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Original Research

Invasive Alien Species *Impatiens glandulifera* Royle – Spread Dynamics, Environmental Impacts and Youth Perception of the Problem

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Abstract

Invasive species have become an urgent problem in many parts of the world, affecting regional biodiversity, environmental health. The presence and expansion of invasive plant species in Europe were also mentioned in earlier centuries, not only nowadays. The plant species *Impatiens glandulifera* Royle was observed in Przedecz Lake (central Poland) riparian zone vegetation in the 1990s. The source of the species in the studied area was its cultivation in surrounding gardens (human vector). Data on Himalayan balsam were collected during studies undertaken in the years 1998, 1999, 2002 and 2005. The rate of spread of the species was astonishing in the studied test field located in the riparian zone of Przedecz Lake. A questionnaire for students was prepared to test their knowledge of invasive plants and to reveal their attitude to this environmental problem. In the studied group of young persons between 20 and 25 years of age, as many as 46% accepted the idea of planting of invasive species in private gardens.

Keywords: *Impatiens glandulifera,* invasive alien species, attitudes towards invasive plants

Introduction

Several alien invasive plants have been observed in the last decades in riparian zones and waters in both Americas, Australia and Europe [1-4]. They were studied according to their increasing presence and the environmental consequences. This is a worldwide problem, and the increasing share of alien species in the structure of plant composition affects both land and water, where modification of environmental conditions is observed. Due to the importance of alien species in the ecosystem, nuisance invasive species should be identified during field studies using methods such as the Mean Trophic Rank and the Lake Habitat Survey [5, 6]. The presence of plants such as *Azolla filiculoides* Lam., *Crassula helmsii* (Kirk) Cockayne, *Elodea nuttallii* (Planch.) H. St. John, *Hydrocotyle ranunculoides* L.f., *Myriophyllum aquaticum* (Vell.) Verdc. and *Impatiens glandulifera* Royle can be recorded in the field protocols.

In central Poland the problem of invasive species is similar as in the rest of Europe [7]. The invasive plant *Impatiens glandulifera* Royle (Himalayan balsam, custodian helmet) was first observed in the Przedecz Lake watershed during studies carried out in the year 1996, as a plant cultivated in gardens surrounding the lake. The plant was introduced to gardens due to

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the attractive appearance of the flowers. In the past, the human vector was responsible for many invasions in different waters including introduction of both plants and animals. For instance, the crabs *Eriocheir sinensis* (H. Milne Edwards, 1853) and *Rhithropanopeus harrisii* (Gould, 1841) appeared in Baltic Sea waters and caused changes of the ecological pyramid [8, 9].

The attitude of inhabitants to invasive alien species play a very important role in limiting the spread of such taxa in a certain area. Dissemination of knowledge of the rate of their multiplication, the spread dynamics and potential harmfulness for the environment is crucial for limitation of their encroachment. Young people are often very interested in nature protection, so they are a target group in many actions and studies undertaken across the world [10, 11].

Therefore main aims of studies were: analyses of the spread dynamics of *Impatiens glandulifera* Royle using test-field, evaluation of possible pressure of Himalayan balsam on surrounding plant species, perception of invasive plants by youths using feedback form.

Material and Methods

Studies of Himalayan balsam were conducted using a test field of 400 m^2 area (square 20×20 metres, 52°19'53.4"N 18°53'56.7"E) located in the riparian zone of Przedecz Lake. The catchment of this lake is a part of Wielkopolska Lakeland, which is second in importance in Poland after the Masurian Lakeland located in the north. The number of invasive plant specimens and their cover were investigated in the years 1998, 1999, 2002 and 2005.

To evaluate potential shifts in taxa composition, the classification of plants in the riparian zone of Przedecz Lake was carried out during the summer months June-September, on the basis of Braun-Blanquet methodology [12]. Identification of particular plant species and communities was based on the keys of the authors Rich and Jermy [13].

A special questionnaire for students from Adam Mickiewicz University and Poznan University of Life Sciences aged between 20 and 25 years was prepared to test their knowledge of invasive plants including Himalayan balsam. The attitude of students to this environmental problem was evaluated using a questionnaire consisting of 10 questions including pictures (without descriptions) of three invasive plants to assess students' visual recognition of them (*Impatiens glandulifera* Royle, *Echinocystis lobata* (Michx.) Torr. & A. Gray, and *Reynoutria japonica* Houtt.). Of 160 inquiry forms that were disseminated to students living in central Poland and studying in the city of Poznan, 129 forms were completed and returned, and 115 properly answered forms were used in the present analyses.

Results

Studies of the Spread of *Impatiens glandulifera*

Studies on the alien invasive plant *Impatiens glandulifera* Royle using a test field were started in the year 1998 after identification of this species in the riparian zone of Przedecz Lake and in the watershed. It became a problem in this area from the mid 1990s, and the first specimens were found in riparian vegetation located between the lake and private gardens, where the plants were cultivated. In 1998, only 8 plants were observed in the test field, and the next year there were 15 plants, covering 20 m^2 in both years (Fig. 1). After 2005, the population was strongly limited by development of a beach for recreation and a park. In June 2020 some small patches were still observed in the south-eastern part of the lake, but the extent of the population was limited by improving the sandy strand, every year before the summer season for recreational purposes.

On the basis of phytosociological studies, several macrophyte groups were distinguished. Identified communities of the riparian zone of Przedecz Lake in

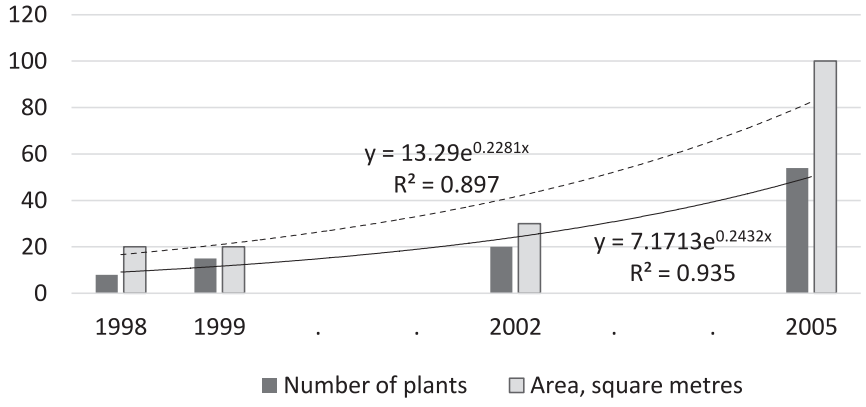

Fig. 1. Spread dynamics of *Impatiens glandulifera* Royle in test-field of 400 m^2, Przedecz Lake riparian zone, summer observations in years 1998, 1999, 2002 and 2005.

Table 1. Environmental impact of *Impatiens glandulifera* in comparison to another types of pressure on riparian vegetation of Przedecz Lake.

Type of pressure	Vanished species	Decrease of the area covered by species
Presence of invasive species Himalayan balsam	*Puccinellia distans*	*Typha latifolia* *Typha angustifolia* *Phragmites australis* *Glyceria maxima* *Plantago major* *Poa pratensis* *Potentilla anserina*
Angling from the shore (weed cutting; poaching)		*Typha latifolia* *Typha angustifolia* *Phragmites australis* *Glyceria maxima* *Carex riparia* *Impatiens glandulifera*
Recreation (adding of sand to improve beach quality; weed cutting; presence of people in water)		all plants within bathing waters and on the bank including *Impatiens glandulifera*

the years 1996-2012, were as follows:
Class: *Phragmitetea* (Tx. et Preisg. 1942)
Order: *Phragmitetalia* (Koch 1926)
Alliance: *Phragmition* (Koch 1926)
Association: *Phragmitetum* (Gams 1927; Schmale 1939)
Association: *Typhetum angustifoliae* (Allorge 1922)
Association: *Typhetum latifoliae* (Soó 1927)
Order: *Magnocaricetalia* (Pign. 1953)
Alliance: *Magnocaricion* (Koch 1926)
Association: *Caricetum ripariae* (Soó 1928)

The list of plant communities lost *Typhetum latifoliae* (Soó 1927) association in the years 2013-2019, but isolated sites with presence of *Typha latifolia* L. were observed in the riparian zone around the studied lake.

During the research, different types of human pressure on the lake and riparian zone were observed (Table 1) to evaluate its potential interactions with native plants and the presence of alien species. The eastern and southern parts of the lake were generally more developed for recreation than other parts. The most frequent activities at the lake were swimming, angling and, close to the waterline, gardening and agriculture. Some of the activities caused a decrease of plant cover but only the presence of Himalayan balsam caused complete disappearance of one species from the riparian vegetation.

Students Answers for Questionnaire

Student's knowledge and attitude on invasive plants including Himalayan balsam were studied in the year 2020. In total, 115 properly completed questionnaires were taken into account and the results are presented in Table 2.

Discussion

Spread Dynamics of Himalayan Balsam and Its Impact on Vegetation

An interesting observation was made in the riparian test field according to the life strategy of Himalayan balsam. In the first two or three years the population density increased, almost without a change in cover, as in Fig. 1, and after that, the area covered by the species started to increase. Both the number of plants and covered area changed exponentially and coefficients of determination R^2 of the trend lines were high and equal to 0.93 and 0.89 respectively. During the research the number of plants and area covered by plants were not measured every year, so it can be presumed that with more data the value of R^2 might not be so high but probably still close to 0.8.

After years of unrestricted development of the population, measures to reduce this problem were undertaken (weed cutting, closure of private gardens located close to the lake and subsequent development of a recreational area with maintained sandy strand), especially after 2005. *Impatiens glandulifera* Royle is still present in the area (riparian vegetation, roadsides, waterlogged areas) with various intensity.

The riparian zone range and its taxonomical structure, beside the environmental aspects, play an important role in socio-ecological issues related to biodiversity, water quality, changes in land use structure and others [14]. This ecosystem is very productive and helps to maintain biodiversity. Thus limiting invasive species pressure on riparian vegetation is an urgent task in Europe and other continents.

The studied species *Impatiens glandulifera* Royle is one of the most widely distributed invasive plants in Polish national parks and was identified in 17 parks

Table. 2. Summary of answers obtained from students questionnaire about alien invasive plants.

Questions	Possible answers	Total	Women	Men	Villages	Towns
		Number of questionaires				
		115	70	45	42	73
		Answers, %				
1. Do you know any invasive plant growing in Europe?	Yes	66.1	62.9	71.1	59.5	69.9
	No	10.4	8.6	13.3	14.3	8.2
	I don't know	23.5	28.6	15.6	26.2	21.9
2. Can plants identified as invasive be introduced into the environment without permission?	Yes	2.6	1.4	4.4	0.0	4.1
	No	66.1	58.6	77.8	66.7	65.8
	I don't know	31.3	40.0	17.8	33.3	30.1
3. Have you ever heard of invasive species such as:	Water fern	0.9	1.4	0.0	0.0	1.4
	Giant hogweed	13.0	12.9	13.3	9.5	15.1
	Sosnowsky's hogweed	87.0	85.7	88.9	78.6	91.8
	Wild cucumber	1.7	2.9	0.0	0.0	2.7
	Himalayan balsam	0.9	1.4	0.0	0.0	1.4
	Japanese knotweed	13.0	12.9	13.3	9.5	15.1
4. Are you familiar with examples of the negative impact of invasive plant species on native plants?	Yes	46.1	37.1	60.0	42.9	47.9
	No	33.9	37.1	28.9	28.6	37.0
	I don't know	20.0	25.7	11.1	28.6	15.1
5. Do you know any examples of the negative impact of invasive plants on humans?	Yes	66.1	64.3	68.9	61.9	68.5
	No	21.7	21.4	22.2	26.2	19.2
	I don't know	12.2	14.3	8.9	11.9	12.3
6. Do you know any example of the removal of invasive plant species in your region?	Yes	15.7	14.3	17.8	11.9	17.8
	No	66.1	65.7	66.7	69.0	64.4
	I don't know	16.5	20.0	11.1	19.0	15.1
7. Have you seen plants shown on pictures in the field? (unsigned photos)	*Impatiens glandulifera*	20.0	25.7	11.1	19.0	20.5
	Echinocystis lobata	27.8	28.6	26.7	19.0	32.9
	Reynoutria japonica	43.5	50.0	33.3	33.3	49.3
8. Why would you introduce an invasive species into your garden? (possibility to point out more than one reason)	Good look	33.0	34.3	31.1	40.5	28.8
	Nice smell	9.6	14.3	2.2	19.0	4.1
	Fast growth	3.5	4.3	2.2	2.4	4.1
	Impressive fence	10.4	8.6	13.3	16.7	6.8
	Cuisine /medicinal qualities	20.9	22.9	17.8	23.8	19.2
	Other	3.5	2.9	4.4	4.8	2.7
	I will never introduce an invasive species into the environment	49.6	47.1	53.3	40.5	54.8
9. Can you see the need to remove invasive plant species from the environment?	Yes	53.9	47.1	64.4	50.0	56.2
	No	12.2	11.4	13.3	9.5	13.7
	I don't know	33.9	41.4	22.2	40.5	30.1
10. If you answered YES to question 9, which methods do you consider as the best? (possibility to point out more than one method)	Manual removal	12.2	8.6	17.8	17.8	17.8
	Mechanical removal	37.4	35.7	40.0	40.0	37.0
	Chemical removal	23.5	25.7	20.0	20.0	21.9

during recent surveys carried out by Bomanowska et al. [15]. The first specimens of Himalayan balsam were identified in the Przedecz Lake riparian zone in 1998 (8 fully grown plants, covering an area of 20 m^2) and after 5 years, it spread for a distance of 4 km along local roads and ditches. Distribution near roads was also observed by other authors [16]. The test field, where the invasive plants were studied, was changed by the local authorities into the town beach covered by concrete paved blocks and sand (close to the water); thus the plant disappeared from this site, but is still observed around the lakeshore and in other parts of the watershed. Initially, the source of Himalayan balsam was local gardens, where it was perceived as an aesthetically appealing plant for garden design, and other possible sources were not identified. The increase of the *Impatiens glandulifera* Royle population

Typha latifolia L. and *Puccinellia distans* (Jacq.) Parl were identified in the riparian zone of the studied lake in 1996, and presence of *Impatiens glandulifera* Royle caused a decline of both species. The broadleaf cattail did not disappear from the littoral zone, but its cover area and density were limited by the presence of Himalayan balsam. A constant decline of *Typha latifolia* L. presence has been observed since 2000 due to the occurrence of Himalayan balsam and the increasing rate of recreational activities. The species *Typha latifolia* L. and *Impatiens glandulifera* Royle to some extent have similar environmental needs. Broadleaf cattail occupies fertile habitats with organic or organic-mineral substrate, occurring rarely on mineral substrate. Himalayan balsam can live both on fertile and poor soils with good moisture or close to water bodies and creates mostly single-species patches of vegetation. The population of this invasive species was growing from the late 1990s and covered the eastern part of Przedecz Lake (Fig. 1) and also surrounding areas, throughout the next few years.

In the riparian zone of Przedecz Lake the halophile grass *Puccinellia* distans (Jacq.) Parl was observed in 1996, and the taxon had completely vanished from the test field by the year 2000. It is not a very common taxon in Poland, but the studied area is located in a region with an active salt mine, Kłodawa. In the studied test field it was the only species which disappeared from the formerly occupied area, and such a phenomenon was not observed in the case of other pressures (Table 1). The Himalayan balsam spread caused that even the population of the cosmopolitan taxon *Phragmites australis* (Cav.) Trin. ex Steud. declined under the pressure of this invasive species.

There are several reasons for the ecological success of *Impatiens glandulifera* Royle, such as creation of shading conditions for other plants, allelophatic pressure and the effective way of 'impatient' propagation. Due to quick growth up to 2 metres, shading seems to be of high importance in competition with other species, similarly as in aquatic ecosystems [17-20]. The plant proliferates using cracking seed pods, which when disturbed can propel seed for a distance of several metres due to their ballistic properties [21]. Unfortunately, this plant can potentially promote soil erosion when growing near waters [22], thus accelerating freshwater eutrophication. On the basis of observations made in the Przedecz Lake riparian zone, it may be due to deterioration of grasses and dicotyledon species in the vicinity of the Himalayan balsam. One of the reasons for rapid spread of this plant in central Poland could be the warm summer periods in last two decades followed by a limited volume of precipitation in comparison to the average in the twentieth century. The species originates from an area between Kashmir (Pakistan) and Uttarakhand (India) where the average total precipitation is very diverse. Precipitation ranged from 124 to 159 mm in Kashmir, whilst in Uttarakhand it ranged from 1285 to 2095 mm (https://pl.climate-data.org/).

Various control strategies to preserve native vegetation have been implemented in countries facing the problem of Himalayan balsam proliferation. Manual removal is one of the preferred methods due to the lack of additional local disturbances, which can occur during implementation of chemical management. Another possibility is spread control using native species to recolonize areas after pior removal of invasive plants [21]. Oliver et al. [23] proposed and tested the use of hot water and cutting, obtaining very promising results. These methods can be implemented to prevent germination of seedlings of the studied plant.

Perceiving of Invasive Plants by Students

To understand how this species could spread in Poland in the near future, a special questionnaire for young people was prepared. Such a method can help in understanding the process and to find possible solutions [24]. The results of the investigation of the students' knowledge about the analysed species were surprising and procured unbiased but valuable opinions. Respondents claimed understanding of the importance of the topic of invasive plants. Up to 66.1% of young people confirmed having knowledge of the impact of alien invasive species on native species and having heard about the possible negative impact on human health (Table 2). The most recognisable invasive plant was Sosnowsky's hogweed (87% in total and 91.8% in the case of town inhabitants), which is well known even in cities, and every year on television and in the press there is information about the health consequences after contact with this species.

Himalayan balsam and water fern were less known by students. This was due to the lack of danger for human health, and some owners of gardens accept *Impatiens glandulifera* Royle for its attractive flowers (33%). Additionally, as many as 25.7% of females and 20.5% of town inhabitants report familiarity with this species shown in the picture without any description. Some of the student respondents (20.9%) were aware of the medicinal value of some invasive plants.

The present research revealed that 49.6% of students were aware of introduction of alien species to the environment (54.8% in the case of town inhabitants), but it means that teaching about invasive species should be improved and perhaps made more attractive. Unfortunately, as many as 46% accepted the idea of planting of invasive species in private gardens due to various reasons (aesthetics, culinary or medical value, and the possibility of a constraining fence around the garden), whilst 66.1% of all respondents stated that such plants cannot be cultivated without permission. From the questionnaire results, it was found that most of the students supported the need for removal of alien invasive species, and they indicated that mechanical removal is the most preferable method, on account of the costs of labour and possible environmental consequences after use of chemicals.

Taking the obtained data into account, it can be presumed that a proportion of the students believe that to some extent they can control invasive plants in their own gardens against proliferation in surrounding areas. Thus dissemination of data on the rate of spread of taxa such as Himalayan balsam is crucial in protection of local biodiversity and environmental health. It would also enhance the use of citizen science in delimitation of distribution of the species and further limitation of its development.

Conclusions

1. The spread dynamics of *Impatiens glandulifera* Royle studied in riparian zone test-field was very rapid. Obtained data showed interesting phenomenon of life strategy of Himalayan balsam, which population densifies in first years without changes in cover and after then, the area covered by the species increasing rapidly.

2.The presence of studied invasive species caused vanishing of weeping alkaligrass *Puccinelia distans* (Jacq.) Parl. from the list of riparian taxa.

3. The presence of plant species *Typha latifolia* L. was significantly limited by the pressure of *Impatiens glandulifera* Royle, thus its community was not identified in recent years.

4. Young people despite declaration of the acknowledgement with alien invasive plant species believe it is safe for environment to cultivate them in private gardens.

5. Education on consequences of the presence of alien invasive plant species like Himalayan balsam in environment is essential in conservation of regional biological diversity.

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Conflict of Interest

The authors declare no conflict of interest.

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