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Habitat Condition of *Tilio–Acerion* Forest Facilitates Successful Invasion of *Impatiens parviflora* DC

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Abstract

Impatiens parviflora DC. occurs in various plant communities. Its occurrence has been confirmed in Poland across 13 natural habitats protected under the Habitats Directive. The aim of our work is to determine the differences between the plots with and without *I. parviflora* in terms of the species richness and ecological conditions of the 9180* habitat-type forest. Using data from 315 plots on which a phytosociological relevés was carried out, we analyzed the geographical variability, the Shannon-Winner index and the indicator species for old forests. Flora diversity was represented using the DCA, and the IndVal index was calculated to determine the species that best characterize the differentiated groups. The highest percentage of monitoring plots with *I. parviflora* is located in the Sudetes Mountains (67.7%) and the lowest in the Bieszczady Mountains (7.5%). Plots with *I. parviflora* were characterized by significantly lower tree cover, a higher number of tree species in the stand, a lower height of both the understory and herb layer and a lower number of old forest species. *Impatiens parviflora* does not affect the total number of species in the understorey but is associated with a lower proportion of species typical of old forests. The presence of *I. parviflora* also correlates with a higher proportion of young trees in the understorey, suggesting a link with successional processes and habitat disturbance. The spread of *I. parviflora* is limited by shade-loving trees such as *Abies alba* Mill. and *Fagus sylvatica* L. The diversity of the distribution of *I. parviflora* depends on local conditions, so conservation efforts should take into account the local ecological context.

Keywords: alien species; habitat protection; Natura 2000; slope forests

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1. Introduction

The Habitats Directive [1] states that natural habitat types (terrestrial or aquatic areas characterized by geographical, abiotic and biotic features and which are entirely natural or semi-natural) threatened with extinction in their natural range or whose natural range is small due to their regression or spatial limitation, or which are outstanding examples of typical features of one or more biogeographical regions, are to be conserved within the borders of the European Union. Protection refers to a series of measures that are necessary for the conservation or restoration of natural habitats and to which the Member States of the European Union have committed themselves. Of particular importance are the priority natural habitat types, i.e., habitats at risk of disappearing, which are mainly found in the EU.

One of the priority habitats protected by the Habitats Directive is the *Tilio–Acerion* forests of slopes, scree and ravines (code 9180*), which, according to the CORINE

classification [2], correspond to the Mixed Ravine and Slope Forests (code 41.4). Habitat type 9180* comprises species-rich deciduous forests with a constant and often dominant proportion of *Acer pseudoplatanus* L. Habitat type 9180* occurs in all mountainous regions of Europe on steep slopes with skeleton-rich soils and active erosion processes. The slopes are usually north-facing, which creates special microclimatic conditions characterized by high humidity, low solar radiation and cool temperatures [3]. In Poland, due to these requirements, they only occur in the mountainous regions of southern Poland and in its foothills. The area of this habitat type in Poland is 20.4 km^2 [4].

Impatiens parviflora DC. is an annual plant that occurs naturally in the mountainous regions of Central Asia. In Europe, the species appeared in the 1830s—the first wild specimens were found in 1831 near the botanical garden in Geneva (Switzerland), where the species was cultivated [5]. In Western Europe, it was mainly found growing near botanical gardens until the end of the 19th century. The first mentions of its occurrence in Poland (in a natural environment) date back to 1850. The current distribution area in Poland covers the entire country [6]. *I. parviflora* has a wide range of ecological requirements for growth and development, which varies in different parts of Europe [7] and is most commonly found in forest communities [5]. It occurs in coniferous and mixed coniferous forests, in mixed forests, deciduous forests (most often in hornbeam forests and beech forests) and even in alder and riparian forests [8]. It also occurs in various non-forest plant communities—disturbed or undisturbed [9–14]. Reproduction of *I. parviflora* is related to its ability to produce a large number of seeds (2000 to 10,000 seeds from one plant) and to their rapid germination [15]. The seeds can remain alive in the soil for up to 3–5 years. The time from germination to flowering is 8–9 weeks. The seeds are actively dispersed up to 3–4 m away. They can also be transported by water currents, mammalian hairs and soil, into the root ball of garden plants [5,16]. Due to the wide geographical distribution of the species and the possibility of mass occurrence, *I. parviflora* is perceived as a threat to 13 natural habitats protected under the Habitats Directive (3220; 3240; 6430; 8210; 8220; 9110; 9130; 9160; 9170; 9180*; 9190; 91E0*; 91F0) [17]. The presence of this species also has a direct impact on the assessment of the conservation status of a particular phytocoenosis [18].

The aim of our work is to determine the differences between the plots with and without *I. parviflora* in terms of the species richness and ecological conditions of the 9180* habitat type forest. In this way, we can learn at a national level about the ecological factors that favour the occurrence of *I. parviflora* in this rare and naturally valuable forest type.

2. Materials and Methods

2.1. Data Collection

Our research is based on 315 plots on which a phytosociological relevés was carried out in 2021. These plots are used to monitor the conservation status of habitat type 9180* as part of the State Environmental Monitoring (SEM) resulting from the provisions of the Habitats Directive [19]. Their distribution is shown in Figure 1.

The phytosociological relevés were carried out according to the method developed by Braun-Blanquet [20]. The percentage cover of each vascular plant species was estimated using a seven-degree cover class scale (r—1–2 plants; +—2–5 plants; 1—species covers < 5%; 2—species cover 5%–25%; 3—species cover 25%–50%; 4—species cover 50%–75%; 5—species cover 75%–100%) [20]. The area of the phytosociological relevés was between 100 and 400 m^2. Within the area of the phytosociological relevés, we estimated cover (%) of the vegetation layers (A—tree layer: height > 5 m, B—shrubs (height 0.5–5 m), C—herbaceous vegetation and trees less than 0.5 m high) and their average height (cm). The height above sea level was determined using a GPS device. The slope gradient (%) was also measured at each sample area. Plant communities were identified for each relevés. But

because relevés are located systematically in vegetation patches, it is not always possible to identify plant communities in the same levels of organization.

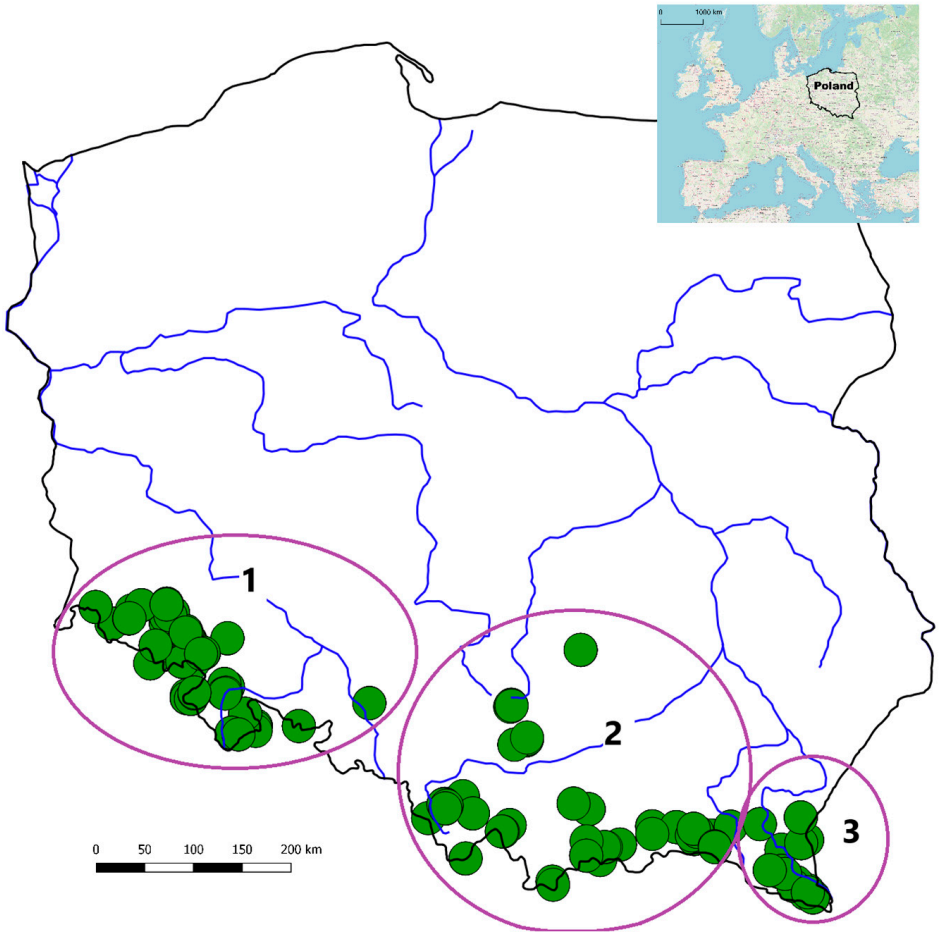

Figure 1. Map of the study area; green dots—locations of phytosociological relevés; 1—Sudetes Mountains; 2—Western Carpathians and Świętokrzyskie Mountains; 3—Bieszczady Mountains.

2.2. Data Analysis

Two plot groups were distinguished: IP0—plots without *Impatiens parviflora* DC. occurrence, IP1—plots with *I. parviflora* occurrence. Based on the floristic lists contained in the phytosociological relevés, the number of plant species in each vegetation layer was determined for each plot. To take into account the geographical variability, the sample plots were divided into groups according to their location: 1—Sudetes Mountains; 2—Western Carpathians and Świętokrzyskie Mountains; 3—Bieszczady Mountains (Figure 1). The Sudetes Mountains occupy the southern part of western Poland. It is a mountain range made of crystalline rock. This mountain range has been repeatedly destroyed and uplifted by erosion. The Carpathians, which lie to the east of the Sudetes Mountains, are a younger and higher mountain range than the Sudetes Mountains. The Carpathians can be divided into the Western Carpathians, which consist mainly of sedimentary rock, and the Eastern Carpathians (Bieszczady Mountains), which consist of sandstone and shale. The Bieszczady Mountains are a gentle mountain range characterized by a large forest cover and a low population density. The Świętokrzyskie Mountains are the lowest mountain range located north of the Western Carpathians. The landscape in the Świętokrzyskie Mountains is characterized by steep slopes, deeply carved valleys, outliers and stone run. The Western Carpathians and the Świętokrzyskie Mountains were grouped together into one group as they have similar floristic communities. Species cover from the Braun-Blanquet scale

was converted into the percentage of the phytosociological releve area: r = 0.01%, + = 0.1%, 1 = 5%, 2 = 17.5%, 3 = 37.5%, 4 = 62.5%, 5 = 87.5% [20]. Only vascular plants were analyzed. The Shannon–Wienner diversity index were calculated for each plot. In addition, the average of the ecological indicator values was calculated for each plot. The ligth index (L), the trophism soil index (Tr) and the humidity soil index (W) were taken into account. The numerical values of the individual species were taken from Zarzycki [21]. Zarzycki's ecological indicators are better suited to Polish conditions. In contrast to Ellenberg's indicator numbers, the values of the indices according to Zarzycki do not range from 1 to 9, but from 1 to 5. The value of a particular ecological indicator on the sample plot was calculated as the average value of the individual species occurring on the plot, weighted according to their cover. The indicator species for old forests (plant species which show fidelity to forests which have documented long-term continuity in the area under consideration) were selected according to Dzwonko and Loster [22]. Statistical analyzes were carried out using R (version 4.3.1) [23]. The mean values of the variables between two groups were compared using a Student *t*-test—package "stats" [23]. Rarefaction curves were calculated using the iNEXT package [24,25].

The relationship between the proportion of *I. parviflora* in the surface cover and tree species surface cover was determined using GLM analyses (Poisson distribution was used)—package "stats". Only species of tree layer whose frequency, in this layer, exceeded 10% were included in the analysis. In this way, we were able to exclude species that only occurred sporadically in the habitat. The species eliminated in this way showed no significant correlation with the *I. parviflora* coverage. For the analysis, the percentage cover of *I. parviflora* was rounded to whole numbers. To achieve the best fit of the model, the function "step" from the package "stats" was used, which performed multiple comparisons of different combinations of the given variables to achieve the lowest possible AIC (Akaike Information Criterion) value of the model. The variables used in the analysis were checked for the presence of collinearities by calculating the Variance Inflation Factor using the "vif" function from the "car" package [26].

Flora diversity was represented using the DCA analysis of the "vegan" package [27]. The relationship between plot order and environmental variables was determined using the permutation test ("vegan" package, function "envfit", 999 iterations). The *p*-value was adjusted using the Bonferroni correction. In the DCA analysis, the species coverage rate was converted from the Braun-Blanquet scale [20] to the ordinal scale of van der Maarel [28]: r = 1; + = 2; 1 = 3; 2 = 5; 3 = 7; 4 = 8; 5 = 9.

To determine the species that best characterize the IP0 and IP1 groups an index called IndVal (indicator value) was calculated [29]. The index is a product of two components A (specificity, i.e., the proportion of individual species of species i occurring in class j) and B (fidelity, i.e., the proportion of plots in class j containing species i). The IndVal index was calculated using the package "indicspecies" [30]. To calculate the IndVal index, the cover-abundance values was converted from the Braun-Blanquet scale to the Van der Maarel scale [28].

We additionally performed linear regression analyses using a package "stats" [23]. Three models were fitted using (1) the presence/absence of *I. parviflora*, (2) cover of *I. parviflora* expressed in the van der Maarel scale (species cover was converted from the Braun-Blanquet scale [20] to the ordinal scale of van der Maarel [28]), and (3) percentage cover of *I. parviflora* (species cover from the Braun-Blanquet scale was converted into the percentage of the phytosociological releve area: r = 0.01%; + = 0.1%; 1 = 5%; 2 = 17.5%; 3 = 37.5%; 4 = 62.5%; 5 = 87.5%) as predictors of the Shannon-Winner index (H).

3. Results

The frequency of *Impatiens parviflora* DC. in the 315 analyzed plots was 46%, the arithmetic mean of the coverage of this species in the phytosociological relevés was 13.2 (SE = 1.3%). The analyzed phytosociological data of 9180* habitat type plots represent six plant communities (Table 1). The proportion of plots where *I. parviflora* was detected ranged from 0% to 79.3% in the individual communities. At the plots in the Bieszczady Mountains (N = 80) *I. parviflora* occurred at 7.5% of the plots, in the Western Carpathians (N = 74) at 40.5% and in the Sudetes Mountains (N = 161) at 67.7%.

Table 1. Number (N) of plots in individual plant communities and frequency (F) of identified plots with *Impatiens parviflora* DC.

Plant Community	Total		Bieszczady Mountains		Western Carpathians		Sudetes Mountains	
	N	F (%)	N	F (%)	N	F (%)	N	F (%)
Acer pseudoplatanus-Aruncus sylvestris	6	50	0	0	0	0	6	50
Aceri-Tilietum Faber 1936	82	79.3	0	0	6	16.7	76	84.2
Arunco dioici-Aceretum pseudoplatani Moor 1952	85	44.7	12	0	28	42.9	45	57.8
Phyllitido-Aceretum pseudoplatani Moor 1952	91	25.3	63	9.5	28	60.7	0	0
Sorbo aucupariae-Aceretum pseudoplatani Celiński et Wojterski (1961 n.n.) 1978	17	0	5	0	12	0	0	0
Tilio platyphylli-Acerion Klika 1955	34	47.1	0	0	0	0	34	47.1
Total	315	46	80	7.5	74	40.5	161	67.7

The analysis of the occurrence of *I. parviflora* in different plant communities and mountain ranges showed that the occurrence of the communities varies between the mountains, which also applies to the abundance of the species. The highest frequency of the species was found in the Sudetes Mountains, the lowest in the Bieszczady Mountains. In the Bieszczady Mountains, 80 plots were described (25.4% of the total number of plots). *I. parviflora* was found only in *Phyllitido–Aceretum pseudoplatani* (63 plots), where its abundance was very low (9.5%). In the other communities, *I. parviflora* was not recorded despite numerous detections (*Arunco dioici–Aceretum pseudoplatani*—12 plots; *Sorbo aucupariae–Aceretum pseudoplatani*—5 plots). In the Western Carpathians, 74 plots (23.5%) were described. The species reached the highest frequency in *Phyllitido–Aceretum pseudoplatani* (60.7%; 28 plots), and it also had a significant proportion in *Arunco dioici–Aceretum pseudoplatani* (42.9%; 28 plots). The occurrence of *I. parviflora* in *Aceri–Tilietum* was low (16.7%; 6 plots). The species was absent in *Sorbo aucupariae–Aceretum pseudoplatani* and *Tilio platyphylli–Acerion*. Most plots were described in the Sudetes Mountains (161 plots, i.e., 51.1% of the total). The highest frequency values were also found here. *I. parviflora* was most common in *Aceri–Tilietum* (84.2%; 76 plots) and very common in *Arunco dioici–Aceretum pseudoplatani* (57.8%; 45 plots). It was also very common in *Tilio platyphylli–Acerion* (47.1%; 34 plots). However, the species was not found in *Phyllitido–Aceretum pseudoplatani*, which is practically absent in the Sudetes Mountains.

Compared to IP0 plots, IP1 plots were characterized by a significantly lower tree cover, a higher number of tree species in the stand, a lower height of both the understory and herb layer and a lower number of old forest species (Table 2). These areas were also characterized by a larger area and were located at a lower altitude above sea level. Compared to the IP0 plots, lower habitat preferences of the flora present in the IP1 plots were found in terms of substrate moisture and higher light incidence on the forest floor.

Table 2. Comparison of the average values (median) of environmental variables between plots with *I. parviflora* (IP1) and without (IP0).

Variable	Abbreviation	IP0 N = 170		IP1 N = 145		*t*-Test
		Mean	SE	Mean	SE	*p*
Tree layer (%)	A	78.59	1.32	74.28	1.14	0.014
Shrub layer (%)	B	21.31	1.3	19.18	1.36	0.259
Herbal layer (%)	C	70.91	1.51	68.31	1.8	0.270
Above sea level.	npm	620.51	17.74	443.67	11.06	0.000
Shannon–Wiener index	H	2.97	0.03	2.94	0.03	0.569
Height A of tree layer (m)	H_A	26.71	0.38	26.96	0.31	0.606
Height B of shrub layer (m)	H_B	3.76	0.18	2.83	0.13	0.000
Height C of herbal layer (cm)	H_C	47.94	1.65	33.93	1.41	0.000
Number of species in A-tree layer	N_A	2.98	0.08	3.59	0.12	0.000
Number of species in B-shrub layer	N_B	3.18	0.18	3.5	0.2	0.224
Number of species in C-herbal layer	N_C	23.21	0.69	22.27	0.63	0.316
Old forests species (number of species)	GSL	13.43	0.44	11.46	0.4	0.001
Trophism soil index	Tr	3.83	0.02	3.87	0.02	0.145
Humidity soil index	W	3.35	0.01	3.28	0.01	0.001
Light index	L	2.43	0.03	2.54	0.03	0.004

The results from linear regression analyses are in Table S1 in Supplementary Materials. In all models, regression coefficients were negative and statistically non-significant ($p > 0.05$), indicating that neither the presence nor the cover of the *I. parviflora* significantly affected plant species diversity.

The analysis of the rarefaction curve showing species richness in the IP0 plots was higher than in the IP1 plots, with the same number of sample plots (Figure 2).

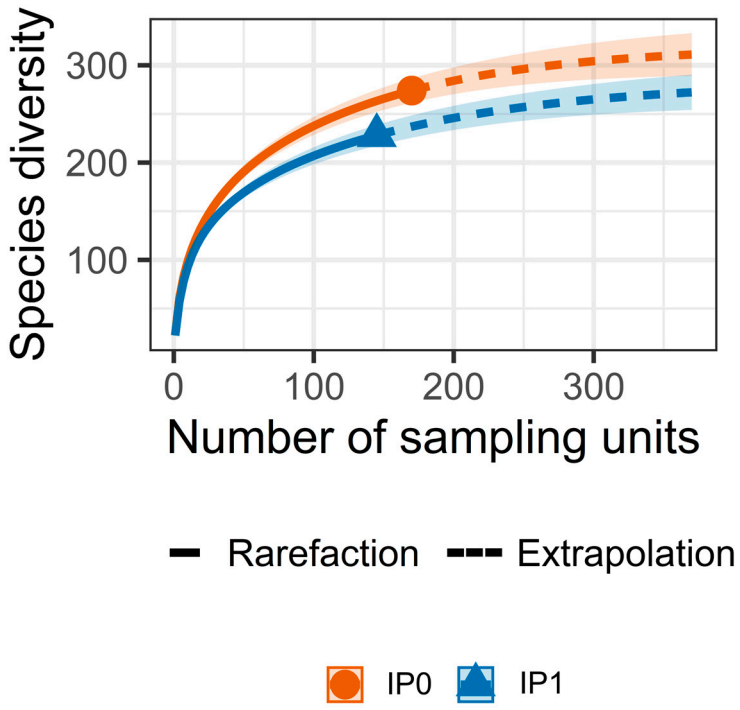

Figure 2. Rarefaction/extrapolation curves of cumulative species richness (Hill's numbers qΔ with q = 0) against the number of sampling plots with *Impatiens parviflora* DC. (blue) and without *I. parviflora* (orange). The shaded area represents 95% confidence intervals obtained using the bootstrap method based on 999 repetitions.

The analysis of the IndVal indicator species showed that the IP0 plots have 17 species from the herb layer, including two tree species, while the IP1 plots have 11 species, including eight tree species (Table 3).

Table 3. List of plant species that are indicators of plots with and without *I. parviflora* in the species composition. Only the species of herbal layer (including trees up to 0.5 m in height) are statistically significant ($p < 0.05$) based on the IndVal analysis. Sequence of the species by IndVal index.

IP0 Plots Species	**IndVal**	**IP1 Plots Species**	**IndVal**
Athyrium filix-femina (L.) Roth	0.650	*Acer platanoides* L.	0.667
Lunaria rediviva L.	0.578	*Dryopteris filix-mas* (L.) Schott	0.667
Oxalis acetosella L.	0.556	*Acer pseudoplatanus* L.	0.614
Impatiens noli-tangere L.	0.549	*Fraxinus excelsior* L.	0.595
Rubus hirtus Waldst. et Kit. agg.	0.525	*Poa nemoralis* L.	0.509
Symphytum cordatum Waldst. et Kit. ex Willd.	0.517	*Quercus petraea* (Matt.) Liebl.	0.415
Asplenium scolopendrium L.	0.515	*Tilia cordata* Mill.	0.414
Glechoma hirsuta Waldst. et Kit.	0.515	*Carpinus betulus* L.	0.413
Dentaria bulbifera L.	0.497	*Tilia platyphyllos* Scop.	0.410
Abies alba Mill.	0.497	*Mycelis muralis* (L.) Dumort.	0.372
Sambucus nigra L.	0.480	*Corylus avellana* L.	0.354
Rubus idaeus L.	0.470	-	-
Polystichum aculeatum (L.) Roth	0.469	-	-
Petasites albus (L.) Gaertn.	0.456	-	-
Circaea lutetiana L.	0.438	-	-
Salvia glutinosa L.	0.437	-	-
Chrysosplenium alternifolium L.	0.414	-	-

Of the 11 tree species in the stand layer whose frequency in the phytosociological relevés was above 10%, the average cover was highest in *Acer pseudoplatanus* and *Fagus sylvatica* L. (Table 4). These species also achieved the highest frequency. Of this group of trees, only *Picea abies* (L.) H.Karst., had no significant association with the occurrence of *I. parviflora*. *Fagus sylvatica, Abies alba, Carpinus betulus* L., *Ulmus glabra* Huds., *Acer pseudoplatanus* and *Acer platanoides* L. had the strongest limiting effect on *I. parviflora* (in decreasing order). *Quercus petraea* (Matt.) Liebl, *Fraxinus excelsior* L., *Tilia cordata* Mill. and *Tilia platyphyllos* Scop. had a positive association with the occurrence of *I. parviflora*. Of the species studied, the occurrence of *I. parviflora* is best explained by the growth of *Fagus sylvatica*.

The DCA analysis showed a positive correlation between the cover of *I. parviflora* and the location of the monitoring plots in the Sudetes Mountains (Figure 3). The plots at this location are characterized by high light incidence on the forest floor, the occurrence of *Aceri–Tilietum* association and low height of the individual vegetation layers. The plots in the Sudetes Mountains are also characterized by the lowest humidity of the substrate, low ground cover and a low proportion of old forest species. The DCA analysis showed a negative correlation between the cover of *I. parviflora* and the plots in the Bieszczady Mountains, which are usually represented by the *Phyllitido–Aceretum pseudoplatani* plant community, the greatest height of the undergrowth and understorey layer, a high trophism soil index and a low light index. The plots located in the Carpathian Mountains showed a negative correlation with the cover of *I. parviflora* and are characterized by the highest altitude above sea level, species richness, low cover of layer A and high cover of layer C. The cover of layer B and the number of species in this layer do not correlate with the arrangement of the sample plots.

Table 4. Descriptive statistics of surface cover in the sample plot of selected tree species (F > 10%) and the result of the GLM analysis (family = Poisson) in the form of an exponential function of the parameter explaining the cover of *I. parviflora* (all variables in one model). AIC = 4932.4. *—*p*-value < 0.05. Abbreviations: F—Species frequency on sample plots; M—Mean; SE—Standard error; exp (coefficient)—exponential function from the value of the model coefficient.

Gatunek	F (%)	M	SE	Exp (Coefficient)
Intercept				9.182 *
Abies alba	17.1	2.81	0.49	0.977 *
Acer platanoides	30.8	7.56	0.86	0.997 *
Acer pseudoplatanus	75.9	30.34	1.53	0.994 *
Carpinus betulus	21.0	3.85	0.57	0.981 *
Fagus sylvatica	56.2	15.03	1.20	0.973 *
Fraxinus excelsior	18.4	4.56	0.64	1.013 *
Picea abies	14.0	1.45	0.28	0.999
Quercus patrea	12.4	2.04	0.38	1.022 *
Tilia cordata	21.6	5.55	0.79	1.011 *
Tilia platyphyllos	26.7	6.71	0.79	1.004 *
Ulmus glabra	16.8	3.02	0.52	0.981 *

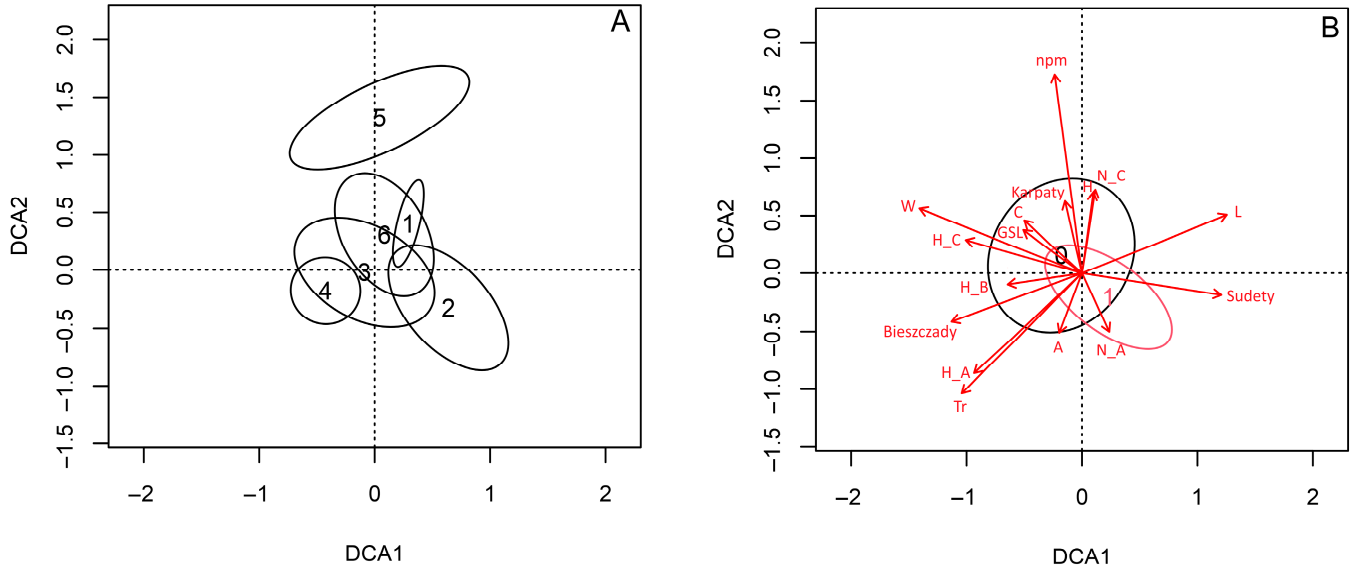

Figure 3. Result of the DCA analysis. (**A**) DCA1 = 0.361; (**B**) DCA2 = 0.294. (**A**) Centroid location (ellipse = 1SD from centroid) of plots according to plant communities belonging to natural habitat type 9180* (1—*Arunco dioici–Aceretum pseudoplatani*, 2—*Aceri–Tilietum*, 3—*Lunario–Aceretum pseudoplatani*, 4—*Phyllitido–Aceretum pseudoplatani*, 5—*Sorbo aucupariae–Aceretum pseudoplatani*, and 6—*Tilio platyphylli–Acerion*). (**B**) Interactions between the centroid locations (ellipse = 1SD from centroid) of plots according to the presence of *I. parviflora* (0—not present, 1—present) and environmental variables (arrows). The variables from Table 2 and the location of the plots were taken into account; Bieszczady—Bieszczady Mountains Karpaty—Western Carpathians, Sudety—Sudetes Mountains, other abbreviations as in Table 2 (Only those variables whose adjustment was statistically significant at $p < 0.05$ based on the permutation test were shown).

4. Discussion

Invasive species are one of the most important direct causes of biodiversity loss and changes in the functioning of forest ecosystems [31,32]. Even non-invasive species that are not native to a particular ecosystem pose such a threat [33]. It is generally believed that *I. parviflora* can pose a significant threat to deciduous forests, especially riparian (91E0*, 91F0), oak-hornbeam (9160, 9170) and beech forests (9110, 9130, 9150) that occur in humid

habitats [17,34]. In our studies, the habitat plots in which *I. parviflora* occurred did not differ significantly from plots without *I. parviflora* in terms of shrub and herb layer cover, and the average number of species was similar. However, the plots with *I. parviflora* were characterized by a lower number of old growth forests species, a higher number of species in the tree layer and a lower cover of this layer. Old growth forests have a floristic composition that differs significantly from that of younger forests [35]. Old growth forest species are generally more shade-tolerant than other forest plant species and avoid dry and moist sites [36]. This group also includes species of geophytes found by Florianova and Münzbergová to be negatively affected by *I. parviflora* in oak-hornbeam forests [37]. Although there is no direct correlation between the occurrence of *I. parviflora* and the average number of herbaceous plants in the plots, our results based on the analysis of indicator species show that the occurrence of old forest species characterizes plots without *I. parviflora*. However, *I. parviflora* was found to be associated with certain species of ground cover, mainly with the regeneration of tree species up to a height of 0.5 m. It is likely that woody species will become strong competitors for *I. parviflora* with increasing height in the long term [38]. Most likely, the relationship between the occurrence of woody species up to 0.5 m in height in the herb layer on the IP1 plots and the more numerous occurrences of species in old forests on the IP0 plots is the reason why there are no differences in the average number of species between plots (with and without *I. parviflora*).

Most alien species are unable to invade the interior of the forest and are restricted to the boundary between the forest and, for example, agricultural land [39]. *I. parviflora* most commonly invades forest habitats in overexposed areas such as forest edges and under natural or artificial gaps in the canopy [40]. Studies from Slovenia [41] confirm the preference of *I. parviflora* in *Tilio–Acerion* forests for disturbed stands with low canopy closure and modified ecological conditions. An important finding is that *I. parviflora* does not grow in plots together with *Athyrium filix-femina* (L.) Roth. This native species most likely prevents the invasion of *I. parviflora* due to its size and considerable competitive ability [42]. It should be noted that areas with *I. parviflora* were characterized by a lower height of the herb layer and shrub layer. The greater height of the lower vegetation layers leads to greater shading of the forest floor [43]. As shown in studies [9,44,45], *I. parviflora* is not competitive in full shade. It is unable to compete effectively for limited resources in the absence of light. This view is supported by our research, which shows that an increasing proportion of *Abies alba* and *Fagus sylvatica* in the stand has a limiting effect on the surface cover of *I. parviflora*. Researchers from Slovakia, who examined plots in oak forests with *Quercus robur* and *Quercus petraea* with *Fagus sylvatica*, showed that the colonization of the plot by *I. parviflora* was only effective if there was no *Fagus sylvatica* in the stand [46].

All the plots (both with and without *I. parviflora*) studied had an average tree cover of over 70% (A), while the average cover value in the plots with *I. parviflora* was significantly lower. The average value of the light index is also significantly higher in the plots with *I. parviflora* and the average value of the moisture index is significantly lower. This indicates that the presence of *I. parviflora* is associated with a slightly greater light incidence on the forest floor. This may be due to the presence of gaps, the presence of trees with openwork crowns (*Fraxinus excelsior*) or the presence of evenly thinned stands [46]. Dobravolskaitė [47] also found a correlation between an increase in the amount of light and the number of *I. parviflora*. At the same time, Dobravolskaitė [47] highlights that *I. parviflora* can also occur in Lithuanian forests in places that are too dark for native species. In addition, lower light exposure leads to higher humidity of the forest floor, which can partially compensate for the lack of light [43]. The results of the monitoring of shady fir forest (habitat type 91P0—Holy Cross fir forests (*Abietetum polonicum*)) show that *I. parviflora* occurs sporadically in this habitat, but does not form dense stands, so it does not pose a threat to the species

composition of the ground cover [48]. Also, in the *Luzulo–Fagetum* beech forests (habitat type 9110), where tree density reached 90%, *I. parviflora* was only found in clumps up to 15% cover [8]. The opposite reaction of *I. parviflora* to light is described by Krokaite [45], who states that an increase in shading favours greater cover of this species. Since they also indicate a negative correlation with the number of herbaceous plant species, it is possible that the light avoidance of *I. parviflora* is due to competition from other plants occurring in the ground layer. Čuda [43] describes the low competitive capabilities of *I. parviflora* and states that *I. parviflora* owes its dispersal success not to its competitive ability, but to its ability to avoid competition through tolerance to light deficiency.

Hejda [42] considers it unlikely that *I. parviflora* affects the native species richness of colonized communities, which could be related to its limited ability to form a dense canopy and a modest root system. Obidziński and Symonides [9] state that *I. parviflora* prefers degraded habitats, and therefore floristically poor communities. The negative relationship between *I. parviflora* and species richness therefore results from its adaptive abilities and its ability to colonize areas where other plant species cannot grow [47]. In our study, the hypothesis of the occurrence of *I. parviflora* in disturbed areas can be supported by the lower number of old-growth forest species in the *I. parviflora* plots. The same applies to the results of the IndVal analysis, which indicate the simultaneous occurrence of numerous woody species in the understorey with *I. parviflora*. Both results may indicate areas in which secondary or primary forest succession is taking place [49].

We found no differences in the number of species in herbal layer in the plots. Similar results were obtained by Hejda [42] for floodplain forests and mesophilic forests with beech and oak, and by Diekmann [50] for different types of lowland communities with *I. parviflora* in Germany. However, our analysis of the rarefaction curves showed differences in species richness at the landscape level. The lower species richness at the landscape level of the *I. parviflora* plot could be primarily due to the fact that it was found in a lower number of plant communities compared to plots without *I. parviflora*. Added to this is its occurrence above sea level. Studies on the spatial variability of *I. parviflora* occurrence have shown that the average altitude above sea level in the plots with *I. parviflora* was almost 180 m lower than in the IP0 plots. In its natural range, *I. parviflora* occurs at an altitude of up to 3000 m above sea level. Studies carried out in Germany (in low mountain ranges at an altitude of 300–1200 m) showed low frost hardiness and a low survival rate of the seedlings [51]. In our research *I. parviflora* was not found in the highest elevations of 9180* habitat type representing the *Sorbo aucupariae–Aceretum pseudoplatani* community. The limiting effect of altitude above sea level on the occurrence of *I. parviflora* was also demonstrated by Lapin et al. in Austria [52]. No differences in the fertility of the substrate, expressed by the trophism soil index (Tr), were found between forests plots with and without *I. parviflora*. Invasive species generally prefer sites with higher fertility, but a necessary condition is temporal coincidence with the availability of dispersal opportunities [53,54]. This suggests that for *I. parviflora*, climate rather than soil fertility is the stronger limiting factor in mountain forests. Areas with and without *I. parviflora* differ not only in their altitude above sea level, but also in their geographical distribution. The areas of 9180* habitat type forests where *I. parviflora* occurs, are concentrated in the south-west of Poland, while the 9180* habitat type forests are equally numerous in the south-east of Poland. This is due to the fact that habitat type 9180* is phytosociologically very diverse within its distribution area throughout the country. In the Bieszczady Mountains (south-east Poland), the soils are more fertile than in the mountain ranges to the west, and the proportion plots with *I. parviflora* is only 7.5%. In the Bieszczady Mountains, *I. parviflora* occurs only sporadically and is restricted to isolated areas of *Phyllitido–Aceretum pseudoplatani*. In the Sudetes Mountains, proportion plots with *I. parviflora* is almost 70%. The results show that

the Sudetes Mountains are the main distribution area of this species in *Tilio–Acerion* forests. In the Western Carpathians, the most important habitats for *I. parviflora* are sycamore communities, especially those with rich substrate and high humidity. The differences in the attendance of *I. parviflora* between the Bieszczady Mountains and the other mountain ranges could be due to the lower anthropogenic pressure in the Bieszczady Mountains and less disturbed sites favouring the distribution of *I. parviflora* [9,40,42,46]. But also to the lack of communities where *I. parviflora* finds optimal conditions, such as *Aceri–Tilietum* (Table 1), which is confirmed by the results of the DCA analysis (Figure 3A). However, the lack of differences in trophism soil index values within the country may also be due to the uneven distribution of *I. parviflora* within the range of habitat 9180*.

The results we have presented refer to the entire range of habitat type 9180* in Poland. Our research also shows that within a natural habitat—a unit that can include many different communities and geographical areas—the influence of ecological factors may depend on local conditions. Therefore, limiting the analysis to a smaller area of habitat occurrence and thus limiting the variability of the analyzed data may lead to different results. The same result can be expected if the analysis is limited to a specific plant community. However, looking at the overall variability of habitat across the country allows general conclusions to be drawn and highlights ecological factors that should be considered when planning research or conservation actions on a smaller spatial scale.

5. Conclusions

Our work is based on a comparison of species composition and ecological conditions in study plots in habitat 9180* with and without *I. parviflora*. The sample plots are located in the entire range of habitat 9180* in Poland. No differences were found in the number of species in the herb layer between the two types of plots analyzed (with and without *I. parviflora*). However, it was found that the presence of *I. parviflora* is associated with a lower number of species typical of old-growth forests. At the same time, *I. parviflora* presence is accompanied by numerous tree species in the herb layer, which could indicate a connection with stand succession processes and confirms the thesis of other authors regarding the association of *I. parviflora* with disturbed sites. *I. parviflora* cannot cope with limited light conditions, so its spread is limited by shade-loving species, especially woody species such as *Abies alba* and *Fagus sylvatica*. The frequency of occurrence of *I. parviflora* varies within the range of habitat type 9180*, most likely due to the different human pressure and the presence of communities where this species finds optimal development conditions (e.g., *Aceri–Tilietum*). We observed a negative relationship between altitude above sea level and the occurrence of *I. parviflora*, indicating climatic constraints. The impact of *I. parviflora* on habitat type 9180* is dependent on local environmental conditions. Therefore, conservation measures should be planned based on the local habitat context.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f16091475/s1, Table S1: Results of linear regression models testing the effect of *Impatiens parviflora* (presence and cover) on Shannon-Wienner index (H).

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