2004-2009 project BG03.PDP1 "Improving the Bulgarian Biodiversity Information System (IBBIS)" with beneficiary – Bulgarian Executive Environment Agency, was a serious application for improving the situation with monitoring, assessment and control of IAS in the country.

The aim of the present study is based on the existing experience to apply methodology for environmental risk assessment of *Impatiens glandulifera*, which will be useful for management and control of the distribution and impact of this invasive alien species in Bulgaria.

2. Matherials and methods

2.1. Investigated area

The study is part of the implementation of project KP-06-M31/3 of 12.12.2019 "Study of the distribution and impact of the invasive alien species *Impatiens glandulifera* Royle on natural habitats in the gorge of the Iskar river between Lozenska and Plana Mountains", funded by the Bulgarian National Science Fund. The object of the risk assessment is an experimental section of the Iskar river gorge (Further defined as “Gorge”) in the Yuzinata locality, close to the village of Kokalyane, Pancharevo municipality, Sofia-city district (Fig. 1).

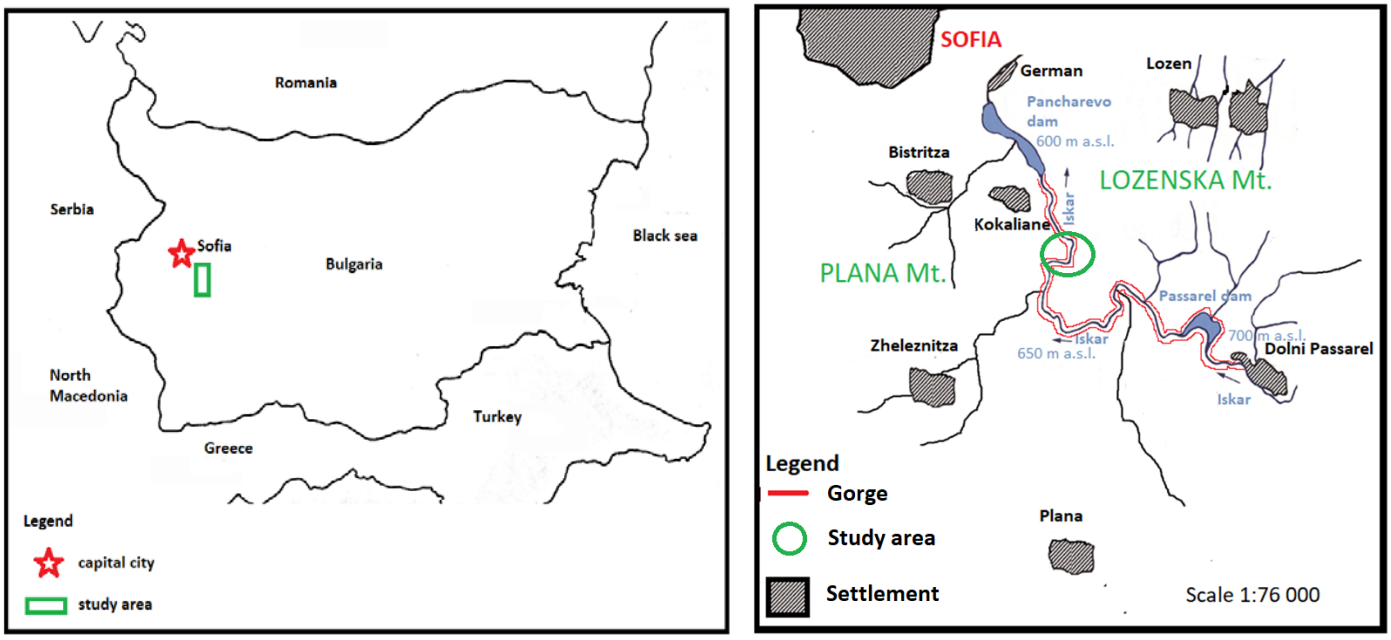

Fig. 1 Map of the study area

The area of the Gorge is 3 km² and the study area represent approximately 3.3% of it or 0.1 km². (Starting point coordinates: 42°34'13.7" N 23°25'58.3" E; End point coordinates: 42 ° 33'42.4 " N, 23 ° 25'26.0" E, Length: 1000 m, Width - 100 m). The average altitude of the site is 630 m. The study area is represented by the following types of Impatiens glandulifera’s localities (according to Kachova et al. 2020): (a) Permanently flooded (by river running waters) riparian type; (b) Periodically flooded riparian type; (c) Type "Scree". The soils in the localities of the first two types of localities are Fluvisols and in the third type are Leptosols.

Fig. 2. Different type of localities: (a) Permanently flooded type (b) Periodically flooded riparian type; (c) Type "Scree".
Photo: Plamen Glogov

2.2. Risk assessment methodology

The adapted methodology for *Impatiens glandulifera's* risk assessment is based on the Methodology for risk assessment of IAS (Bulgarian Executive Environment Agency, 2020) and on "The South Australia's Weed Risk Management System protocol" by Virtue (2008), based on a detailed questionnaire which consists of two groups of questions. The first group of "IAS (weed) comparative risk" questions are divided into three main criteria: invasiveness, impacts and potential distribution. The second group of questions concerning the "feasibility of containment" are also divided into three main criteria: control costs, current distribution and persistence. The questionnaire was completed independently by representatives of the scientific community, governmental and local organizations, as follows:
1. D-r Vanya Kachova, Forest Research Institute, Bulgarian Academy of Sciences; 2. D-r Simeon Bogdanov, University of Forestry; 3. Forest engineer Stoyan Toshev, Regional Forest Directorate - Sofia; 4. Forest engineer Kyril Pironkov, State Forest Enterprise – Sofia; 5. Forest engeneer Alexander Krosnev, State Forest Enterprise - Samokov; 6. Forest engineer Radoslav Panorov, expert in Sustainable Energy Development Agency; 7. Forest engeneer Violeta Petrova, ecologist in municipality of Pancharevo. The scores of the experts' evaluation based on the questionnaires completed by them are averaged and applied for the Final phase of Risk assessment - Determing priorities (Virtue, 2008).

2.3. Collection of experimental data

The study was conducted in the period July-August, 2020. The methodology for risk assessment is applied in practice with data from the experimental section in the Iskar River gorge between Lozenska and Plana Mountains. All the localities of *I. glandulifera* (including single individuals) are described within the investigated area.

In each of the localities were measured and determinated:

- geographical coordinates;
- distance of the locality from the river (line I: from 0 to 5 m; line II: from 5 to 20 m; line III: from 20 to 50 m;
- size of the locality;
- role of *I. glandulifera* in the community (dominant, co-dominant, assectator (accompanying species with small abundance) or species with single participation)
- density (number per m^2 of *I. glandulifera* individuals and its co-dominants;
- range of predominant heights of *I. glandulifera* and its co-dominants;
- main vectors of anthropogenic impact (fishermen, tourists, campers, pets, waste, cars, etc.)

Footnotes should be rare.

3. Results

In the study area of 0.1 km^2 24 localities of *I. glandulifera* populations with sizes between 1 and 120 m^2 were identified (Table 1). The total range of the invasive species is 549 m^2 or 0.5% of the study area.

Table 1. Biological and ecological data for the localities of *Impatiens glandulifera* in the study area

Loclaity				Role of *Impatiens glandulifera*	Impatiens glandulifera		Co-dominant		Anthropogenic factors
No	Geographical coordinates	Distance from the river (line)	Size of the locality (m^2)		Range of predominant height (mm)	Density (Number of individulas per m^2)	Range of predominant height (mm)	Density (Number of individulas per m^2)	
1	42°34'06.8"N, 23°25'50.1"E	III	6	Dominant	160-180	30	n.a.	n.a.	Cars, fishermen, waste disposal
2	42°34'05.3"N, 23°25'48.0"E	III	12	Dominant	160-180	33	n.a.	n.a.	Cars, fishermen, waste disposal
3	42°34'10.127"N 23°25'58.524"E	I	40	Dominant	180-200	41	n.a.	n.a.	Cars, tourists
4	42°34'3.467"N 23°25'49.608"E	I	8	Co-dominant with *Rubus caesius*	180-200	23	10	120-140	Cars, tourists
5	42°34'6.944"N 23°25'59.224"E	I	8	Co-dominant with *Rubus caesius*	180-200	23	10	120-140	Fishermen
6	42°34'2.664"N 23°25'49.938"E	II	30	Co-dominant with *Rubus caesius*	170-190	27	19	130-150	Cars, fishermen, waste disposal

7	42°34'03.5"N 23°25'50.8"E	II	9	Co-dominant with *Urtica dioica*	170-190	25	21	160-180	Cars, fishermen, waste disposal, herbalists (picking nettles)
8	42°34'3.48"N 23°25'50.891"E	I	43	Co-dominant with *Rubus caesius*	150-170	24	14	100-120	Cars, fishermen
9	42°34'03.3"N 23°25'50.7"E	I	30	Dominant	160-180	31	n.a.	n.a.	Cars, fishermen
10	42°34'03.2"N 23°25'47.9"E	II	45	Dominant	170-190	46	n.a.	n.a.	Cars, fishermen
11	42°34'3.176"N 23°25'47.885"E	I	56	Dominant	180-200	39	n.a.	n.a.	Cars, fishermen
12	42°34'4.106"N 23°25'45.131"E	I	60	Dominant	200-220	38	n.a.	n.a.	Fishermen
13	42°34'03.4"N 23°25'46.7"E	II	12	Co-dominant with *Urtica dioica*	179-190	23	17	160-180	Cars, fishermen, herbalists (picking nettles)
14	42°34'5.006"N 23°25'42.95"E.	I	40	Dominant	160-180	36	n.a.	n.a.	Fishermen
15	42°34'2.076"N 23°25'48.594"E	III	120	Dominant	110-130	42	n.a.	n.a.	N.a
16	42°34'2.722"N 23°25'27’52"E	II	9	Co-dominant with *Urtica dioica*	170-190	20	16	160-180	Cars, fishermen
17	42°34'03.0"N, 23°25'34.3"E	II	6	Co-dominant with *Urtica dioica*	160-180	17	16	160-180	Cars, fishermen
18	42°33'44.8"N 23°25'29.541"E	II	8	Co-dominant with *Urtica dioica*	160-180	19	23	160-180	Cars, fishermen
19	42°33'44.2"N 23°25'29.63"E	I	2	assectator	100-120	8	4	40-60	Cars, fishermen
20	42°34'01.6"N 23°25'27.102"E	I	1	single participatio n	172,8	1	n.a.	n.a.	Waste disposal
21	42°34'1.449"N 23°25'26.401"E	I	1	single participatio n	165	1	n.a.	n.a.	Waste disposal
22	42°34'5.687"N 23°25'40’042"E	I	1	single participatio n	140-160	2	n.a.	n.a.	Waste disposal
23	42°33'43.214" N 23°25'28.022"E	I	1	assectator	177,3	1	n.a.	n.a.	Waste disposal
24	42°34'1.395" N 23°25'26.502"E	I	1	single partcipation	150-170	4	35	140-160	Cars

The largest number are the localities of line I - 14 (58.3%), followed by those of line II - 7 (29.2%) and line III - 3 (12.5%). In 10 (41.7%) of the localities the Hymalayan balsam- is a monodominant species, in 8 (33.3%) it dominates together with Urtica dioica and Rubus caesius. Single participation of the species was registered in four localities (16.7%). The population density of the Impatiens glandulifera ranges between 30 and 52 individuals per m^2 in monodominant communities and between 17 and 26 individuals per m^2 in mixed phytocoenoses with its participation. The predominant heights are in the range of 150-220 mm in the localities

of line I, 160-190 mm of line II and 100-180 of line III. Only in two of the localities (both of the “scree” type) no impact of anthropogenic factors has been established.

The evaluation of “Comparative IAS risk (Table 2) show similar scores between the experts on each of the questions. The methodology of The South Australia's Weed Risk Management System protocol by Virtue (2008) was mainly used, but additional clarity was provided on each of the questions for the scope of interpretation with an emphasis on IAS using the Methodology for risk assessment of invasive alien species (Bulgarian Executive Environment Agency, 2020). The numbers in column “Expert (№) evaluation scores” follow the order of the experts presented in the methodology.

Table 2. Comparative IAS risk

Question	Expert (№) evaluation scores							Average score	Scale of scores
	1	2	3	4	5	6	7		
1. Invasiveness									
1.1. What is the IAS’s ability to establish amongst existing plants?	3	2	3	3	2	2	3	2.1	very high - 3; high - 2; medium - 1; low - 0; don’t know - ?
1.2. What is the IAS's tolerance to average IAS management practices in the land use?	3	3	3	3	3	3	3	3	very high - 3; high - 2; medium - 1; low - 0; don’t know - ?
1.3. What is the reproductive ability of the IAS in the land use?	3	3	3	3	3	3	3	3	high - 3; medium-high - 2; medium-low - 1; low - 0; don’t know - ?
1.4. How likely is long-distance dispersal (>100 m) by natural means? (a) flying birds; (b) other wild animals; (c) water; (d) wind	6	5	5	6	6	5	6	3	The interval in which the average value (5.57) falls has the highest score equivalent (3)
1.5. How likely is long-distance dispersal (>100 m) by human means? (a) deliberate spread by people; (b) accidentally by people and vehicles; (c)цontaminated produce; (d) domestic/farm animals	4	3	4	4	4	4	5	2	The interval in which the average value (4.71) falls has the score equivalent - 2
2. Imacts									
2.1. Does the IAS reduce the establishment of native plants?	3	1	2	2	1	1	3	1.9	50% reduction - 3; 10-50% reduction- 2; <10% reduction- 1; none- 0; don’t know- ?
2.2. Does the IAS reduce the amount of native vegetation?	4	2	3	3	2	2	4	2.9	50% reduction - 4; 25%-50% reduction - 3; 10-25% reduction - 2; <10% reduction - 1; none - 0; don't know-?
2.3. Does the IAS reduce biodiversity (plants and animals) such that it is not suitable for nature conservation and/or nature-based tourism.	3	2	2	2	1	1	3	2,0	high - 3; medium - 2; low - 1; none - 0; don’t know - ?

2.4. Does the IAS restrict the physical movement of people, animals, vehicles, machinery and/or water?	2	2	2	2	2	2	2	2,0	high - 3; medium - 2; low - 1; none - 0; don't know - ?
2.5. Does the IAS affect the health of animals and/or people?	1	0	0	0	0	0	0	0.1	high - 3; medium - 2; low - 1; none - 0; don't know - ?
2.6. Does the IAS have major, positive or negative effects on environmental health?	2	1	1	2	2	1	2	2,0	The interval in which the average value (1.57) falls has the score equivalent - 2
3. Potential distribution									
3.1. What percentage of the total study area is suitable for the IAS?	2	1	1	2	2	1	1	1.2	10 - > 80% of the study area; 8 - 60-80% of the study area; 6 - 40-60% of the study area,4 - 20-40% of the study area, 2 - 10-20% of the study area; 1 - 5-10% of the study area, 0.5 - 1-5% of the study area, 0 - The IAS is not suited to growing in any part of the of the study area; ? - don't know

The results of Comparative IAS risk score (Table 3) calculated manually adjusting the raw scores are as follows (Virtue, 2008): Invasiveness = 8.8; Impacts = 5.7; Potential distribution = 1.2; Comparative Weed Risk = Invasiveness x Impacts x Potential distribution = 60.1. So IAS risk score is <101 and falls in Frequency band: 40-60% which means that IAS risk is assessed as "medium".

The evaluation of "The feasibility of containment" (Table 3) also show similar scores between the experts on each of the questions. The numbers in column "Expert (№) evaluation scores" follow the order of the experts presented in the methodology.

Table 3. Feasibility of containment

Question	Expert (№) evaluation scores							Average scores	Scale of scores
	1	2	3	4	5	6	7		
1. Control costs									
1.1. How detectable is the IAS? (a) height at maturity, (b) shoot growth present, (c) distinguishing feautres; (d) pre-reproductive height in relation to other vegetation	2	2	1	2	2	1	1	1.4	The interval in which the average value (1.57) falls has the lowest score equivalent (0)
1.2. What is general accessibility of known infestations?	2	2	2	2	2	2	2	2,0	2 - low; 1 - medium; 0 - high; 0 - not present; ? - don't know
1.3. How expensive is control of the IAS, using techniques which both maximise efficacy and minimise off-target damage? (a) chemicals, fuel and equipment operating costs; (b) labour costs	4	2	2	2	2	4	4	2.9	very high - 4; high -3; medium - 2; low - 1; low - 1; not aplicable - 0; don't know - ? (Total (a+b), range between 0 and 8)
1.4. What is the likely level of cooperation from landholders within the land use at risk?	2	2	1	1	2	1	2	1.6	2 - low; 1 - medium; 0 - high; 0 - not present; ? - don't know
2. Current distribution									

2.1. What percentage of the study area is currently infested by the weed?	0	0	0	0	0	0	0	0.1	10 - >80% of study area; 8 - 60-80% of the study area; 6 - 40-60% of the study area; 4 - 20-40% of the study area; 2 - 10-20% of the study area; 1 - 5-10% of the study area; 0.5 - 1-5% of the study area; 0.1 - >1% of the study area; 2 - 0% of the study area but in 20-40% of Gorge; 1- 0% of study area but in 10-20% of Gorge; 0.5 - 0% of study area but in 5-10% Gorge; 0.1 - 0% of study area but in 1-5% Gorge; 0.05- 0% of land use but <1% of Gorge; 0 - the species is not known in the present board; ? - don't know
2.2. What is the pattern of the IAS's distribution across the Gorge area?	1	0	1	1	1	0	1	0.7	2 - widespread; 1 - evenly; scattered - 0; restricted; 0 -not present, ? - don't know
3. Persistence									
3.1. How effective are targeted control treatments applied to infestations of the IAS?	3	2	3	3	3	3	3	2.9	3 - low; 2 – medium; 1 - high; 0 - very high; ? - don't know
3.2. What is the minimum time period for reproduction of sexual or vegetative propagules?	3	3	3	3	3	3	3	3,0	3 - < 1 month; 2 - <1 year; 1 - < 2years, 0 - > 2 years; ? - don't know
3.3. What is the maximum longevity of sexual or vegetative propagules?	0	0	0	0	0	0	0	0,0	2 - >5 years; 1 2-5 years; 0 - < 2 years; ? - don't know
3.4. How likely are new propagules to continue to arrive at control sites, or start new infestations? (a) long distant dispersla by natural means (frequent (3 points) to rare (0 points); (b) growth (commonly planted (2 points) to not planted (0 pints)	3	2	3	3	3	1	3	2.6	Total (a+b) score: 0 to 4

The results of Feasibility of containment score calculated manually adjusting the raw scores are as follows (Virtue, 2008): Control costs: = 5.2; Current distribution = 0.7; Persistence = 7.7; Feasibility of containment = Control costs x Current distribution x Persistence = 28.0. So Feasibility score is <31 and falls in Frequency band: 20-40% which means that Feasibility of containment is assessed as "High".

Based on matrix of recommendation management (Table 4), when IAS risk index is assessed as „Medium" and feasibility index as "High" is recommended IAS plants management - "Protect sites". It **aims to prevent spread of the IAS (weed) species to key sites/assets of high economic, environmental and/or social value,** (Virtue, 2008).

Table 4 Matrix of IAS plants recommendations of management (Virtue, 2008; Hasbi, Rosleine, 2020)

WEED RISK	FEASIBILITY OF CONTAINMENT				
	Negligible >113	*Low >56*	*Medium >31*	*High >14*	*Very High <14*
Negligible <13	LIMITED ACTION	LIMITED ACTION	LIMITED ACTION	LIMITED ACTION	MONITOR
Low <39	LIMITED ACTION	LIMITED ACTION	LIMITED ACTION	MONITOR	MONITOR
Medium <101	MANAGE SITES	MANAGE SITES	MANAGE SITES	PROTECT SITES	CONTAIN SPREAD
High <192	MANAGE WEED	MANAGE WEED	PROTECT SITES	CONTAIN SPREAD	DESTROY INFESTATIONS
Very High >192	MANAGE WEED	PROTECT SITES & MANAGE WEED	CONTAIN SPREAD	DESTROY INFESTATIONS	ERADICATE

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4. Discussion

The “Protect sites” recommendation includes a wide range of measures, which will be considered for both the study area and the Gorge as a whole, in order to assess their prospects and applicability.

Measure 1: *IAS may be of limited current distribution but only threatens limited industries/habitats (lower IAS risk). Or the IAS may be more widespread but is yet to invade/impact upon many key industries/habitats (higher IAS risk). (Virtue, 2008).*

With its impressive height and population density, the Hymalayan balsam stands out among the other plants in the grass layer and creates the apparent impression of a high degree of invasion in the study area. However, the current risk assessment showed a much lower threat arising from this species for the natural habitats in the study area. The low value of 'Comparative weed (IAS) risk' is due to the low estimates of the 'Potential distribution' of the species. According to the evaluators, most of the study area is occupied by tree and shrub vegetation (the first one is autochtonic and belongs to the union *Alnion incanae* Pawłowski et al. 1928, and the secondary phytocoenoses are dominated by *Corylus avellana* L. and native species such as *Aegopodium podagraria*, *Rubus caesius* et al. *Impatiens glandulifera*, settles mainly in the open riparian areas, which make up a small percentage of the entire study area. As it falls within NATURA 2000, the associated habitat management regimes provide a potential guarantee for the large-scale preservation of its natural communities.

The registered anthropogenic impacts have a relatively low influence on the native plant communities (no fellings, fires and other activities have been identified that would lead to significant and targeted removal of tree and shrub vegetation and exposure of large areas of the river banks).

On the other hand, the region is anthropogenically burdened by the regular appearance of tourists, fishermen and herbalists. They facilitate the transport of seeds of the plant and by clearing the local vegetation of camping and fishing places facilitate the accommodation of the Hymalayan balsam. In addition, the small landfills favor the spread of the species on their sites. Implementation of this measure requires:

- Awareness - people need to be informed about the threat of this non native plant;
- Strict control of the NATURA 2000 habitat management protocol including the ban on waste disposal;
- Periodic cleaning of the riparian zone from waste, locall weeds and IAS;

Measure 2: Surveillance and mapping to locate all infested areas (Virtue, 2008).

The coordinates of all Hymalayan balsam localities (Table 1) are marked in the study area which is one of the most problematic in terms of invasion of the Hymalayan balsam (Table 1). Preliminary observations on the entire territory of the Gorge show that the localities of the species have a relatively larger size and significantly higher concentration in the first 1/4 of the territory of the Gorge, namely the section Devil's Bridge – Kokalyane. Devil’s Bridge is the mouth of the river Vedena, a tributary of the Iskar River, which passes through the village of Zheleznitsa (Fig. 1). Difficulty is the mapping (and respectively the elimination) of single individuals, which appear on sand deposits in the middle of the stream or on the remains of rotting wood and are a serious seed bank guaranteeing the survival of the population.

Measure 3: Identification of key sites/assets in the management area (Virtue, 2008).

The following localities are assessed as key sites:
- localities in which *Impatiens glandulifera* is the dominant or co-dominant species (Localities No 1 to 18, Table 1)
- localities playing the role of "connecting units" for further spread of the species in uninfected areas (this includes localities with strategic location of II and III line and localities of single species, isolated from the main populations, but with potential for conquest of new localities (Localities No 1 to 6, 7, 15, 23, Table 1).

Measure 4. Control of infestations in close proximity to key sites/assets, aiming for a significant reduction in IAS density (Virtue, 2008).

This measure is related to the previous one. In June, 2020 (before flowering) the population of *I. glandulifera* was reduced for the following localities in the study area (Table 1),

- Localities No 6 and 8 – eradication (Fig. 3a)
- Localities No 8 to 12 and 14, 15- mowing under the lowest node of the stem (Fig. 3b) .

The best results are given by the combination of measures - eradication of individuals in the juvenile phase (in April) and mowing of mature individuals - in early June.

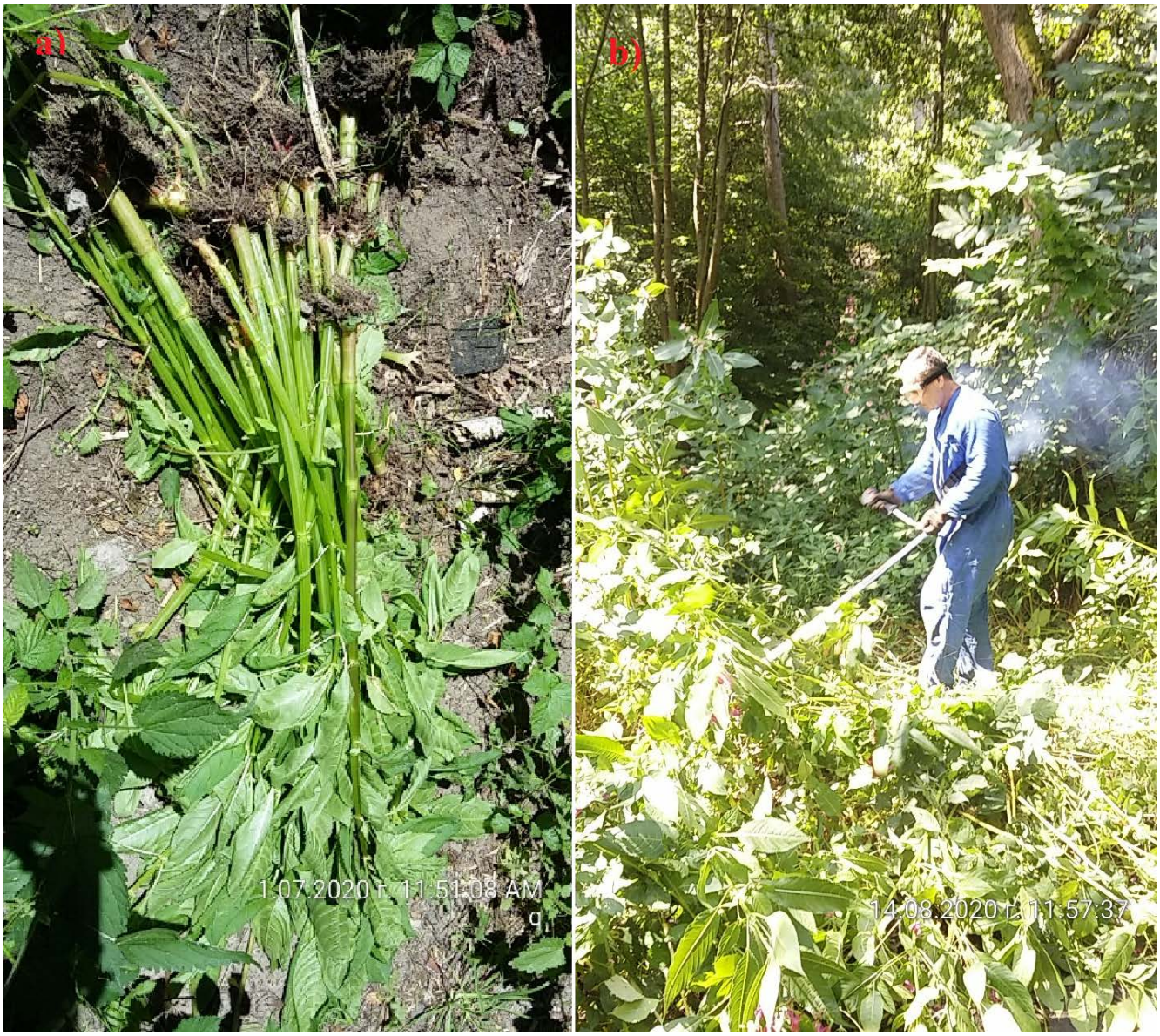

Fig. 3. Reduction of *I. glandulifera*'s populations: (a) Eradication (b) Mowing;
Photo: Plamen Glogov

Measure 5. Limits on movement and sale of species within management area (Virtue, 2008).

Most important for the qualitatively implementation of this measure are the public awareness rising campaigns, as most people spread the plant unintentially without knowing about the great damage it can bring to biodiversity and habitats. For this reason, in July, 2020 we held lectures among the local population of Sofia and Pancharevo on the topic "Hymalayan balsam - beautiful and dangerous." (Fig. 4)

Fig. 4. Lecture in front of the local people on the topic "Hymalayan balsam - beautiful and dangerous."
Photo: Mira Georgieva

In order to educate and strengthen the interest of the children's audience, we announced a children's drawing competition titled "How to deal with the dangerous foreign plant Hymalayan balsam" in which more than 40 authors from all over the country took part with drawings and ideas, many of which are original and applicable in practice (Fig.5).

Fig.5. Insects trophically related to *I. glandulifera* (*Deilephila elpenor*, *Xanthorhoe biriviata*, *Aphis fabae*, *Chrysolina herbacea* and *Pristerognatha fuligana).* Painting by Petar Arnaudov, 10 years old.
Photo: Plamen Glogov

Measure 6: Must not allow to spread from cultivated plants (if grown) in close proximity to key sites/assets

This measure is a continuation of the previous one and is of key importance to the awareness of the local people.There is a high probability that in the past the main routes of distribution of the Hymalayan balsam along the Iskar River were through its tributaries such as Vedena, Okolska River, Pancharevska River and others that pass through settlements with gardens in their houses, where this plant was grown as an ornamental. The localities of the whole territory of the Gorge and the density of the populations of *Impatiens glandulifera* are unevenly distributed. According to the evaluators and authors of the publication, in parallel with the monitoring measure it is necessary to reduce the populations of *Impatiens glandulifera* in localities where it forms dense monodominant coenoses.

Measure 7: Monitor change in current distribution within and in close proximity to key sites/assets

The immediate task is the application of an adequate methodology for monitoring and identification of measures to limit larger populations of this invasive alien species, forming monodominant phytocenoses in the study area. Specific indicators at the level of population (morphological and others) and habitat (floristic, phytocenological and ecological) are needed, on the basis of which to assess and predict changes in the invasiveness of the species.

According to Kachova and others. (2020) for the entire riparian area in the Gorge, which is 3 km², the total area of the populations of *Impatiens glandulifera* is 0.005 km² or 0.2%. According to Glogov et al. (2019) about 50 localities of *Impatiens glandulifera* with sizes between 50 and 100 m² have been established on the whole territory of the Gorge. The study area is one of the most affected by this invasive species and the results of the risk assessment of the Hymalayan balsam's spread in it can be considered representative of the entire riparian area of the Gorge.

The present study confirmed the findings of Hasbi & Rosleine (2020) that the Weed Risk Management Guide developed by Virtue (2008) can be easily adapted and used to assess the risk of invasive alien species such as *Impatiens glandulifera*. The questions in it are completely relevant to the IAS and cover all the necessary requirements for both the comprehensiveness and objectivity of the assessment. The guide facilitates the evaluators as much as possible in choosing specific answers and calculating the final results of the evaluation.

The Matrix of IAS plants recommendations of management and the subsequent guidelines for the implementation of the specific measures are practically applicable and largely feasible both for the studied plant and for other invasive species that have been identified in the invetigated area such as *Ailanthus altissima* (Mill.) Swingle, *Acer negundo* L., *Robinia pseudoacacia* L., *Reynoutria* × *bohemica* Chrtek & Chrtková, *Solidago gigantea* Aiton, *Erigeron annuus* (L.) Pers. and *Oenothera biennis* L.

There is a high probability that in the past the main routes of distribution of the Hymalayan balsam along the Iskar River were through its tributaries such as Vedena, Okolska River, Pancharevska River and others that pass through settlements with gardens in their houses, where this plant was grown as an ornamental. The localities of the whole territory of the Gorge and the density of the populations of *Impatiens glandulifera* are unevenly distributed.

4. Conclusions

The risk assessment of the invasive alien species *Impatiens glandulifera* in the experimental area showed that at the present stage the level of risk of its spread and impact is medium and requires a set of measures, including information and publicity for the purpose of prevention, reduction of the population in case of predominant presence of the species or the strategic function of its localities and conducting regular monitoring to trace the changes in the invasiveness of the species.

Due to the significant distribution along the river of single individuals of the Hymalayan balsam, it is impossible to completely destroy the species at once. It is achievable as a immediate result in the studied area this exotic plant to be limited to an assectator, as it contributes to the enrichment of bee grazing in the area.

The methodology used in the Weed Risk Management Guide is largely applicable, easy and convenient for studies that are related to the risk assessment of invasive alien species.

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