



***Isophya modesta* Frivaldszky, 1868 (Orthoptera: Tettigoniidae): a new bush-cricket species in Poland**

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Abstract: *Isophya modesta*, a bush-cricket species belonging to the subfamily Phaneropterinae, was found for the first time outside of the forest-steppe zone. This study is the first report on *I. modesta* in Poland. It was found at our sites in the Przemyśl Foothills (Pogórze Przemyskie) in the south-eastern Polish Carpathians, where *I. modesta* inhabits xerothermic grasslands, dry and semi-dry meadows, but also successional meadows on abandoned arable land. One site occupied by *I. modesta* in the Przemyśl Foothills is located within a nature reserve, but other sites may be threatened by secondary succession or afforestation. We estimated population densities of around 30–80 adult individuals per hectare, and the whole known population consisted of a total of 3,000 to 15,000 adult individuals. The discovered populations may either be insular in character or connected by a continuous range with populations from Opilia Upland in Western Ukraine.

Key words: modest plump bush-cricket, insects, distribution, forest-steppe, Pogórze Przemyskie

INTRODUCTION

Isophya modesta is a bush-cricket species belonging to the subfamily Phaneropterinae (Cigliano et al. 2022). The genus *Isophya* comprises, as indicated by its name (Greek: isos = same, phýe = figure) (Sehnal 2017), morphologically similar, often cryptic species. *Isophya* is a genus occurring from Western Europe to the Middle East and Central Asia (Cigliano et al. 2022). To date, five *Isophya* species were known to occur in Poland (Żurawlew et al. 2021).

Isophya modesta is a thermophilous species found throughout the forest-steppe zone (Chobanov et al. 2016). It is endemic to Europe and occurs in Slovakia, Hungary, Romania, and central and eastern Ukraine, with the easternmost populations near the city of Penza in Russia (Dobrolyubova 2013), and the northernmost on the outskirts of Moscow (Heller et al. 2004). The westernmost populations are found in lowland Austria (Sehnal 2017). However, the occupied range is heavily fragmented (Chobanov et al. 2016). In Hungary, *I. modesta* inhabits semi-dry steppe-meadows in close proximity to forests (Bauer & Kenyeres 2006) and other kinds of grassy and bushy habitats (Vadkerti & Szövényi 2005), while in Slovakia it has been found in ecotones of xerotherm forest-steppes (Krištín et al. 2011). It has been suggested that *I. modesta* may have originally been a steppe and forest-steppe dweller (Chobanov et al. 2016). *I. modesta* has been assessed as Least Concern on the European Red List (Hochkirch et al. 2016) but is considered vulnerable in the Carpathians (Krištín & Iorgu 2014) and is protected in Hungary (Vadkerti & Szövényi 2005). Historical records of *I. modesta* from Poland (Ramme 1951) concern areas outside the current Polish borders, but the possible presence of *I. modesta* within present Polish borders has been suggested (Bazyłuk 1956).

The Carpathians are a diversity hotspot for Orthopterans, with many endemic species in the eastern part, but also a few endemic species present in the Western Carpathians (Kenyeres et al. 2009). However, Orthoptera of the Polish Carpathians have been largely understudied, as manifested by the recent discovery of two species new to the Polish fauna: *Poecilimon schmidtii*

Fieber and *Pholidoptera transsylvanica* Fischer (Krištín & Jarčuška 2016; Krištín et al. 2019), as well as the massive range extension of species previously thought to be extremely rare, for example *Isophya stysi* Cejchan (Guzik & Guzik 2022). The Western Carpathians form a natural border between the forest zone of Northern Europe and the forest-steppe zone of the Pannonian Basin; thus, besides specifically mountainous species, they also harbour some thermophilous species (Krištín et al. 2019; 2020) and may be the first region of Poland reached by southern orthoptera species expanding their ranges (Żurawlew et al. 2021). Carpathian grasslands harbour a high diversity of different groups of organisms, from plants (Zarzycki et al. 2022) to rare vertebrates (Munteanu et al. 2018), which makes their protection an important conservation goal. To enable the successful protection of this unique fauna, it is important to study the species composition of this biogeographical region, especially in terms of endemic Orthoptera species.

Studying local orthopteran fauna may also provide an insight into the land use history and characteristics of a local ecosystem (Kaňuch et al. 2014; Fumy et al. 2021). This may be the case especially for *Isophya* species, which are sensitive to intensified agriculture and flightless, thus having restricted mobility (Krištín & Iorgu 2014). This may make *Isophya* species good indicators of local land use history.

In this study, we present the first record of *I. modesta* in Poland. We describe its occupied habitat and estimate the size and density of the discovered population.

MATERIALS and METHODS

We visited previously selected sites with habitats potentially suitable for *I. modesta* in the evening and at night, on warm and windless days with no rainfall. We searched for the species both visually and by listening. We recorded stridulating males directly in the field using smartphones under temperatures around 20 °C. We used the obtained recordings to generate oscillograms. Due to the limited audio spectrum of the recording device, we did not capture high frequencies, but most of the frequencies of the song of *I. modesta* lie within the audible range. To obtain pictures of the stridulatory file, we used a Scanning Electron Microscope (13.9 mm x34 BSE 3D).

We estimated the population density, population size, and occupied area as follows. In mid-July, from a single spot, we would hear 2–5 singing males. Based on our field experience of searching for singing males, we estimated that we could hear them from as far as 20 m. Assuming there were as many females as males, we calculated population density by multiplying the number of singing males by 2 and dividing by the area of a circle with a radius of 20 m. We estimated the area occupied by *I. modesta* by measuring the area of the meadows. To obtain approximate total population size we multiplied the occupied area by the computed population density.

RESULTS

Isophya modesta was discovered in Poland in July 2020 in Rybotycze, a site located in the Przemyśl Foothills (Pogórze Przemyskie), a range of hills on the north-eastern tip of the Polish Carpathians, next to the planned Turnicki National Park (Bara et al. 2018). In August 2020 and July 2021 three more occupied sites in the area were discovered (Fig. 1). The species was found in the following sites:

1. Makowa (49°38'44"N 22°41'02"E; 49°38'24"N 22°40'18"E), consisting of two subpopulations partially separated by a forest
2. Rybotycze (49°39'49"N 22°38'53"E)
3. Kopystańka (49°41'02"N 22°37'33"E), located in the Kopystańka nature reserve
4. Cisowa (49°42'40"N 22°34'58"E)

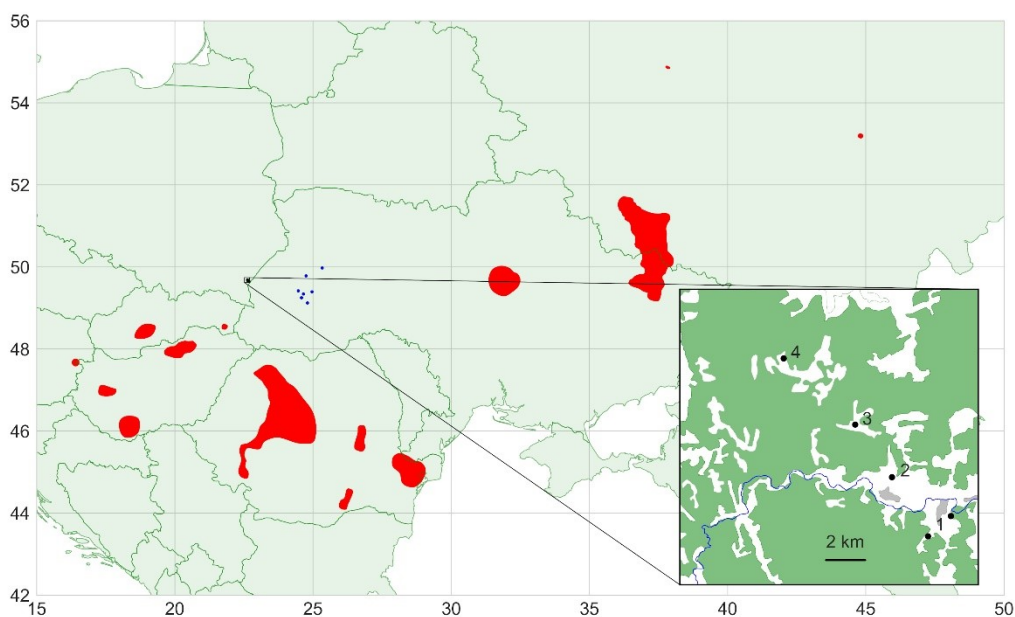


Fig. 1. New localities of *Isophya modesta* in Poland (black points: 1 - Makowa, 2 - Rybotycze, 3 - Kopystańka, 4 - Cisowa); historical localities from Kuntze & Noskiewicz (1933, 1938) (blue points); known distribution from Chobanov et al. (2016) (red polygons).

Individuals from the discovered populations were bigger than specimens of other *Isophya* species known from Poland. In males, the visible part of the tegmina was longer than the pronotum (Fig. 2a), and females were characteristic due to their long, steadily curved, ovipositors (Fig. 2b). The male stridulatory file of a single photographed individual bears 112 teeth, with teeth density increasing at the lateral edge of the tegmen (Fig. 2c). Two collected specimens, an adult female and male, are kept in the private collection of Michał Brodacki.

The song was emitted in isolated syllables. Each syllable started with a short “buzz”, which is visible on the oscillogram as a dense impulse sequence (~200 ms) (Fig. 3). A long break of several seconds was followed by a sequence of clicks that started off slowly (at the beginning, the single clicks could be distinguished by the naked ear) and accelerated towards the end. The rhythm of these clicks was similar to that produced by a ping-pong ball falling to the floor. The second part of the syllable is visible on the oscillogram as a sequence of impulses condensing towards the end (~2000 ms) (Fig. 3).

Isophya modesta inhabits various open habitats on the discovered sites, from well preserved dense xerothermic and dry grasslands to successional grasslands on abandoned arable land (Fig. 4).

Habitats at the Makowa site consisted of a xerothermic grassland identified as *Cirsio-Brachypodium pinnati* by Kucharzyk (2010) located only on the hill Góra Filipa (Fig. 4b), as well as abandoned arable land with plant communities containing *Arctium* sp. L., *Rumex obtusifolius* L., *Erigeron annuus* agg. (L.) Pers., *Dactylis glomerata* L., *Artemisia vulgaris* L., *Lysimachia vulgaris* L., *Dipsacus sylvestris* L., and *Urtica dioica* L. However, most of the area occupied by *I. modesta* at the Makowa site was covered by dense dry grasslands containing plant species characteristic for xerothermic grasslands, dry forest edges, and meadows (Figs 4b–4d). Species of xerothermic grasslands were represented by: *Salvia verticillata* L., *Brachypodium pinnatum* (L.) P. Beauv., *Centaurea scabiosa* L., *Allium oleraceum* L., *Gentiana cruciata* L., *Crepis praemorsa* (L.)

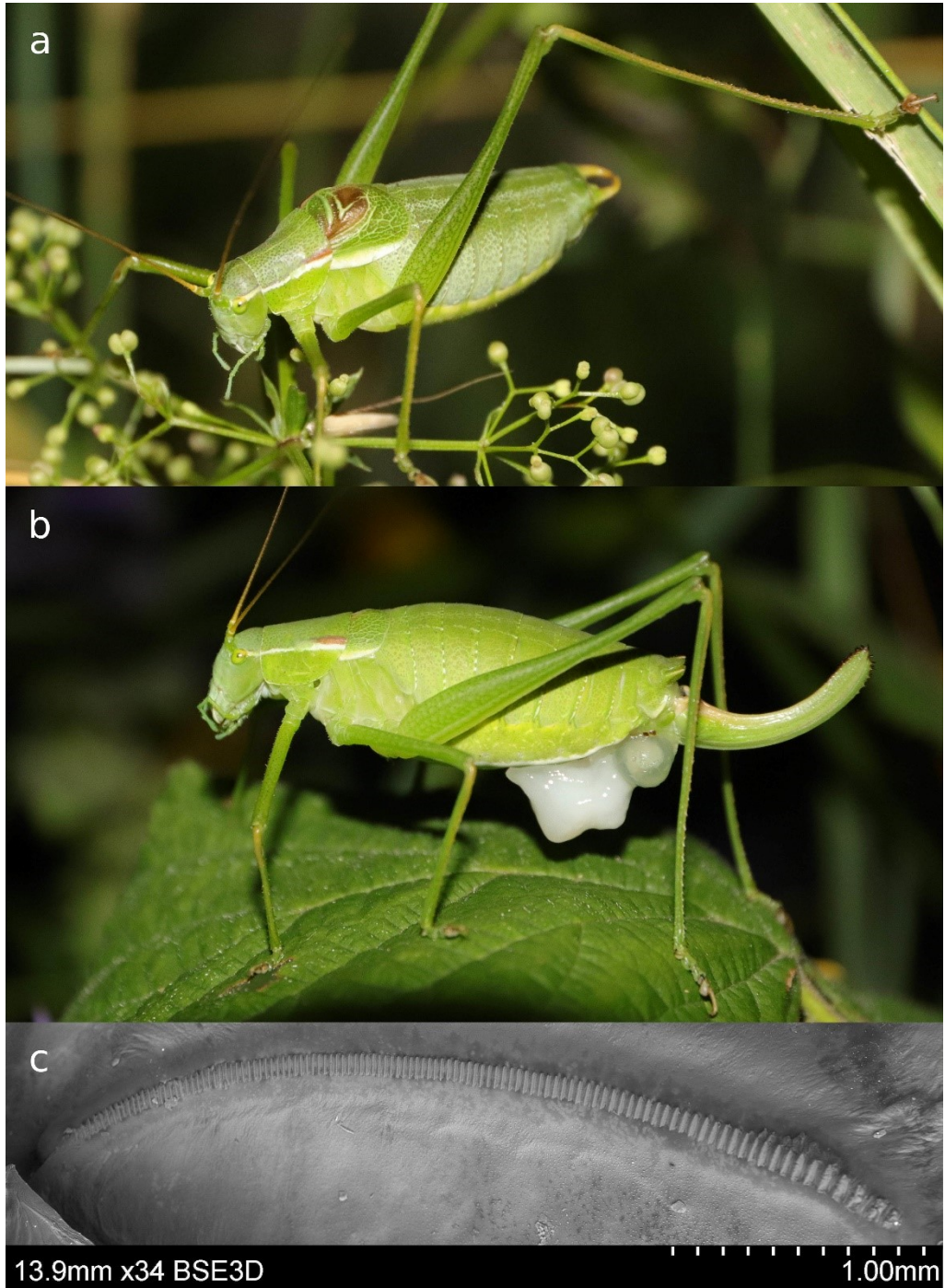


Fig. 2. *Isophya modesta* from the Przemyśl Foothills. a – adult male, the characteristic long tegmina are visible; b – adult female with a spermatophore attached below the abdomen; c – stridulatory file on the underside of male left tegmen bearing 112 teeth.

Turcz., *Dianthus carthusianorum* L., *Filipendula vulgaris* Moench, and *Plantago media* L. Species of dry forest edges were represented by: *Agrimonia eupatoria* L., *Coronilla varia* L., *Origanum vulgare* L., *Primula veris* L., *Astragalus glycyphyllos* L., *Stachys officinalis* (L.) Trevis., *Pimpinella saxifraga* L., *Trifolium medium* L., *Genista tinctoria* L., and *Melampyrum nemorosum* L.. Meadow species were represented by: *Lotus corniculatus* L., *Geranium pratense* L., *Arrhenatherum elatius* (L.) P. Beauv. ex J. & C. Presl, *Daucus carota* L., *Dactylis glomerata* L., *Lathyrus pratensis* L., *Holcus lanatus* L., *Trisetum flavescens* (L.) P. Beauv., *Gymnadenia conopsea* (L.) R. Br., *Prunella vulgaris* L., *Colchicum autumnale* L., *Knautia arvensis* (L.) Coult., *Rhinanthus* sp. L., *Leucanthemum vulgare* Lam., and *Cirsium arvense* (L.) Scop. While some grasslands at the Makowa site are mown, others are abandoned. At the Góra Filipa hill the occurrence of infrequent fires stops secondary succession to some extent (Kucharzyk 2010). The site is surrounded by mixed forests, and in the southernmost, isolated part, single pines growing within the grassland create a forest-steppe-like habitat structure (Fig. 4d).

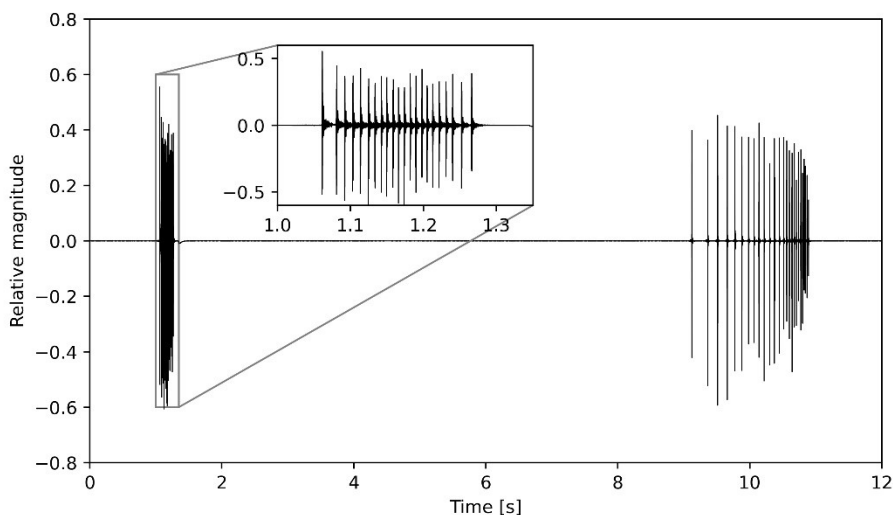


Fig. 3. Oscillographic representation of the song of *Isophya modesta* from the Przemyśl Foothills.

At the Rybotycze site, the habitat consisted mostly of semi-dry meadows characterised by *Stachys officinalis*, *Trifolium medium*, *Galium verum* L., in part overgrown with *Calamagrostis epigejos* (L.) Roth. At the edge of this meadow there is a steep slope covered by a xerothermic grassland overgrown with *Brachypodium pinnatum* and with some *Gentiana cruciata*. At this site, *I. modesta* was mostly found within the meadow and not in the xerothermic slope. This site appears not to be mown regularly; shrubs and trees, especially pines, are encroaching. The Rybotycze site is mostly surrounded by young mixed forests.

At the Kopystańka site the habitat occupied by *I. modesta* consisted of dry, semi-dry, to moist meadows (Fig. 4a). The meadows at this site had a similar meadow species composition as described from the Makowa site, but lacked few of the species characteristic for xerothermic grasslands. A peculiarity of this site was the rather consistent presence of *Sanguisorba officinalis* L. and *Cirsium decussatum* Janka. The plant communities of this site are described in detail by Barabasz-Krasny & Sołtys-Lelek (2010). The grasslands in the Kopystańka reserve are mown yearly to protect them from secondary succession (Pawlaczyk et al. 2013) and are mostly surrounded by old-growth beech forests.



Fig. 4. Habitat of *Isophya modesta* in the Przemyśl Foothills; a – semi-dry meadow in Kopystańka reserve, b – dense meadow on abandoned arable land at Makowa with Góra Filipa hill covered with xerothermic grassland in the background, c – dry dense grassland with xerothermic species such as *Salvia verticillata*, *Brachypodium pinnatum*, and *Gentiana cruciata* at Makowa site, d – semi-dry grassland at the southernmost part of the Makowa site with abundant *Trifolium medium* and solitary pines creating a forest-steppe like habitat structure.

The habitat of the Cisowa site was not assessed in detail; it consisted of dense, semi-dry meadows located on a gentle southern slope surrounded by mixed forests.

In the discovered localities, *I. modesta* coexisted with the following Orthoptera species: *Bicolorana bicolor* (Philippi), *Chorthippus apricarius* (L.), *Chorthippus dorsatus* (Zetterstedt), *Chrysochraon dispar* (Germar), *Decticus verrucivorus* (L.), *Euthystira brachyptera* (Ocskay), *Gomphocerippus rufus* (L.), *Isophya pienensis* Maran, *Leptophyes albovittata* (Kollar), *Oecanthus pellucens* (Scopoli), *Omocestus viridulus* (L.), *Phaneroptera falcata* (Poda), *Pholidoptera griseoptera* (De Geer), *Pseudochorthippus montanus* (Charpentier), *Pseudochorthippus parallelus* (Zetterstedt), *Roeseliana roeselii* (Hagenbach), *Ruspolia nitidula* (Scopoli), *Stenobothrus lineatus* (Panzer), *Tettigonia cantans* (Fuessly), *Tettigonia viridissima* (L.). Some species, such as *Bicolorana bicolor* and *Stenobothrus lineatus*, are characteristic for xerothermic grasslands, but others, for example *Isophya pienensis* and *Gomphocerippus rufus*, represent mountainous fauna. The thermophilous species *Ruspolia nitidula*, *Phaneroptera falcata*, and *Oecanthus pellucens* probably spread around this region relatively recently (Żurawlew et al. 2021).

Population density of *I. modesta* at the discovered sites in the years of this study was 30 to 80 adult individuals per hectare. The density steadily declines during the season, with highest abundance occurring in late June/early July. In the Przemyśl Foothills, *I. modesta* occupies an area of 1–2 km², and during the years of this study the whole population consisted of 3,000 to 15,000 adult individuals.

DISCUSSION

The discovered localities of *I. modesta* in Poland make the first records of this species outside of the forest-steppe zone. Its occupation of various dry but not steppic meadows shows that the species is not clearly bound to pure forest-steppe habitats.

The morphology and song structure of the individuals of the discovered population strictly matches *I. modesta* (Sehnal 2017, Heller et al. 2004, Orci & Haller 2004). The number of teeth on the stridulatory file is within the range of *I. modesta* (Heller et al. 2004; Chobanov et al. 2013), and the arrangement and size of the teeth coincides with that of *I. modesta* (Orci & Haller 2004). The length of both parts of the syllable is within the range of *I. modesta* (Orci & Heller 2004). The results of this study do not show whether the discovered population belongs to the nominate subspecies or to *I. modesta rossica*, as the only difference between the two taxa lies in the timing of female response song (Orci & Heller 2004). However, it has also been suggested that the two subspecies may be synonymous (Chobanov et al. 2013).

The grasslands occupied by *I. modesta* differed in plant species composition compared to meadows most commonly found in this part of the Carpathians (Barabasz-Krasny & Sołtys-Lelek 2010, Kucharzyk 2010, Zarzycki et al. 2022). The overall insular range of *I. modesta* may have resulted from the fragmentation of a continuous range at the end of the last glaciation, when steppic and forest-steppe habitats were much more common (Pokorný et al. 2015). If so, the populations of the Przemyśl Foothills may also be of such ancient origin. On the other hand, it is also possible that *I. modesta* reached this area after the forest had been cleared by humans in the early historical period.

The presence of *I. modesta* at multiple localities in the Opillia Upland (Kuntze & Noskiewicz 1933, 1938) indicates the possible existence of a continuous range that would directly connect the discovered populations in the Przemyśl Foothills with the known range in Ukraine. However, the habitats occupied by *I. modesta* in the Opillia Upland differ substantially from the ones occupied in the Przemyśl Foothills. In the Opillia Upland, *I. modesta* was found only on steppic

grasslands with dense vegetation, where it coexisted with other forest-steppe species: *Poecilimon brunneri* Frivaldszky and *Poecilimon fussi* Fieber (Kuntze & Noskiewicz 1933, 1938).

I. modesta seems to be rather common at the discovered sites. However, its habitat – extensively used grasslands – is threatened by secondary succession, intensification of agriculture, and urbanisation all throughout the Carpathians (Kadlečík 2014). While the population from Kopystańka should be regarded as safe, this area being a nature reserve mown extensively to prevent shrub and tree encroachment (Pawlaczyk et al. 2013), the populations from Cisowa, Rybotycze, and Makowa are not protected. The area of Góra Filipa in Makowa was proposed for protection as an ecological site due to its unique xerothermic flora (Kucharzyk 2011). This ecological site, however, has not yet come into existence. Cisowa, Makowa, and especially Rybotycze populations may be threatened by secondary succession and afforestation (Pawlaczyk et al. 2013; Kucharzyk 2010).

The Makowa, Rybotycze, and part of the Kopystańka site find themselves within the buffer zone of the proposed Turnicki National Park (Bara et al. 2018). Turnicki National Park is a proposed conservation area especially focused on the primaeval Carpathian forests of the Przemyśl Foothills, but it would also protect the highly biodiverse ecotone zones and grasslands of this area (Bara et al. 2018). To show our support for the planned Turnicki National Park, honour the work of countless nature lovers towards its creation, and stress the unique natural character of this area, we suggest the Polish name of *I. modesta* to be ‘zrówieńka turnicka’. The finding of *I. modesta* emphasises the unique natural character of the Przemyśl Foothills, which not only harbours primaeval Carpathian beech forests, but also grasslands of national importance.

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STRESZCZENIE

[*Isophya modesta* Frivaldszky, 1868 (Orthoptera: Tettigoniidae) nowy gatunek owada prostoskrzydłego dla Polski]

Publikacja przedstawia pierwsze stwierdzenia *Isophya modesta* Frivaldszky, 1868 w Polsce. W 2020 i 2021 roku *I. modesta* odnaleziona została na pięciu stanowiskach na Pogórze Przemyskim. Gatunek ten do tej pory wykazywany był z rozproszonych stanowisk w strefie lasostepu środkowej i wschodniej Europy. Na Pogórze Przemyskim *I. modesta* występuje na ciepłych i suchych obszarach łąkowych oraz na murawach kserotermicznych. Szacunkowa liczebność wykrytej w Polsce populacji wynosi 3000–15000 dorosłych osobników. Tylko jedno z odkrytych stanowisk (rezerwat Kopystańka) znajduje się na terenie prawnie chronionym. Dwa z pozostałych stanowisk (stanowisko w Makowej oraz stanowisko w Rybotyczach) zlokalizowane są w otulinie planowanego Turnickiego Parku Narodowego. Odkryte stanowiska stanowią pierwsze miejsce występowania *I. modesta* poza strefą lasostepu i mogą wskazywać na pierwotny charakter łąk i muraw Pogórza Przemyskiego. Aby okazać nasze poparcie dla planowanego Turnickiego Parku Narodowego, uhonorować pracę niezliczonych miłośników przyrody na rzecz jego utworzenia, a także podkreślić wyjątkowy charakter przyrodniczy tego obszaru, proponujemy, aby polska nazwa *I. modesta* brzmiała: zrówieńka turnicka.