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Article

Long-Lasting Bisexual Lures for Assessing Moth Biodiversity and Monitoring Alien Species in Zoos and Botanical Gardens: Case Study in Zoo of Debrecen (NE Hungary)

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Abstract: Zoos and botanical gardens have a special role in the promotion, presentation and conservation of biodiversity in urbanised environments. Additionally, they provide special habitats for alien and invasive species. The formerly used methods of biodiversity assessments (e.g., light trapping, transect counts, etc.) are mostly labour-intensive and/or not efficient enough. In the Zoo of Debrecen, the efficacy and suitability of a synthetic (FLO) and a semisynthetic (SBL) lure for this purpose were proven. The qualitative and quantitative compositions of a moderately rich moth assemblage including 52 moth species were revealed, and the appearance and population dynamics of three invasive (*Helicoverpa armigera*, *Autographa gamma* and *Cydalima pespectalis*) and nine harmful pest species were also recorded. The results proved that the lures tested and traps used provide an easy-to-use, standardised and relatively cheap method for Zoos and botanical gardens to assess their biodiversity even in the case of limited resources.

Keywords: traps; semisynthetic bisexual lure (SBL); phenylacetaldehyde-based lure (FLO); Lepidoptera; pest species

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1. Introduction

Urban and suburban parks often sustain a surprisingly high moth diversity in densely populated regions [1–3]. Debrecen is the second largest town in Hungary with more than 200,000 inhabitants. The Zoo at the northern suburban area of the city acts as a multifunctional garden, serving the well-being and education of the local and regional society, visited by several tens of thousands of people per year. The park preserves a part of the Nagyerdő (Debrecen's Great Forest), which is one of the last remains of a native oak forest formerly covering significant parts of the region. However, the area suffers from pressure from communal traffic, the light pollution of the neighbouring urban areas, the sinking of the ground water table, intensive forestry and park management (mowing, fertilising, planting alien species, etc.) and other anthropogenic disturbances.

Therefore, we conducted a survey of night-active moths to identify, on one hand, which components of the nature-like moth assemblages of the region have been preserved and, on the other, what economically important species (incl. pests, aliens and invasives) have colonised in this semi-natural but disturbed suburban habitat. At the same time, we tested recently developed methods using feeding attractant semiochemicals that can complement and, in some cases, even substitute the widely used light and pheromone traps [4]. The attraction of noctuid moths to phenylacetaldehyde was reported on decades ago [5], and in North American experiments, the attractivity of isoamyl alcohol was also proven [6,7]. However, these semiochemicals were not efficient enough for practical use in insect trapping. In Hungary, experiments were started in the late 1990s by the CSALOMON® research group of the Plant Protection Institute of CAR, HUN-REN (Budapest, Hungary). As a result, a new series of innovative feeding attractants including combinations of the mentioned compounds and synthetic and/or organic (e.g., red wine) synergist materials was developed [8]. One of the most efficient type of lures is the synthetic, floral scent-like FLO (floral) lure containing phenylacetaldehyde, (E)-anethol, benzyl acetate and eugenol (1:1:1:1). Another semisynthetic lure with the scent of fermenting liquids is the SBL (semisynthetic bisexual lure) which contains isoamyl alcohol, acetic acid and red wine (1:1:1). Further details on these lures and a discussion on their efficiency and selectivity can be found in [4,9,10].

Based on experiments performed mainly in the Carpathian Lowland (Hungary, West Romania and West Ukraine), traps baited with these feeding attractants proved to be easy-to-use, standardised and efficient tools for studying moth assemblages in nature-like, semi-natural and anthropogenic ecosystems. This method provided new results for both basic studies (faunistical, biogeographical and ecological) and practical applications (pest management, forestry and nature conservation) [9–15]. Beyond the faunistical and ecological surveys, traps were used for detecting and monitoring several invasive pests e.g., the Cotton Bollworm (*Helicoverpa armigera* Hb.) [16]. Traps with such or similar lures were used on the Beet Armyworm (*Spodoptera exigua* Hb.) [17] and the East Asian Buxus moth (*Cydalimna perspectalis* Wlk.) [18,19]. Botanical and Zoological Gardens often provide suitable habitats for such alien species (pests and invasives); however, they are traditionally overlooked or under-studied. Our study provides data on the role of these non-traditionally managed areas both in terms of biodiversity conservation and how they serve as a potential refuge, source and/or "stepping stone" for alien and invasive species. Additionally, a new, easy-to-use, standardised innovative method for studying them is also promoted.

2. Materials and Methods

2.1. Field Tests

Trappings were carried out at the Zoo of Debrecen in Hungary. Traps were hung on trees, at a height of 1.8–2 m at a 20–25 m distance from each other, at the border of the park, in a margin of a deciduous forest. The test was run 25 May–5 October 2023. Both types of baited traps were used in eight repetitions (8 × 2 = 16 traps in total). Lures were replaced monthly with new ones. Traps were checked, and samples (individuals caught) were taken weekly.

2.2. Traps

CSALOMON® VARL+ funnel traps were used (Plant Protection Institute, CAR, HUN-REN, Budapest; photos of the trap can be viewed at www.csalomontraps.com (accessd on 20 October 2024)). Similar traps have routinely been used for trapping several noctuids [4,8,11]. To kill captured insects, a small piece (1 × 1 cm) of a household anti-moth insecticide strip (Chemotox® SaraLee, Temana Intl. Ltd., Slouth, UK; active ingredient 15% dichlorvos) was placed into the container of traps.

2.3. Baits

SBL: 1:1:1 mixture of isoamyl alcohol, acetic acid and red wine, filled in 4 mL polypropylene tubes. The mixture was administered to dental rolls inside the tubes and could evaporate through a small opening (Ø = 4 mm), which was opened at the time the mixture was set out [9,10,13,14].

FLO lure: mixture of phenylacetaldehyde, (*E*)-anethol, benzyl acetate and eugenol (1:1:1:1). The compounds evaporated through the wall of the polyethylene bag dispensers used [20].

2.4. Data Analysis

The insects caught by traps were identified at the species level, and their abundance was provided for each sample. Lepidoptera taxa were identified according to Varga [21]; the taxonomic list follows the system of Lafontaine and Schmidt [22], with the modifications of Zahiri et al. [23]. The number, relative frequency and ratio of the families, subfamilies and species were provided for the whole sample and for the two lure types tested separately. The number and ratio of pests, invasive species, differential species (species caught only with a given lure type) and the species belonging to different life forms were also given. The pest status was determined based on Mészáros and Szabóky [24,25] and Zúbrik et al. [26], and in the case of life forms, Varga et al. [27] was followed.

These values were used to present the formerly described selectivity and attractivity of baits and proved the ability of traps to be used to assess the biodiversity and monitoring of several alien species in the special kind of habitat studied.

3. Results

During the 133-day sampling period, 52 moth species (Table 1) were caught, with 1943 individuals of which 31.6% were females. Regarding the number of species caught, the SBL was more effective since it attracted 43 species, while the FLO traps caught 19 species. Nevertheless, considering the abundances, SBL traps were less effective since they caught a lot fewer individuals (566) than the FLO traps (1377). The species caught belonged to six families, of which Noctuidae was the most species-rich and abundant, followed by Erebidae, Crambidae, Geometridae, Pyralidae and Thyatiridae (Figure 1).

Table 1. A list of the moths caught at the Zoo of Debrecen in 2023 with traps baited with phenylacetaldehyde-based (FLO) and isoamyl alcohol-based (SBL) lures.

Family	Subfamily	Species	FLO	SBL
Crambidae	Spilomelinae	*Cydalima perspectalis* (Walker, 1859)	+	+
Crambidae		*Patania ruralis* (Scopoli, 1763)	+	+
Pyralidae	Phycitinae	*Plodia interpunctella* (Hübner, [1813])	+	+
Thyatiridae	Thyatirinae	*Habrosyne pyritoides* (Hufnagel, 1766)		+
Thyatiridae	Thyatirinae	*Tethea or* ([Denis & Schiffermüller], 1775)		+
Geometridae	Ennominae	*Ligdia adustata* ([Denis & Schiffermüller], 1775)	+	+
Geometridae	Sterrhinae	*Idaea aversata* (Linnaeus, 1758)	+	
Erebidae	Hypeninae	*Hypena rostralis* (Linnaeus, 1758)		+
Erebidae	Scoliopteryginae	*Scoliopteryx libatrix* (Linnaeus, 1758)		+
Erebidae	Catocalinae	*Catocala promissa* ([Denis & Schiffermüller], 1775)	+	+
Erebidae	Catocalinae	*Catocala nupta* (Linnaeus, 1767)		+
Erebidae	Catocalinae	*Lygephila pastinum* (Treitschke, 1826)		+
Erebidae	Ctenuchinae	*Amata phegea* (Linnaeus, 1758)	+	+
Erebidae	Ctenuchinae	*Dysauxes ancilla* (Linnaeus, 1767)	+	
Noctuidae	Acronictinae	*Acronicta rumicis* (Linnaeus, 1758)		+
Noctuidae	Amphipyrinae	*Amphipyra pyramidea* (Linnaeus, 1758)		+
Noctuidae	Plusiinae	*Autographa gamma* (Linnaeus, 1758)	+	

Table 1. *Cont.*

Family	Subfamily	Species	FLO	SBL
Noctuidae	Plusiinae	*Trichoplusia ni* (Hübner, [1803])	+	
Noctuidae	Plusiinae	*Macdunnoughia confusa* Stephens, 1850	+	+
Noctuidae	Plusiinae	*Abrostola triplasia* (Linnaeus, 1758)	+	+
Noctuidae	Plusiinae	*Abrostola tripartita* (Hufnagel, 1766)	+	
Noctuidae	Plusiinae	*Diachrysia chrysitis* (Linnaeus, 1758)	+	
Noctuidae	Plusiinae	*Diachrysia stenochrysis* (Warren, 1913)	+	
Noctuidae	Heliothinae	*Helicoverpa armigera* (Hübner, [1808])	+	
Noctuidae	Hadeninae	*Lacanobia oleracea* (Linnaeus, 1758)		+
Noctuidae	Hadeninae	*Mamestra brassicae* (Linnaeus, 1758)		+
Noctuidae	Hadeninae	*Hadena bicruris* (Hufnagel, 1766)	+	
Noctuidae	Hadeninae	*Mythimna turca* (Linnaeus, 1761)	+	+
Noctuidae	Hadeninae	*Mythimna vitellina* (Hübner, [1808])		+
Noctuidae	Hadeninae	*Mythimna albipuncta* ([Denis & Schiffermüller], 1775)	+	+
Noctuidae	Noctuinae	*Noctua pronuba* (Linnaeus, 1758)		+
Noctuidae	Noctuinae	*Noctua fimbriata* (Schreber, 1759)		+
Noctuidae	Noctuinae	*Noctua orbona* (Hufnagel, 1766)		+
Noctuidae	Noctuinae	*Noctua janthe* (Borkhausen, 1792)		+
Noctuidae	Noctuinae	*Agrotis segetum* ([Denis & Schiffermüller], 1775)		+
Noctuidae	Noctuinae	*Agrotis exclamationis* (Linnaeus, 1758)		+
Noctuidae	Noctuinae	*Agrotis bigramma* (Esper, 1790)		+
Noctuidae	Xyleninae	*Charanyca trigrammica* (Hufnagel, 1766)		+
Noctuidae	Xyleninae	*Dypterygia scabriuscula* (Linnaeus, 1758)		+
Noctuidae	Xyleninae	*Trachea atriplicis* (Linnaeus, 1758)		+
Noctuidae	Xyleninae	*Athetis gluteosa* (Treitschke, 1835)		+
Noctuidae	Xyleninae	*Oligia latruncula* ([Denis & Schiffermüller], 1775)		+
Noctuidae	Xyleninae	*Oligia strigilis* (Linnaeus, 1758)		+
Noctuidae	Xyleninae	*Phlogophora meticulosa* (Linnaeus, 1758)		+
Noctuidae	Xyleninae	*Cosmia affinis* (Linnaeus, 1767)		+
Noctuidae	Xyleninae	*Thalpophila matura* (Hufnagel, 1766)		+
Noctuidae	Xyleninae	*Apterogenum ypsillon* ([Denis & Schiffermüller], 1775)		+
Noctuidae	Xyleninae	*Agrochola litura* (Linnaeus, 1761)		+
Noctuidae	Xyleninae	*Tiliacea aurago* ([Denis & Schiffermüller], 1775)		+
Noctuidae	Xyleninae	*Conistra vaccinii* (Linnaeus, 1761)		+
Noctuidae	Xyleninae	*Conistra erythrocephala* ([Denis & Schiffermüller], 1775)		+
Noctuidae	Noctuinae	*Xestia xanthographa* ([Denis & Schiffermüller], 1775)		+

The number of differential species of SBL traps was higher, especially regarding the most abundant families of Noctuidae and Erebidae, while the two species belonging to the Thyatiridae family were caught only by this lure type. On the other hand, in the case of Geometridae, only FLO traps had two different species. Except these specificities, the lures tested attracted species of most families similarly; nevertheless, both the qualitative and quantitative compositions of the samples taken with different lure types showed notable differences (Figure 1).

The relative frequencies of only six species were higher than 5%. Four of them belonged to Noctuidae (*Amphipyra pyramidea* L.: 5.9%; *Abrostola triplasia* L.: 9.4%; *Autographa gamma* L.: 5.8% and *Dypterygia scabriuscula* L.: 6.0%), while one belonged to the Erebidae (*Amata phegea* L.: 26.0%) and another to the Crambidae (*Patania ruralis* Scop.: 21.1%) family. Four of these most abundant species (*P. ruralis*, *A. phagea*, *A triplasia* and *A. gamma*) were caught almost only by FLO traps, while *D. scabriuscula* was a differential species for the SBL. The subdominant *Macdunnoughia confusa* Step. (4.7%) was attracted by the FLO lure, while *Noctua pronuba* L. (4.2%) and *Trachea atriplicis* L. (4.2%) preferred the SBL.

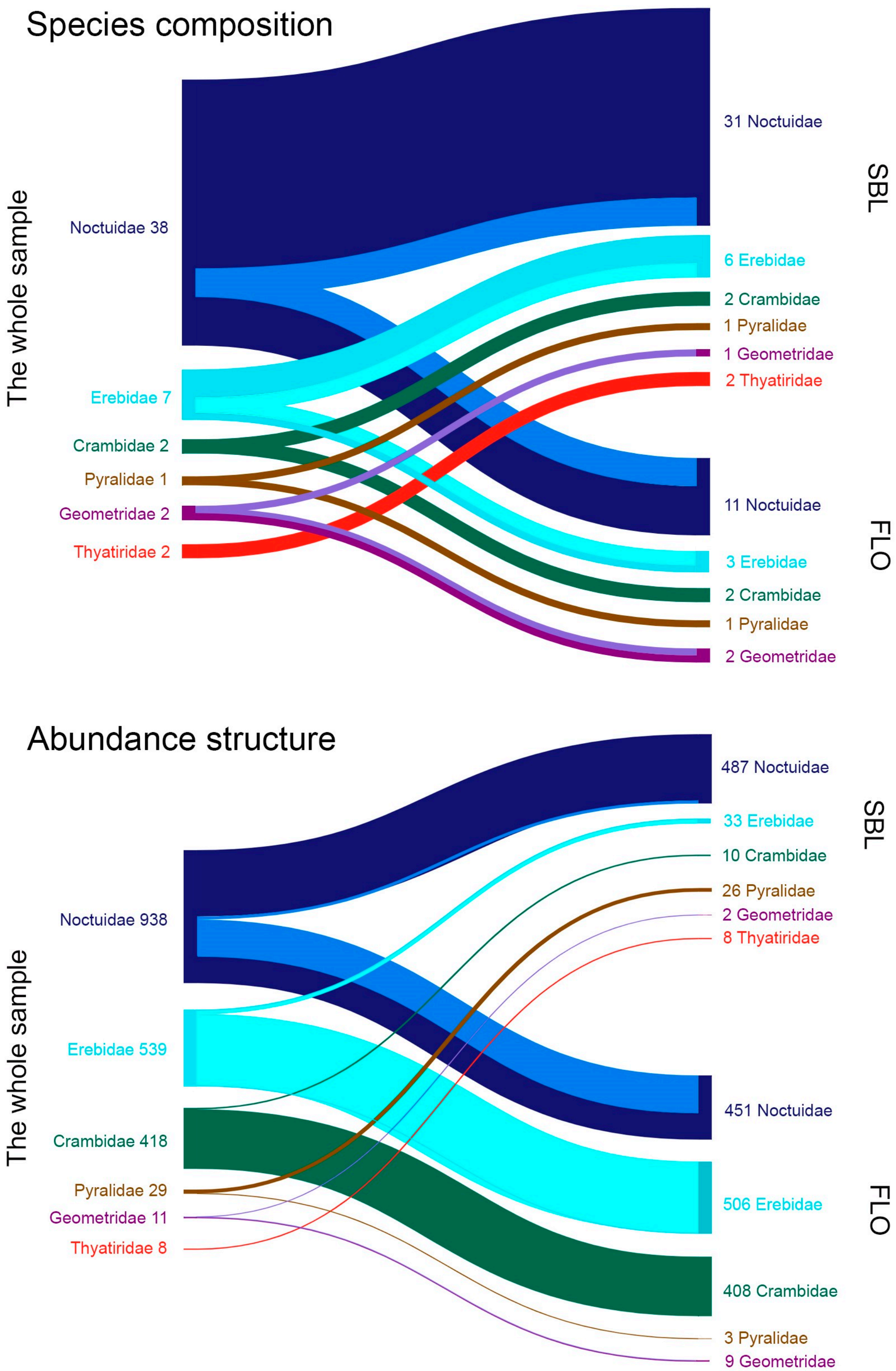

Figure 1. Composition of whole Lepidoptera sample and samples collected with different lure types (SBL and FLO) regarding number of species and individuals caught by families.

Due to the relatively low number of moths captured, only the phenology of the most abundant species could be characterised. *A. phegea* was monovoltine with a swarming period of about four weeks with a peak at mid-June. *A. triplasia*, *A. gamma* and *M. confusa* were on the wing from early June to mid-October, with an unexpected third peak between mid-September and October, probably referring to a formerly not recorded third generation. The adults of *D. scabriuscula*, *T. atriplicis* and *A. pyramidea* showed a long swarm from early June to August, without any high peaks, while P. ruralis had a similar long flying period with a late unusual peak in September, referring to a second or third generation in the given year. Some probably migrating individuals of the worldwide important pest Helicoverpa armigera were caught at the end of the vegetation period until mid-October.

The lures tested showed different attractivity to species belonging to different life forms referring to the habitat and food source preferences of species [27,28]. Generalist species mostly belonging to the Noctuidae family were mainly attracted by the SBL, and the Silvicolous species showed a similar preference (Table 2). In contrast, the species of the migratory and Altoherbosa (tall forb) life forms exclusively preferred the FLO lure. This seems to be the consequence of the taxonomic composition, since one of them (migratory species) belongs to the Heliothinae subfamily; however, the other six (four Altoherbosa and two migratory species), feeding on tall forbs and preferring Urtica dioica, all belong to the Plusiinae subfamily. Beyond that, most of the individuals of the only Lichenophagous species A. phegea were caught also with FLO traps (Table 2).

Table 2. The composition of the moth assemblage sampled considering the number (and ratio) and abundances (frequencies) of invasive and pest species and species belonging to different life forms of macro-moths.

	Species						**Individuals**					
	SBL		**FLO**		**Sum**		**SBL**		**FLO**		**Sum**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Invasives	1	2.3	3	15.8	3	5.8	1	0.2	155	11.3	156	8.0
Pests	2	4.7	9	47.4	9	17.3	88	15.5	144	10.5	232	11.9
S	**43**		**19**		**52**		**566**		**1377**		**1943**	
Life forms (macro-moths: 49 species, 1496 individuals)												
Generalist	13	32.5	2	12.5	13	26.5	247	46.6	87	9.0	334	22.3
Migratory	0	0	3	18.75	3	6.1	0	0.0	150	15.5	150	10.0
Steppic	3	7.5	1	6.25	4	8.2	5	0.9	7	0.7	12	0.8
Mesophilous	3	7.5	2	12.5	4	8.2	7	1.3	14	1.4	21	1.4
Altoherbosa	1	2.5	4	25	4	8.2	9	1.7	200	20.7	209	14.0
Moor–marsh	2	5	0	0	2	4.1	2	0.4	0	0.0	2	0.1
Silvicolous	11	27.5	3	18.75	12	24.5	236	44.5	10	1.0	246	16.4
Birch–alder	1	2.5	0	0	1	2.0	1	0.2	0	0.0	1	0.1
Oakwood	1	2.5	0	0	1	2.0	3	0.6	0	0.0	3	0.2
Willow–poplar	4	10	0	0	4	8.2	13	2.5	0	0.0	13	0.9
Lichenophagous	1	2.5	1	6.25	1	2.0	7	1.3	498	51.6	505	33.8
Sum	**40**		**16**		**49**		**530**		**966**		**1496**	

In the studied habitat, our traps caught three invasive and nine pest species. In total, they gave 23.1% of the species, and their relative frequency was 18.9% in total (Figure 2). Among them, *Cydalima perspectalis* was introduced from East Asia to Europe and spread through the continent in the last decade [18]. The widely distributed harmful pest species *H. armigera* was a subdominant, while the migratory *A. gamma* was an abundant member of the local assemblage. The latter has a more or less stabile native population in the Carpathian Basin but also belongs to the migratory species in other regions. Other pests had only low abundances, but their appearance referred to the disturbances and special character of the studied habitat (Figure 2, Table 2).

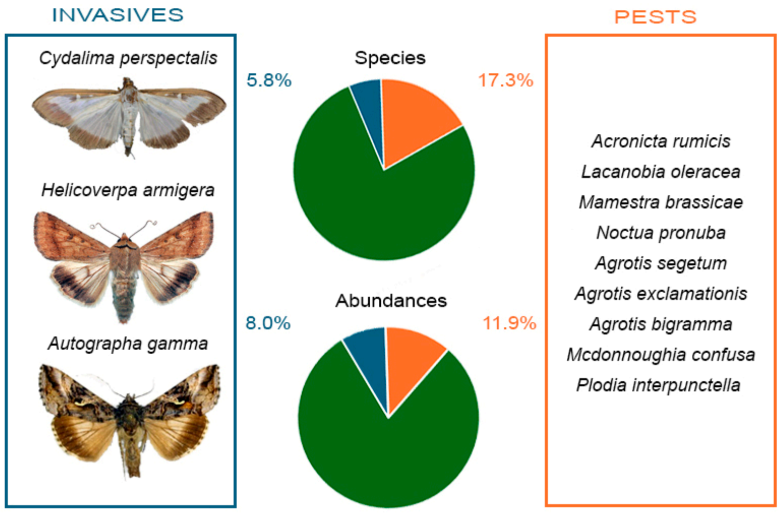

Figure 2. Ratio and relative frequencies of invasive and pest species in moth assemblage of Zoo of Debrecen.

4. Discussion

Intensive urbanisation has destroyed not only lots of natural and semi-natural habitats but also fragmented and isolated their remaining patches in city parks, gardens, etc. [2,29,30]. Since urbanisation is seeming to accelerate [31,32], a further decline, isolation and extinction of local populations may be expected, including that of plants and animals, birds and moths, etc. [1,33,34]. Thus, surveying and understanding the effects of urbanisation on populations and communities constitute high-priority tasks that need innovative methods and solutions.

While recent surveys on night-active insects mostly used traditional methods such as light trapping with actinic tubes or mercury vapor lamps e.g., [1–3], in the present study, two recently developed [4,8,11] bisexual lures, SBL and FLO, were used. These lures proved to be attractive and selective mainly for species belonging to the Noctuidae, Erebidae and Crambidae families. Considering the number of species caught, the SBL was more efficient and was selective to Xyleninae and Noctuinae species, while the less effective FLO provided more data on Plusiinae species. Because of the different selectivity, these lures complement each other, and their parallel use can be recommended for biodiversity assessment, as was formerly published [4]. The general composition of the samples was quite similar to the samples of light traps, showing some unique characters [4,10,15]. The method used provided reliable data on the moth assemblages of the suburban park of Debrecen Zoo, with the high dominance of Noctuidae, Erebidae and Crambidae; in this respect, the results were similar to those obtained with samples in different suburban areas of Delhi, India [3], with other methods.

Despite the complexity of habitats, including small fragments of natural woody vegetation, the number of species recorded was relatively low, compared to the species richness of neighbouring forests in the NE Hungarian lowland [10,12]. The nearly complete absence of oakwood components is especially remarkable (Table 2). The number and abundances of economically important species were also low. Nevertheless, the appearance of the migrating *Autographa gamma* and *Helicoverpa armigera* and relatively large numbers of generalists such as *Noctua pronuba*, *Amphipyra pyramidea*, *Dypterigia scabriuscula* and *Trachea atriplicis* were also recorded.

The lures tested proved to be appropriate for assessing diversity and describing the composition of a moth assemblage, and they provide an easy-to-use, standardised and cost- and labour-effective method. The efficiency and simplicity of this method make it suitable for both large-scale and long-term experiments, collecting comparable data on insect communities including different taxa (e.g., Lepidoptera, *Bombus* sp., Diptera, Orthoptera, etc.) [35–37]. In conclusion, the presentation, promotion and also the conservation of biodiversity are all important missions of zooparks and botanical gardens, which need these kinds of innovative solutions, especially considering the usually limited resources available for environmental monitoring.

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References

1. Lintott, P.R.; Bunnefeld, N.; Fuentes-Montemayor, E.; Minderman, J.; Blackmore, L.M.; Goulson, D.; Park, K.J. Moth species richness, abundance and diversity in fragmented urban woodlands: Implications for conservation and management strategies. *Biodivers. Conserv.* **2014**, *23*, 2875–2901. [CrossRef]
2. Ellis, E.E.; Wilkinson, T.L. Moth assemblages within urban domestic gardens respond positively to habitat complexity, but only at a scale that extends beyond the garden boundary. *Urban Ecosyst.* **2020**, *24*, 469–479. [CrossRef]
3. Paul, M. Impact of urbanization on moth (Insecta: Lepidoptera: Heterocera) diversity across different urban landscapes of Delhi, India. *Acta Ecol. Sin.* **2021**, *41*, 204–209. [CrossRef]
4. Szanyi, S.; Molnár, A.; Szanyi, K.; Tóth, M.; Jósvai, J.; Varga, Z.; Nagy, A. Traps with synthetic, bisexual generic attractants as a new method supplementing light traps for assessing composition and diversity of Macroheterocera assemblages. *Sci. Rep.* **2024**, *14*, 20212. [CrossRef]
5. Cantelo, W.W.; Jacobson, M. Phenylacetaldehyde attracts moths to bladder flower and to blacklight traps. *Environ. Entomol.* **1979**, *8*, 444–447. [CrossRef]
6. Landolt, P.J. New chemical attractants for trapping *Lacanobia subjuncta*, *Mamestra configurata*, and *Xestia c-nigrum* (Lepidoptera: Noctuidae). *J. Econ. Entomol.* **2000**, *93*, 101–106. [CrossRef]
7. Landolt, P.J.; Alfaro, J.F. Trapping *Lacanobia subjuncta*, *Xestia c-nigrum* and *Mamestra configurata* (Lepidoptera: Noctuidae) with acetic acid and 3-methyl-1-butanol in controlled relesase dispensers. *Environ. Entomol.* **2001**, *30*, 656–662. [CrossRef]
8. Tóth, M.; Szarukán, I.; Dorogi, B.; Gulyás, A.; Nagy, P.; Rozgonyi, Z. Male and female noctuid moths attracted to synthetic lures in Europe. *J. Chem. Ecol.* **2010**, *36*, 592–598. [CrossRef]
9. Nagy, A.; Szarukán, I.; Gém, F.; Nyitrai, R.; Füsti-Molnár, B.; Némerth, A.; Kozák, L.; Molnár, A.; Katona, K.; Szanyi, S.; et al. Preliminary data on the effect of semi-synthetic baits for Noctuidae (Lepidoptera) on the non-target Lepidoptera species. *Acta Agrar. Debreceniensis* **2015**, *66*, 71–80. [CrossRef]
10. Szanyi, S.; Nagy, A.; Molnár, A.; Katona, K.; Tóth, M.; Varga, Z. Night-active Macroheterocera species in traps with synthetic attractants in the Velyka Dobron' Game Reserve (Ukraine, Transcarpathia). *Acta Zool. Acad. Sci. Hung.* **2017**, *63*, 97–114. [CrossRef]
11. Tóth, M.; Szarukán, I.; Nagy, A.; Gém, F.; Nyitrai, R.; Kecskés, Z.; Krakkó, L.; Jósvai, J.K.; Bélai, I. Félszintetikus "biszex" csalétkek kártevő rovarok nőstényeinek és hímjeinek fogására [Semi-synthetic "bisex" baits for catching of males and females of pest species]. *Növényvédelem* **2015**, *51*, 197–205.
12. Szanyi, S.; Molnár, A.; Kozák, L.; Szalárdi, T.; Varga, Z.; Tóth, M.; Nagy, A. Nyírségi Macroheterocera együttesek vizsgálata illatanyagcsapdák alkalmazásával—[Study on the Macroheterocera assemblages of the Nyírség (Northeast Hungary) using volatile traps—In Hungarian]. *Erdészettudományi Közlemények* **2019**, *9*, 51–68. [CrossRef]
13. Szanyi, S.; Szarukán, I.; Nagy, A.; Jósvai, J.; Imrei, Z.; Varga, Z.; Tóth, M. Comparing performance of synthetic sex attractants and a semisynthetic bisexual lure in Orthosia and Conistra species (Lepidoptera: Noctuidae). *Acta Phytopathol. Entomol. Hung.* **2020**, *55*, 115–122. [CrossRef]
14. Szanyi, S.; Varga, Z.; Nagy, A.; Jósvai, J.K.; Imrei, Z.; Tóth, M. Bisexual lures and their comparison with synthetic sex attractants for trapping Orthosia species (Lepidoptera: Noctuidae). *J. Appl. Entomol.* **2022**, *146*, 1109–1115. [CrossRef]

15. Szalárdi, T.; Szanyi, S.; Szarukán, I.; Tóth, M.; Nagy, A. Semiochemical baited traps of lepidopteran pests of economic importance can deliver reliable data also on wide range of non-target species: Case study in the Hajdúság Region of East Pannonian Lowland (East Hungary). *Biodivers. Data J.* **2021**, *9*, e72305. [CrossRef] [PubMed]
16. Tóth, M.; Nagy, A.; Szarukán, I.; Ary, K.; Cserenyec, A.; Fenyődi, B.; Gombás, D.; Lajkó, T.; Merva, L.; Szabó, J.; et al. One Decade's Research Efforts in Hungary to Develop a Bisexual Lure for the Cotton Bollworm *Helicoverpa armigera* Hübner. *Acta Phytopathol. Entomol. Hung.* **2020**, *55*, 53–62. [CrossRef]
17. Chowdary, L.R.; Kumar, G.V.S.; Bharathi, S.; Sarada, O.; Nagaraju, Y.; Chandrashekara, K.M.; Harish, G.N. Off-season survival and life history of beet armyworm, *Spodoptera exigua* (Hubner) on various host plants. *Sci. Rep.* **2024**, *14*, 13721. [CrossRef]
18. Molnár, B.P.; Kárpáti, Z.; Nagy, A.; Szarukán, I.; Csabai, J.; Koczor, S.; Tóth, M. Development of a Female-Targeted Lure for the Box Tree Moth *Cydalima perspectalis* (Lepidoptera: Crambidae): A Preliminary Report. *J. Chem. Ecol.* **2019**, *45*, 657–666. [CrossRef]
19. Nagy, A.; Szarukán, I.; Csabai, J.; Molnár, A.; Molnár, B.P.; Kárpáti, Z.; Szanyi, S.; Tóth, M. Distribution of the box tree moth (Cydalima perspectalis Walker 1859) in the north-eastern part of the Carpathian Basin with a new Ukrainian record and Hungarian data. *EPPO Bull.* **2017**, *47*, 279–282. [CrossRef]
20. Tóth, M.; Répási, V.; Szocs, G. Chemical attractants for females of pest Pyralids and Phycitids (Lepidoptera: Pyralidae, Phycitidae). *Acta Phytopathol. Entomol. Hung.* **2002**, *37*, 375–384. [CrossRef]
21. Varga, Z. *Magyarország Nagylepkéi—Macrolepidoptera of Hungary*; Heterocera Press: Budapest, Hungary, 2012; p. 354.
22. Lafontaine, D.; Schmidt, C. Annotated check list of the Noctuoidea (Insecta, Lepidoptera) of North America north of Mexico. *ZooKeys* **2010**, *40*, 1–239. [CrossRef]
23. Zahiri, R.; Holloway, J.D.; Kitching, I.J.; Lafontaine, J.D.; Mutanen, M.; Wahlberg, N. Molecular phylogenetics of Erebidae (Lepidoptera, Noctuoidea). *Syst. Entomol.* **2011**, *37*, 102–124. [CrossRef]
24. Mészáros, Z.; Szabóky, C. *A Magyarországi Molylepkék Gyakorlati Albuma*; Balázs, K., Ed.; Agroinform: Budapest, Hungary, 2005; pp. 1–178.
25. Mészáros, Z.; Szabóky, C. *A Magyarországi Nagylepkék Gyakorlati Albuma*; Szalkay József Magyar Lepkészeti Egyesület: Budapest, Hungary, 2012; p. 185.
26. Zúbrik, M.; Kunca, A.; Csóka, G. *Insects and Diseases Damaging Trees and Shrubs of Europe*; Zúbrik, M., Kunca, A., Csóka, G.N.A.P., Eds.; NAP: Ann Arbor, MI, USA, 2013; 535p, Available online: www.napeditions.com (accessed on 12 November 2024).
27. Varga, Z.; Ronkay, L.; Bálint, Z.; László, M.G.; Peregovits, L. *Checklist of the Fauna of Hungary*; Macrolepidoptera; Hungarian Natural History Museum: Budapest, Hungary, 2004; Volume 3, p. 106.
28. Varga, Z. Zoogeographic division of Hungary based on components of the Macrolepidoptera-fauna (in Hung. with German summary). *Folia Entomol. Hung.* **1964**, *17*, 119–167.
29. McKinney, M.L. Urbanization as a major cause of biotic homogenization. *Biol. Conserv.* **2006**, *127*, 247–260. [CrossRef]
30. Di Mauro, D.; Dietz, T.; Rockwood, L. Determining the effect of urbanization on generalist butterfly species diversity in butterfly gardens. *Urban Ecosyst.* **2007**, *10*, 427–439. [CrossRef]
31. Seto, K.C.; Güneralp, B.; Hutyra, L.R. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 16083–16088. [CrossRef]
32. Aronson, M.F.J.; La Sorte, F.A.; Nilon, C.H.; Katti, M.; Goddard, M.A.; Lepczyk, C.A.; Warren, P.S.; Williams, N.S.G.; Cilliers, S.; Clarkson, B.; et al. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proc. R. Soc. B Biol. Sci.* **2014**, *281*, 20133330. [CrossRef]
33. Rickman, J.K.; Connor, E.F. The effect of urbanization on the quality of remnant habitats for leaf-mining Lepidoptera on Quercus agrifolia. *Ecography* **2003**, *26*, 777–787. [CrossRef]
34. Merckx, T.; Marini, L.; Feber, R.E.; Macdonald, D.W. Hedgerow trees and extended-width field margins enhance macro-moth diversity: Implications for management. *J. Appl. Ecol.* **2012**, *49*, 1396–1404. [CrossRef]
35. Arnóczkyné Jakab, D.A.; Tóth, M.; Szarukán, I.; Szanyi, S.; Józan, Z.; Sárospataki, M.; Nagy, A. Long-term changes in the composition and distribution of the Hungarian bumble bee fauna (Hymenoptera, Apidae, Bombus). *J. Hymenopt. Res.* **2023**, *96*, 207–237. [CrossRef]
36. Nagy, A.; Katona, P.; Molnár, A.; Rádai, Z.; Tóth, M.; Szanyi, K.; Szanyi, S. Wide range of brachyceran fly taxa attracted to synthetic and Semi-Synthetic generic noctuid lures and the description of new attractants for sciomyzidae and heleomyzidae families. *Insects* **2023**, *14*, 705. [CrossRef]
37. Nagy, A.; Ősz, A.; Tóth, M.; Rácz, I.A.; Kovács, S.; Szanyi, S. Nontarget catches of traps with chemical lures may refer to the flower-visitation, probable pollination, and feeding of bush crickets (Ensifera: Tettigoniidae). *Ecol. Evol.* **2023**, *13*, e10249. [CrossRef] [PubMed]