Fragmented distribution of *Isophya pienensis* Maran, 1954 (Insecta, Orthoptera) in mountains: a result of permanent forest opening in highly forested landscape

Abstract

**Background and Purpose:** *Isophya pienensis* Maran, 1954 (Orthoptera) is a stenotopic katydid occurring locally in Central and Eastern Europe. The purpose of the study was to document the habitat associations of *I. pienensis* in the Beskids in relation to historical land use and present landscape structure.

**Materials and Methods:** *Isophya pienensis* was studied in the Moravian-Silesian Beskids Mountains at 15 sites representing small unforested areas surrounded by spruce forests on the massifs of the Smrk (1,276 m a.s.l.) and Knehyne (1,256 m a.s.l.) mountains. Thirty-minute timed counts were used.

**Results and Conclusions:** *Isophya pienensis* was found at 5 of the 15 sites but was not found at elevations below 1,000 m a.s.l. The occurrence of *I. pienensis* in the Beskids on small, isolated, shady sites at elevations over 1,000 m is not a result of its being a mountain species. Rather, it is due to the persistence of open-forest habitats and of ecotones near forest lodges where broadleaf vegetation is maintained on shady spots by occasional mowing. The permanent occurrence of *I. pienensis* probably depends on the presence of heterogeneous, early successional stages of forests and their ecotones, which were historically maintained by selective cutting, grazing, and charcoal production on a mosaic of grasslands.

INTRODUCTION

The genus *Isophya* (Orthoptera) contains 89 katydid species worldwide (1). At first glance, these thickest species appear to be very similar to one another. Taxonomically, it is a problematic genus because the species-specific characters are very subtle. Forty-six species of *Isophya* occur in Europe (2, 3), and most occur in southeastern Europe; four species are endemic to the Western Carpathians (4, 5). Information on the ranges and ecological requirements of *Isophya* spp. is fragmentary.

*Isophya pienensis* Maran, 1954 (Orthoptera) was described recently from the Pieniny Mountains in Slovakia (6) and it is a stenotopic katydid species occurring locally in Central and Eastern Europe (2). Its occurrence has also been recorded in Ukraine, Poland, and Romania.
(2). *I. pienensis* was found in the Czech Republic for the first time in 2004 at several localities in the Moravian-Silesian Beskids Mountains (7, 8). Other findings have been published from South Moravia (Soběšice), the Rychnovské hory Mountains (Petříkov) in North Moravia, the Orlické hory Mountains (Deštné) in northeast Bohemia, and the White Carpathians (9–12). Although its identification is difficult, *I. pienensis* can be distinguished from other species because of its characteristic stridulation and the structure of its stridulatory apparatus (4).

*Isophya* spp. are characterized by their low mobility; their topographical distribution in low-density, isolated populations; and their close ties to specific sites. The latter characteristic is partially the consequence of their preference for dicotyledonous plants as food (3).

It is interesting that *I. pienensis* occurs mainly at higher elevations in the Western Carpathians (7, 8, 11, 12) but at lower elevations in other areas (6, 9, 10, 13, 14). Thus, it is apparent that *I. pienensis* cannot be considered a mountain species. The most common species of the *Isophya, I. kraussii* Br. von Wattenwyl, 1878, ranges widely from the warm and dry areas of South Moravia’s Pavlovské kopce Hills (ca. 300 m a.s.l.) (15) to North Moravia’s Hrubý Jeseník Mountains (1,400 m a.s.l.) (personal observation).

The purpose of this study was to document the habitat associations of *I. pienensis* in mountain regions of the Moravian-Silesian Beskids in relation to historical land use and present landscape structure.

**MATERIALS AND METHODS**

**Study area and sites**

The study was conducted in the Moravian-Silesian Beskids, which are part of the Outer Western Carpathians. Fifteen «open sites» (i.e., sites without forest) were selected on Smrk Mountain and Knehyne Mountain (Table 1). The sites were located in ecotones (transitional areas near hunting lodges and roads) and forest openings. Site elevation ranged from 603 to 1162 m a.s.l., and site area ranged from < 200 m² to > 400 m². The sites were surrounded by forest stands dominated by Norway spruce (*Picea abies*) with occasional European beech (*Fagus sylvatica*). The larger sites were dominated by subalpine meadows or wet meadows of *Molinia arundinacea* and mesophilic oat-grass meadows (17). Other sites had been deforested and were dominated by herbs and especially by stinging nettle (*Urtica dioica*), European raspberry (*Rubus idaeus*), and ragwort (*Senecio nemorensis*). As indicated in Table 1, sites were regularly mown, occasionally mown, or not mown. Shading of sites was visually assessed as minimal, medium, or intensive; the degree of shading reflected site proximity to the surrounding forest, site orientation, and slope.

**Identification**

The identification of *I. pienensis* is facilitated by its characteristic stridulation, which greatly differs from that of other *Isophya* spp. Stridulation by isolated males consists of individual syllables (300–400 ms long; 74–97 impulses) produced at very irregular intervals (2–20 s), either individually or in clusters of 2–3 syllables (rarely to 7) with internal intervals of 0.3–2.5 s. This stridulation pattern differs from that of *I. kraussii* males, which produce long uninterrupted sequences of syllables (2, 4, 8). The most important morphological feature is the male’s comb-like stridulatory apparatus, which consists of 180–210 teeth (vs. 260–310 in *I. kraussii* and 50–80 in *I. camptothypha*) (2, 4, 8).

The shape of the male cerci is also distinctive for *I. pienensis*. The cerci of *I. pienensis* males are bowed and are less pointed than those of *I. kraussii* males and less truncated than those of *I. camptothypha* males (2). The cerci of *I. pienensis* males are most similar to those of *I. kraussii* males. The greatest morphological differences between *I. pienensis* and *I. kraussii* are in the structure of the stridulatory apparatus (as noted earlier), in the curve of the male cerci (as noted earlier), and also in the male subgenital plates. The subgenital plate is much deeper and sharply carved in *I. pienensis* than in *I. kraussii* (6).

**Data collection**

Katydids were collected on 2 days (29 August and 14 September 2007) between 10:00 and 16:00 using timed counts (18). The search period for a single site was 30 min. First, 10 min of intensive sweeping (circular shape, 40 cm diameter) was performed so that the inconspicuous individuals of *I. pienensis* were forced into activity. The subsequent survey (20 min) involved only visual observation of the already active katydids. The unequal size of the sites was compensated for by searching at a constant speed, and thus approximately the same area was searched at each site. During the searching, the time was recorded when the first individual was found. After they were identified to species, the captured katydid was returned to the capture site.

The distances of the katydids from the forest edge (for the first katydid found at a given site), the heights at which they were found, and the plants upon which the individuals were sitting were recorded. Because of the small size of the data set, the chi-square test, Wilcoxon signed-rank test, and Spearman’s rank correlation coefficient were used (calculated in Statistica 9.0) to compare the number of specimens detected and the time during the sampling period when the first specimen was detected between the two sampling dates and only for sites in which *I. pienensis* was detected.

Because *I. pienensis* prefers open areas, land-use development and changes were analysed for forested and nonforested land-use categories; nonforested categories include arable land, permanent grassland, permanent cultures, water areas, built-up areas, recreational areas, and other areas. Special attention was paid to permanent grassland, which is considered the main habitat of *I. pienensis*. Land-use development and the historical changes of habitats were analyzed from 1836 to 2006 within a
4-km wide zone surrounding all sites in which *I. pienensis* was detected. The land-use data were extracted from topographical maps from five time periods (for details, see 19). These maps were scanned, georeferenced, and vectorized. Georeferencing and vectorization were performed with ArcGIS 9.2 (ESRI software). On-screen vectorization was applied.

**RESULTS**

**Distribution and habitat associations of Isophya pienensis**

*I. pienensis* was found at 5 of the 15 sites (Table 2). On both sampling dates, its abundance was greatest at site 1, which was also the only site where *I. pienensis* males were found. *I. pienensis* was also relatively abundant at site 3, followed by site 8, 7, and 11 (Table 2).

The numbers of *I. pienensis* detected and search time until the first individual was detected did not significantly differ between the two sampling dates (Wilcoxon signed-rank test for numbers detected: n = 5, z = 0.94; p > 0.34; Wilcoxon signed-rank test for search time until

<table>
<thead>
<tr>
<th>Site number</th>
<th>Site name</th>
<th>Slope exposure</th>
<th>Longitude; Latitude</th>
<th>Elevation [m a.s.l.]</th>
<th>Site area [m²]</th>
<th>Shading</th>
<th>Regular mowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hubertka Lodge</td>
<td>SW</td>
<td>49°29’52.939”N, 18°21’34.136”E</td>
<td>1162</td>
<td>&lt;200</td>
<td>medium</td>
<td>partly</td>
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<tr>
<td>2</td>
<td>vicinity of road</td>
<td>SW</td>
<td>49°29’48.401”N, 18°21’43.174”E</td>
<td>1132</td>
<td>&lt;0</td>
<td>medium</td>
<td>no</td>
</tr>
<tr>
<td>3</td>
<td>hunting lodge 1</td>
<td>SE</td>
<td>49°30’12.892”N, 18°22’34.142”E</td>
<td>1066</td>
<td>200–400</td>
<td>medium</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>Rakové</td>
<td>S</td>
<td>49°28’42.792”N, 18°21’9.249”E</td>
<td>753</td>
<td>&gt;400</td>
<td>minimal</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>Blëstový</td>
<td>SE</td>
<td>49°28’40.991”N, 18°23’35.272”E</td>
<td>603</td>
<td>&gt;400</td>
<td>minimal</td>
<td>yes</td>
</tr>
<tr>
<td>6</td>
<td>V Jâmë</td>
<td>E</td>
<td>49°28’37.112”N, 18°20’28.298”E</td>
<td>632</td>
<td>&gt;400</td>
<td>minimal</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>hunting lodge 2</td>
<td>SE</td>
<td>49°29’28.695”N, 18°19’9.818”E</td>
<td>1067</td>
<td>200–400</td>
<td>medium</td>
<td>no</td>
</tr>
<tr>
<td>8</td>
<td>hunting lodge 3</td>
<td>SE</td>
<td>49°29’32.370”N, 18°19’6.164”E</td>
<td>1094</td>
<td>&lt;200</td>
<td>medium</td>
<td>no</td>
</tr>
<tr>
<td>9</td>
<td>around a parking lot</td>
<td>SE</td>
<td>49°29’29.080”N, 18°18’58.410”E</td>
<td>1124</td>
<td>&lt;200</td>
<td>minimal</td>
<td>no</td>
</tr>
<tr>
<td>10</td>
<td>along a road 1</td>
<td>SSW</td>
<td>49°29’32.186”N, 18°18’39.874”E</td>
<td>1118</td>
<td>&lt;200</td>
<td>medium</td>
<td>no</td>
</tr>
<tr>
<td>11</td>
<td>upper enclave</td>
<td>SE</td>
<td>49°29’29.014”N, 18°18’9.826”E</td>
<td>1160</td>
<td>200–400</td>
<td>medium</td>
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<tr>
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<td>SE</td>
<td>49°29’14.745”N, 18°18’24.576”E</td>
<td>1075</td>
<td>&lt;200</td>
<td>medium</td>
<td>no</td>
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<tr>
<td>13</td>
<td>forest clearing</td>
<td>SE</td>
<td>49°29’10.101”N, 18°18’23.865”E</td>
<td>1131</td>
<td>&lt;200</td>
<td>intensive</td>
<td>no</td>
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<td>14</td>
<td>hunting lodge 4</td>
<td>S</td>
<td>49°28’43.551”N, 18°18’48.992”E</td>
<td>1004</td>
<td>200–400</td>
<td>medium</td>
<td>yes</td>
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<tr>
<td>15</td>
<td>Ráztoky</td>
<td>SE</td>
<td>49°28’13.184”N, 18°20’2.216”E</td>
<td>680</td>
<td>&gt;400</td>
<td>minimal</td>
<td>yes</td>
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**TABLE 2**

<table>
<thead>
<tr>
<th>Site number</th>
<th>August 29</th>
<th>September 14</th>
</tr>
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<tbody>
<tr>
<td>Site</td>
<td>Numbers of <em>I. pienensis</em> detected</td>
<td>Minute of detection</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>---------------------</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
the first individual was detected: \( n = 5, z = 1.28; \) \( p > 0.20 \).

I. pienensis abundance was negatively correlated (\( r = –0.90; p < 0.001 \)) with the search time until the first individual was detected.

The observed sex ratio (male:female) was approximately 1:9, which was significantly different from the expected ratio of 1:1 (\( \chi^2 = 32.96; p < 0.001 \)).

I. pienensis was not detected in any forest ecotone. The average distance of the detected katydids from the continuous forest was 8.2 ± 7.8 m (\( n = 9 \)).

The number of I. pienensis individuals detected was 21 on European raspberry (Rubus idaeus), 10 on Senecio nemorensis, 9 on Urtica dioica, 3 on Vaccinium myrtillus, 3 on Hypericum, 3 on Poa sp., 1 on Pinus mugo, and 1 on Gentiana asclepiades. The katydids most frequently occurred 31–50 cm (median 42 cm) above the soil surface (Figure 1).

Sites where the katydids were detected were small to medium-sized, with medium shading and without mowing.

### Historical land use and present landscape structure

The Moravian-Silesian Beskids geomorphological unit (Moravskoslezské Beskydy) covers 633.3 km\(^2\). Forests have dominated the area from at least 1830 until the present (Figures 2, 3). The area of permanent grassland was greatest (185 km\(^2\)) in the 1830s (Fig. 4, 5). It decreased to about 120 km\(^2\) in the 1870s and was nearly 55 km\(^2\) in the 1950s (Fig. 5). Although the first significant decrease (from the 1830s to the 1870s) was predominately caused by afforestation, the decrease from the 1870s to the 1950s has been attributed to both afforestation and the conversion of permanent grassland into arable land. The area of permanent grassland increased slightly in the 1990s but then decreased slightly in the 2000s due to further afforestation (Fig. 5).

Forest covered more than 92% of the study area in the 19th century and 94% at the beginning of the 21st century.
This part, however, is represented by lower altitudes at the base of mountains. The increase in permanent grassland has resulted from the conversion of arable land back into permanent grassland.

**DISCUSSION**

A total of 51 individuals of *I. pienensis* were found at the studied sites in 2007, which is the highest number of this sparsely occurring species detected to date within a single study. In research conducted in Pieniny National Park, both Straka (14) and Maran (6) detected only four individuals. The methods used in the latter studies were evidently inefficient at detecting a well-camouflaged species that is active mainly at night. In mountain environments, *I. pienensis* typically hides deep in the vegetation during the day. In the current study, we detected *I. pienensis* by net sweeping on vegetation (where the individuals were probably collecting solar radiation) for 10 min followed by visual surveying for 20 min. The negative correlation between detected abundance and time elapsed until the first individual was detected confirms the appropriateness of using timed counting to quantify *I. pienensis* population density. Because some sites were quite large, we were not always able to survey an entire site. We compensated for this shortcoming by surveying for identical times at all sites, which, along with maintaining a constant survey speed, ensured that similar areas were surveyed. Another shortcoming of this method is the potential to miss *I. pienensis* individuals if they are aggregated in parts of large sites that are not surveyed. This problem could be reduced by the surveying of multiple locations at larger sites.

The female-biased sex ratio observed here can be explained by our conducting the survey late in the season. Female katydids generally survive longer than male katydids (20), i.e., males die after mating while females survive long into autumn (7, 8) and lay eggs. At the end of July, when adult katydids emerge (see 7, 8), the sex ratio might have been balanced, but the study was not conducted at that time.

This research has expanded the number of sites at which the occurrence of *I. pienensis* has been documented. The two new sites are located near the top of Knehyne Mountain. The distribution of *I. pienensis* has been described for Central and Eastern Europe (6, 13, 14), and isolated *I. pienensis* populations are known to occur from the outer arch of the Carpathians from Ukraine to the Czech Republic. We assume that the apparently isolated sites with *I. pienensis* will form a continuous band that will span the Carpathians and neighboring areas (e.g., Brno, Orlické hory Mts.) in the Czech Republic.

The results of this and earlier studies indicate that *I. pienensis* prefers ecotonal communities and communities with the structure of open broadleaf forests. In Slovakia, individuals have been found most frequently on higher, bushy vegetation (6, 14) but also on other types of higher vegetation both in Pieniny and the Bukovské vrchy Mountains of northeastern Slovakia (Kočárek & Holuša’s own observation). According to Mafan (6), *I. pienensis* in Pieniny National Park seeks larger shrubs, mainly hazelnut trees and rosehips, as *I. brevipes* and *I. breviceuda*, while *I. kraussii* (in the text identified as *Isophya pyrenea* (Serville, 1838)) lives near the ground in the grass and on herbaceous vegetation (6, 12). The preference of *I. pienensis* for higher, bushy vegetation was also described in another study (14). In southwest Poland, *I. pienensis* was even found on willows near roads (13). Whereas *I. pienensis* has been detected most frequently on high bushes in Slovakia and Poland, the current study indicates that *I. pienensis* in the Beskides prefers taller herbaceous vegetation, and especially prefers *Rubus idaeus, Senecio nemorensis,* and *Urtica dioica.*
The *I. pienensis* populations in the White Carpathians and Beskids occur exclusively in mountain biotopes (7, 8, 11, 12), while in other areas this species is common and numerous on meadows below 1,000 m a.s.l. (6, 9, 10, 13, 14). The species was not detected at sites < 1,000 m a.s.l. in the current study, but our results could be affected by the lateness of our surveys, i.e., *I. pienensis* numbers could decline in the late season at middle altitudes. *I. pienensis* occurred in the studied area only rarely and most frequently near mountain lodges and in ecotones at the edges of roads where occasional hand-mowing is used to maintain the taller broadleaf vegetation. Whereas *I. pienensis* has been detected in these small, hand-mown, isolated sites, it has not been detected in larger deforested sites that are machine-mown all the way to the surrounding forest (21).

The prevalence of *I. pienensis* in the Beskids was probably greatest at the end of the 19th century. Mountain forests in the Beskids were a part of a large and continually forested area and were only minimally affected by humans for centuries. At the end of the 15th century, however, the landscape began to be affected by selective cutting, grazing, and charcoal production. This gave rise to open, mixed forests alternating with grass stands sparsely covered with trees and shrubs. The landscape consisted of a fine-grained mosaic of sheltered sunny patches with high humidity and rich vegetation. Because of substantial forest damage and an insufficiency of wood, goat grazing was forbidden and intensive forest management was initiated in the early 19th century. The intensive forest management included large-scale clear-cutting and subsequent artificial renewal by sowing spruce and later by transplanting spruce. Nevertheless, beech and other broadleaf trees still constituted some two-thirds of the forests as late as 1840 (22). Hunting lodges were most frequently constructed at the turn of 19th and 20th centuries. Sites with lower vegetation began to become overgrown, and in most places these were gradually replaced by open, mixed forests alternating with grass stands.

Although it remains a matter of debate as to what are the «natural» habitats of *I. pienensis*, there is an emerging consensus that disturbances such as fires, feeding by large herbivores, water logging, and pest outbreaks probably kept the woods more open throughout most of the Holocene than has been the case under the recent, probably greatest at the end of the 19th century. Mountain forests as late as 1840. Hunting lodges were most frequently constructed at the turn of 19th and 20th centuries. Sites with lower vegetation began to become overgrown, and in most places these were gradually replaced entirely by dense forests.

The occurrence of *I. pienensis* in small, shaded sites at elevations above 1,000 m in the Western Carpathians is not the result of its being a mountain species. Its presence at these sites is due to the persistence of open forest habitat and of ecotones surrounding forest lodges, where broadleaf vegetation is maintained in shady places by occasional mowing. *I. pienensis* occurrence probably depends on heterogeneous, early successional stages of forests and their ecotones, which historically were maintained by coppicing, pasturing, and farming on grassland mosaics.

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