



In memoriam



## Professor Mitko Subchev (1945–2023)

In April 2023, Bulgarian science lost an eminent zoologist and leading researcher who played a pivotal role in advancing insect chemical ecology in Bulgaria. Dr Mitko Subchev was a professor at the Institute of Zoology (now Institute of Biodiversity and Ecosystem Research), Bulgarian Academy of Sciences.

### Brief Biographical Data

Mitko Angelov Subchev was born on August 1, 1945, in Krushevo Village, Gabrovo Province, Bulgaria. In 1963, he graduated from the 32 Secondary School “St. Kliment Ohridski” in Sofia. During his studies at the Biological Faculty, Sofia University “St. Kliment Ohridski” (1965–1970), he became interested in ectosymbiotic worms (or crayfish worms) of the genus *Branchiobdella* Odier, 1823 (Annelida: Branchiobdellidae) and this group of invertebrate animals was the subject of his master thesis under the supervision of Dr Georgi Kozarov. Mitko Subchev earned a master’s degree in Biology (Zoology) from Sofia University “St. Kliment Ohridski” in 1970. In the same year, he was appointed as a biologist at the Plant Protection Station in Veliko Tarnovo, where he worked on rearing of the egg parasitoid *Trichogramma* Westwood, 1833 (Hymenoptera) until 1972. From 1972 to 1975, Mitko Subchev was a PhD student at the Ukrainian Agricultural Academy in Kiev, Ukraine. For his PhD thesis, he worked primarily on lepidopteran pheromones. In 1975, he defended a dissertation entitled *Sex pheromones of some species of moth (Lepidoptera: Tortricidae, Geometridae, Gelechiidae)*. His scientific career began at the Institute of Zoology, Bulgarian Academy of Sciences, in 1975, initially as a junior researcher. In this institute, he was promoted to Associate Professor in 1986. In 1994, he defended a DSc dissertation entitled *Pheromone communication in the family Noctuidae (Insecta: Lepidoptera)*. In 1996, M. Subchev was appointed to Professor and held this position until his mandatory retirement in 2013. Among his administrative positions at the Institute of Zoology were Deputy Director (2000–2003) and Scientific Secretary (1997–2000). In 1996, Subchev started his own research group *Insect Chemical Ecology* and he worked with several researchers – Lyudmila Stanimirova, Irina Krasteva, Teodora Toshova, Albena Mircheva, Vasiliy Abaev, etc. Teodora Toshova received her PhD under the guidance of Mitko Subchev.

Professor Subchev was one of the main initiators and organizers of international scientific events: International conference *Noctuid sex pheromone communication – theory and application*, 12–16 September 1994 Sofia, Bulgaria, International Scientific conference *Biodiversity and ecological problems of Balkan fauna*, 26–29 May 1997, Sofia, Bulgaria and *XI International Symposium on Zygaenidae*, 17–21 September 2008, Sofia, Bulgaria. He was a member of professional societies such as the Bulgarian Entomological Society and the International Society of Chemical Ecology. Over four decades, M. Subchev presented reports at many national and international scientific forums.

Dr Mitko Subchev taught *Insect Behaviour* at the Biological Faculty of Sofia University “St. Kliment Ohridski”. He was a member of the editorial board of the journal *Acta Zoologica Bulgarica* and contributed very much to the scientific level of this journal.

Mitko Subchev managed to conduct his extensive research using research grants from the Bulgarian National Scientific Fund, SYNTHESYS (Synthesis of Systematic Resources) EU programme and formal institutional collaborations (under bilateral agreements of the Bulgarian Academy of Sciences) as well as informal collaborations with researchers from many countries. Between 1975 and 2009, he often visited the Plant Protection Institute of the Hungarian Academy of Sciences (Budapest) where he collaborated with Dr Miklós Tóth and Dr Gabor Szöcs. He also had several visits to Prof. Wittko Francke at the Hamburg University (Germany). These successful collaborations resulted in numerous joint scientific publications.

### Brief Summary of Research Impact

Prof. Mitko Subchev published 190 articles, a large part of them in peer-reviewed journals (Appendix 1). According to the diversity of the topics he has explored, his works can be classified into two main groups:

- crayfish worms (Branchiobdellidae) – taxonomy and faunistics;
- insect chemical communication, with a focus to chemoreception, insect behaviour, pheromone identification, understanding of biosynthetic pathways of natural products, biological function of the target compounds and application of semiochemicals for monitoring the distribution and seasonal activity of target pests.

### Crayfish worms

Based on materials in his diploma thesis, M. Subchev published his first scientific article on the Branchiobdellidae in Bulgaria (Kozarov et al. 1972). Although his studies primarily focused on insect behavior and chemical communication, he continued publishing on crayfish worms throughout his entire scientific career.

Dr Subchev described three species of the genus *Branchiobdella* Odier, 1823: *B. kozarovi* Subchev, 1978 (type locality: a manmade pond near the village of Razdelna, Varna Province, Bulgaria), *B. teresae* Subchev, 1986 (type locality: Suyang-san, South Hwanghae, North Korea) and *B. bulgariensis* Subchev & Rimcheska, 2021 (type locality: Topolnitsa River near the village of Dushantzi, Sofia Province, Bulgaria). In collaboration with colleagues (GELDER et al. 1994), he described the spermatozoa of *B. kozarovi*, expanding the knowledge of interspecific variation within the genus *Branchiobdella*.

In collaboration, he reported the branchiobdellidans *B. pentodonta* (SUBCHEV et al. 2007) and *B. astaci* (SUBCHEV et al. 2020) for the first time for the Greek fauna, *Cirrodrilus suzukii* (Yamaguchi, 1934) and *Sinodrilus heterorchis* (Liu & Zhang, 1983) for the first time from Democratic People’s Republic of Korea (SUBCHEV et al. 1991). *Hystricosoma chappuis* Michaelsen, 1926 (Polychaeta: Aeolosomatidae) was reported as new species for Bulgaria (SUBCHEV & STANIMIROVA 1986) and Greece (SUBCHEV et al. 2007). During examination of crayfish collection in the Natural History Museum in Budapest, Hungary, he found *B. hexodonta* in the gill chamber of *Austropotamobius torrentium* (Schränk, 1803) from Albania; this study presented the first record of the genus *Branchiobdella* in this country (SUBCHEV 2011).

In the framework of SYNTHESYS program, Mitko Subchev visited several European museums for examination of the collections of crayfish and their epibionts. These were the Museum für Naturkunde (Berlin, Germany), Muséum national d’Histoire naturelle (Paris, France), Swedish Museum of Natural History (Stockholm, Sweden), Natural History Museum of Vienna (Austria), The Natural History Museum (London, UK), the Natural History Museum of Copenhagen (Denmark), Royal Belgian Institute of Natural Science (Brussels, Belgium) and the National Museum of Prague (Czech Republic). These visits resulted in gathering abundant information on occurrence of crayfish worms in many countries:

- *B. hexodonta* Gruber, 1883 was a new record for France (SUBCHEV 2008),
- *B. parasita* Braun, 1805 and *B. pentodonta* Whitman, 1882 was reported for the first time from Denmark (SUBCHEV 2009),
- *B. astaci* Odier, 1823 was reported for the first time from Austria, Slovenia, Slovakia and Ukraine and a microscopic re-description of *B. papillosa* Neesemann & Hutter, 2002 was made (SUBCHEV & GELDER 2010),
- *B. kozarovi* was recorded in the Asian part of Turkey (SUBCHEV 2012),

- *Branchiobdella* spp. (*B. parasita*, *B. pentadonta* and *B. hexadonta*) were reported for the first time from Belgium (SUBCHEV 2016).

In 2014, Dr Subchev published a review of the eight European species of genus *Branchiobdella* known at that time and revised their synonymy. Information about the type material, type locality and characteristic morphological features are presented for each of them (SUBCHEV 2014a). The latest study on crayfish worms was published recently (SUBCHEV et al. 2024).

### Insect chemical ecology

*Morphological aspect.* The morphological investigations were focused on the antennal sensilla receptors that perceive pheromone compounds and the pheromone glands that emit sex pheromones.

The morphology of the antennal sensilla apparatus was described in the several lepidopteran species. These were *Archips rosana* (L., 1758), *A. xylosteana* (L., 1758) (Tortricidae) (SUBCHEV 1977b), *Mamestra brassicae* L., 1758 (Noctuidae) (SUBCHEV & STANIMIROVA 1980), *Scoliopteryx libatrix* L., 1758 (Erebidae) (SUBCHEV 1980a, ANDERSEN et al. 2000), *Thaumetopoea pityocampa* (Denis & Schiffermüller) (Notodontidae) (SUBCHEV & STANIMIROVA 1983) and the geometrids *Operophtera brumata* (Linnaeus, 1758) and *Agriopis aurantiaria* (Hübner) (SUBCHEV 1977a).

HALLBERG & SUBCHEV (1997) reported an unusual location of the sex pheromone glands of the females of *Theresimima ampellophaga* (Bayle-Barelle, 1809) (Zygaenidae). They are situated dorsally on the abdomen, on the anterior part of the 3rd-5th abdominal tergites and the glandular epithelium of the gland consists of two cell types: gland cells with a central microvilli-lined cavity and wrapping cells. The investigations by SUBCHEV (1980d) and SUBCHEV & PILARSKA (1997) revealed that the sex pheromone glands of *A. rosana*, *A. xylosteana* (Linnaeus, 1758) and *S. libatrix* were located dorsally on the intersegmental membrane between the 8<sup>th</sup> and 9<sup>th</sup> abdominal segments.

*Behavioral aspect.* Investigations involved studying patterns of calling behaviour (stereotyped rhythmic motor pattern) in female moths in a period when they emit the sex pheromone to attract of conspecific males and the subsequent sensing of these chemical cues by males and their behavioral responses. In several papers, he studied and described the calling behavior of females of a model species, the cabbage moth *M. brassicae* – calling posture (an ovipositor extended at an angle of 140° towards the body axis and slightly raised wings) and influence of photoperiod (including abnormal photoperiods), age, temperature and light on the calling behavior (SUBCHEV 1980b, 1983a, 1985). He was the first to report in Lepidoptera that the duration of the light period determined the time of the mean onset of calling of females of this species. Investigations of calling behavior of *S. libatrix* and *T. pityocampa* (SUBCHEV et al. 1994b, SUBCHEV & PILARSKA 1997) showed that the calling posture of the females was characterised by curved abdomens with pheromone glands (situated dorsally in the intersegmental membrane between the 8th and 9th abdominal segments) exposed dorsally. On the other hand, SUBCHEV & HARIZANOV (1990) observed uncommon calling posture of *Th. ampellophaga* females at the time of active attraction of the conspecific males. Later, HALLBERG & SUBCHEV (1997) concluded that the sex pheromone gland in females is situated on the anterior part of the 3rd-5th abdominal tergites. Female calling behavior and male responsiveness of this species had a distinct diel periodicity (TOSHOVA & SUBCHEV 2003, SUBCHEV et al. 2004). Direct observations on the diurnal rhythm of calling were also reported for two more zygaenid species, *Rhagades pruni* (Denis & Schiffermüller) and *Illiberis rotundata* Jordan, 1907 (TOSHOVA & SUBCHEV 2005). TOSHOVA et al. (2007) indicated that mate recognition and successful copulation of male *Th. ampellophaga* depends on the joint effect of different stimuli – olfactory (pheromone cue), visual and tactile; however, the pheromone stimulus appears to be the primary factor mediating this behavior.

*Chemical aspect.* Studies of M. Subchev on the insect chemical communication were in two directions.

1. Field and or electroantennographic (EAG) screening of chemicals (known pheromone compounds, their isomers or plant compounds) for possible behavioral activity on target and non-target insect species/groups. The first paper related to the results obtained by field screening was about a sex attractant for the males of *Athrips* sp. (= *Rhynchopacha* sp.) (Lepidoptera: Gelechiidae), (*E*)-5-tetradecenyl acetate (SUBCHEV & KUZNETZOV 1974). Later sex attractants of more than 100 lepidopteran species belonging to different families (Lepidoptera: Argyresthiidae, Autostichidae, Gelechiidae, Geometridae, Coleophoridae, Cosmopterigidae, Gracillariidae, Crambidae, Noctuidae, Notodontidae, Plutellidae, Pterophoridae, Pyralidae, Sesiidae, Tortricidae and Zygaenidae) were published with Dr Subchev as a main contributor or co-author (Appendix 2). Data about the pheromone attractants of Zygaenidae species obtained by Mitko Subchev and



**Fig. 1.** Participants of the XI International Symposium on Zygaenidae, 17-21 September 2008, Sofia, Bulgaria.

collaborators can be seen in the review article of SUBCHEV (2014b). In addition, attractants (including sex attractants, aggregation attractants and plant attractants) for coleopteran species belonging to Cerambycidae, Chrysomelidae, Curculionidae, Elateridae and Scarabaeidae (IMREI et al. 2014, TOSHOVA et al. 2009b, 2010b, 2016, 2019, TÓTH et al. 2007a, 2008, 2009, etc.) species were found. SUBCHEV & MYRSINA (1977) reported attraction of females of *Tricimba cincta* (Meigen, 1830) (Diptera: Chloropidae) by trans-5-dodecenol.

Based on EAG screening, EAG-active substances were found for many noctuid species (SUBCHEV et al. 1994c, 1995b, SUBCHEV 1997).

The inhibitory effect of substances on the sex pheromones/attractants of several species was established: *Alsophila aceraria* (Denis & Schiffermüller), *O. brumata* (SUBCHEV et al. 1986b), *Autographa gamma* (L., 1758) (SUBCHEV et al. 1987b), *Neosphaleroptera nubilana* (Hübner, 1796-1799) (SUBCHEV et al. 1990), *Atethmia ambusta* (Denis & Schiffermüller) (SUBCHEV et al. 1995a), *Xestia c-nigrum* (L., 1758) (SUBCHEV et al. 1996) and *Megalophanes viciella* (Denis & Schiffermüller) (SUBCHEV et al. 2002).

2) Identification of insect sex pheromones – direct chemical analysis of the extracts of female moths or pheromone glands, synthesis and behavioral activity of single compounds or mixtures. In these studies, chemical analysis and synthesis of biologically-active compounds were performed by chemists. The sex pheromones of the vine bud moth, *Th. ampellophaga*, and *I. rotundata* were identified by coupled gas chromatography-electroantennography (GC-EAG), coupled gas chromatography-mass spectrometry (GC-MS), and synthesis as (2*R*)-butyl (7*Z*)-tetradecenoate and a mixture of (2*R*)-butyl (7*Z*)-dodecenoate and (2*R*)-butyl (9*Z*)-tetradecenoate, respectively (SUBCHEV et al. 1998a, SUBCHEV et al. 2009). Other unusual sex pheromones for order Lepidoptera were those of *M. viciella*, 1-methylethyl octanoate (SUBCHEV et al. 2000a) and *S. libatrix*, (6*Z*,13*S*)-methylheneicosene (FRANCKE et al. 2000, TOSHOVA et al. 2003). The sex pheromone of *S. libatrix* was found to reach its highest levels on pheromone glands of 3-day-old females (SUBCHEV & JURENKA 2001). SUBCHEV et al. (2003a) and MOLNÁR et al. (2012) identified the sex pheromones of two lepidopteran leaf-miners *Phyllonorycter platani* (Staudinger, 1870) and *Tischeria ekebladella* (Bjerkander, 1795) as (Z10)-tetradecenyl acetate and a mixture of (3*Z*,6*Z*,9*Z*)-tricoso-3,6,9-triene and (3*Z*,6*Z*,9*Z*,19*Z*)-tricoso-3,6,9,19-tetraene (only tetraene had behavioral activity), respectively. TÓTH et al. (2002) identified the chemical composition of the female-produced sex pheromone of *Agriotes brevis* Candèze, 1863 (Coleoptera: Elateridae).

Based on large-scale investigations in countries in Europe, Asia and Africa a pheromone variation among populations of the turnip moth *Agrotis segetum* (Denis & Schiffermüller) was reported (SUBCHEV et al. 1986c, HANSSON et al. 1990, TÓTH et al. 1992).

Jurenka and coauthors showed that the methyl-branched pheromone of the gypsy moth, *Lymantria dispar* Linnaeus, 1758, 2-methyl-7R,8S-epoxy-octadecane (disparlure), was derived from an alkene precursor, 2-methyl-Z7-octadecene (JURENKA & SUBCHEV 2000, JURENKA et al. 2003).

*Practical aspect.* Traps baited with pheromones and other semiochemicals are widely used for detection and monitoring pest populations. However lure compositions, dispenser type, trap design and proper traps placement are all important factors for the development of an attractant trap system suitable for catching target species (FURLAN et al. 2001, SUBCHEV et al. 2004b, KUTINKOVA et al. 2008, VUTS et al. 2010a, 2010b, TOSHOVA et al. 2019, etc.). The importance of visual stimuli for optimal attraction to the chemical lure was reported for several beetle species, including scarab beetles (SCHMERA et al. 2004, VUTS et al. 2010b), the alfalfa longhorn beetle *Plagionotus floralis* Pallas, 1773 (IMREI et al. 2014) and *Pseudovadonia livida* (Fabricius, 1776) (TOSHOVA et al. 2016). Numerous publications by Dr Subchev and collaborators have dealt with the application of traps baited with semiochemical lures for monitoring of seasonal activity of adults of species from different families of Lepidoptera (Cossidae, Erebidae, Gelechiidae, Geometridae, Gracillariidae, Lyonetidae, Noctuidae, Pyralidae, Sesiidae, Tortricidae and Zygaenidae) and Coleoptera (Cerambycidae, Chrysomelidae, Curculionidae, Elateridae and Scarabaeidae). In addition, semiochemical-baited traps are highly efficient in faunistic studies.

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Traveling was the great passion of Mitko Subchev. During his participation in scientific conferences and private trips, he visited more than half of the countries in the world, including many of the most beautiful places on Earth (Fig. 2).

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Fig. 2. Mitko Subchev, Mongolia, 23 July 2022 (Mitko Subchev's archive).

## Appendix 1. List of publications of Professor Mitko Subchev

- Kozarov G., Michailova P. & Subchev M. 1972. Studies on Branchiobdellidae (Oligochaeta, Annelida) in Bulgaria. *Annuaire de l'Université de Sofia, Faculté de biologie* 64 (1): 77–89 (In Bulgarian).
- Subchev M. & Kuznetsov N. 1974. Preliminary identification of the sex pheromone of *Rhynchopacha* sp. (Lepidoptera: Gelechiidae) by field screening tests. *Comptes rendus de l'Académie bulgare des Sciences* 27 (7): 993-994.
- Subchev M. A. 1975. Mating behavior of the meadow moth *Loxostege sticticalis* (Lepidoptera: Pyraustidae). *Scientific works of the Ukrainian Agricultural Academy* 30: 90-92. (In Ukrainian).
- Subchev M. A. & Myrsina R. A. 1976. Testing of some higher olefinic alcohols and their derivatives for attractiveness to representatives of the Lepidoptera. *Scientific works of the Ukrainian Agricultural Academy* 161:69-71. (In Russian).
- Subchev M. A. & Yatsenko V. G. 1976. The use of sex attractant traps to record the flight dynamics of the rose tortrix (Lepidoptera, Tortricidae). *Scientific Works of the Ukrainian Agricultural Academy* 161: 28-29. (In Russian).
- Myrsina R. A., Subchev M. A., Pogrebnyak R. S. & Sveshchuk A. A. 1977. Synthesis of trans-olefinic alcohols and study of their activity on insects. In: *Physiologically active substances*. Kiev: Naukova dumka 9: 68-70. (In Russian).
- Subchev M. 1977a. Antennae of two geometrid species (Lepidoptera: Geometridae) and their receptor sensillae. *Acta Zoologica Bulgarica*, 8: 15-22. (In Russian, English summary).
- Subchev M. A. 1977b. Morphology of the antennae of *Archips rosana* and *A. xylosteana* (Lepidoptera: Tortricidae). *Scientific works of the Ukrainian Agricultural Academy* 200: 69-72. (In Russian).
- Subchev M. A. & Myrsina R. A. 1977. Attraction of females of *Tricimba cincta* (Diptera: Chloropidae) by trans-5-dodecenol. *Scientific works of the Ukrainian Agricultural Academy* 200: 52-53. (In Russian).
- Subchev M. 1978. A new branchiobdellid - *Branchiobdella kozarovi* sp. n. (Oligochaeta, Branchiobdellidae) from Bulgaria. *Acta Zoologica Bulgarica*, 9: 78-80.
- Subchev M. 1980a. Auricillica-like sensilla and their unusual associations on the antennae of *Scoliopteryx libatrix* L. (Lepidoptera, Noctuidae). *Acta Zoologica Bulgarica* 16: 12-16.
- Subchev M. A. 1980b. Calling Behaviour of Female Cabbage Moths (*Mamestra brassicae* L.) (Lepidoptera, Noctuidae). *Ecology (Sofia)* 7: 33-38. (In Russian, English abstract)
- Subchev M. A. 1980c. Pheromone attraction of males by females of three geometrid moths (Lepidoptera: Geometridae). *Ecology (Sofia)* 6: 80-83. (In Russian, English summary).
- Subchev M. A. 1980d. Pheromone glands and Attractivity of Female *Archips rosanus* (L.) and *Archips xylosteanus* (L.) (Lepidoptera, Tortricidae). *Ecology (Sofia)* 6: 84-89. (In Russian, English summary).
- Subchev M. A. & Stanimirova L. S. 1980. The antennal sensor apparatus of the cabbage moth *Mamestra brassicae* L. (Lepidoptera: Noctuidae). *Acta Zoologica Bulgarica* 16: 17–29. (In Russian, English abstract).
- Michailova P. & Subchev M. 1981. On the karyotype of three species of the family Branchiobdellidae (Annelida: Oligochaeta). *Comptes rendus de l'Académie bulgare des Sciences* 34 (2): 265-267.
- Subchev M. A. 1981. Z-11-Hexadecenyl Acetate – sexual attractant for males of eight species of moths (Insecta, Lepidoptera). *Ecology (Sofia)* 9: 59-62. (In Russian, English summary).
- Subchev M. A. & Stanimirova L. S. 1981. Attractivity Field tests of the Synthetic pheromone of the cabbage moth (*Mamestra brassicae* L.) (Lepidoptera: Noctuidae). *Ecology (Sofia)* 9: 63-67. (In Russian, English summary).
- Subchev M. 1983a. Effect of age, temperature, photoperiod and light on the calling of *Mamestra brassicae* L. females. *Ecology (Sofia)* 12: 65-75.
- Subchev M. 1983b. Sex pheromones of *Mamestra brassicae* (Lepidoptera: Noctuidae) and their possible use in plant protection: investigations in Bulgaria. In: *International Conference on Integrated Plant Protection, Budapest, 4th-9th July 1983*, 4: 135-139.
- Subchev M. A. 1983c. Interaction between synthetic sex pheromones of the cabbage armyworm (*Mamestra brassicae* L.) (Lepidoptera: Noctuidae) in traps. *Ecology (Sofia)* 11: 80-83. (In Russian, English summary).
- Subchev M. A. & Stanimirova L. S. 1983. Morphological, morphometric and quantitative characteristics of antennal sensilla of the processionary moth *Thaumetopoea pityocampa* Schiff. (Lepidoptera, Thaumetopoidae). *Acta Zoologica Bulgarica* 23: 9-18. (In Russian, English summary).
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- Subchev M. A. 1984b. On Hungarian Branchiobdellids (Oligochaeta: Branchiobdellidae). *Miscellanea Zoologica Hungarica* 2: 47-50.
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- Subchev M. A. 1985. Effect of abnormal light/dark cycles on the calling of *Mamestra brassicae* L. (Lepidoptera, Noctuidae) females. *Ecology (Sofia)* 16: 70-74.
- Subchev M. A., Stamenova, M. B. & Borisova Y. A. 1985a. Effect of the time of the day, age of insects and pheromone dose on the sexual reaction of *Musca domestica* L. (Dip-

- tera, Muscidae). Ecology (Sofia) 17: 62-67. (In Russian, English summary).
- Subchev M. A., Stanimirova L. S. & Kovalev B. G. 1985b. The effect of the dose, minor components and presence of an additional source of cis-11-hexadecenyl-acetate on the attractivity of the synthetic sex heromone of the cabbage moth (*Mamestra brassicae* L.). Ecology (Sofia) 15: 43-49. (in Russian, English summary).
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**Appendix 2. List of sex attractants for species of the order Lepidoptera. The species names were updated by searching the Global Biodiversity Information Facility (GBIF Secretariat 2023: GBIF Backbone Taxonomy. <https://doi.org/10.15468/390mei>; accessed in November 2024) to the currently accepted names. Legend: Ac - acetate, Al - aldehyde, OH - alcohol, Hy - polyene hydrocarbon (abbreviations used in the specialized literature); \* There are no other reports of sex attractants for the taxon according to the Pherobase (El-Sayed AM 2024. The Pherobase: Database of Pheromones and Semiochemicals. <https://www.pherobase.com>; accessed in November 2024).**

Family, taxon	Compounds (ratio)	Reference
<b>Argyresthiidae</b>		
* <i>Argyresthia mendica</i> Haworth, 1828	Z11-16Ac; Z11-16Al	Subchev et al. 1986a, Ecology
<b>Autostichidae</b>		
* <i>Donaspastus pannonicus</i> Gozmány, 1952	Z8-13Ac	Subchev et al. 1999b, C. R. Acad. Bulg. Sci.
* <i>Oegoconia deauratella</i> (Herrich-Schäffer, 1854)	Z8-13Ac + Z10-15Ac (10:1)	Subchev et al. 1999b, C. R. Acad. Bulg. Sci.
<b>Coleophoridae</b>		
* <i>Coleophora albitarsella</i> Zeller, 1849	Z5-10Ac + Z7-12Ac (1:1)	Subchev et al. 1990, J. Appl. Ent.
<b>Cosmopterigidae</b>		
* <i>Pancalia leuwenhoekella</i> (Linnaeus, 1758)	Z8-13Ac	Subchev et al. 1999b, C. R. Acad. Bulg. Sci.
<b>Crambidae</b>		
<i>Agriphila straminella</i> (Denis & Schiffermüller) 1775	Z11-16Al	Subchev et al. 1986a, Ecology
* <i>Chrysocrambus craterellus</i> Scopoli, 1763	Z9-14Ac	Subchev & Tóth 2006, Plant Sci.
* <i>Eudonia lacustrata</i> Panzer, 1804 (= <i>Wiltesia crataegella</i> )	Z11-16Ac	Subchev 1981, Ecology; Subchev et al. 1990, J. Appl. Ent.
<b>Gelechiidae</b>		
* <i>Athrips</i> sp. (= <i>Rhynchopacha</i> sp.)	Z5-14Ac	Subchev & Kuznetzov 1974
* <i>Gelechia sestertiella</i> Heydenreich, 1851	E5-15Ac	Subchev & Myrsina 1976
<b>Geometridae</b>		
<i>Alcis repandata</i> (Linnaeus, 1758)	Z6Z9-19Hy + Z3Z6Z9-19Hy; Z6Z9-19Hy + 1Z3Z6Z9-19Hy	Subchev et al. 1986b, Z. Naturforsch.
<i>Alsophila aceraria</i> (Denis & Schiffermüller) 1775 (= <i>A. quadripunctata</i> )	Z3Z6Z9-19Hy	Subchev et al. 1986b, Z. Naturforsch.

Family, taxon	Compounds (ratio)	Reference
* <i>Archiearis notha</i> (Hübner) (= <i>Brephos notha</i> )	Z3Z6Z9-19Hy + Z6Y9-19Hy; Z3Z6Z9-19Hy + 1Z3Z6Z9- 19Hy; Z3Z6Z9-19Hy + 1Z3Z6Z9-19Hy + Z6Z9-19Hy +Z6Y9-19Hy	Subchev et al. 1986b, Z. Naturforsch.
<i>Ecliptopera silaceata</i> (Denis & Schifferrmüller) 1775	1Z3Z6Z9-19Hy + Z6Z9-19Hy; 1Z3Z6Z9-19Hy + Z3Z6Z9-19Hy + Z6Y9-19Hy	Subchev et al. 1986b, Z. Naturforsch.
<i>Eupithecia subnotata</i> (Hübner)	Z3Z6Z9-19Hy	Subchev et al. 1986b, Z. Naturforsch.
<i>Operophtera brumata</i> (Linnaeus, 1758)	1Z3Z6Z9-19Hy	Subchev et al. 1986b, Z. Naturforsch.
* <i>Ourapteryx sambucaria</i> (Linnaeus, 1758)	Z3Z6Z9-19Hy	Subchev et al. 1986b, Z. Naturforsch.
<b>Gracillariidae</b>		
<i>Phyllonorycter gerasimowi</i> (Hering, 1930) (= <i>Phyllonorycter pyrifoliella</i> Grsm.)	E10-12Ac	Subchev et al. 1999a, Acta Zool. Bulg.
* <i>Phyllonorycter sublautella</i> (Stainton, 1869)	Z10-14Ac	Subchev & Tomov 2008, Acta Zool. Bulg.
<b>Noctuidae</b>		
* <i>Agrochola humilis</i> (Denis & Schifferrmüller) 1775	Z11-16Al + Z9-14Al (100:3)	Subchev & Pop 1994, C. R. Acad. Bulg. Sci.
* <i>Agrochola lychnidis</i> (Denis & Schifferrmüller) 1775	Z9-14Al	Subchev & Pop 1994, C. R. Acad. Bulg. Sci.
<i>Agrochola litura</i> Linnaeus, 1761	Z9-14Al	Subchev et al. 1990, J. Appl. Ent.; Subchev & Pop 1994
* <i>Agrochola lota</i> Clerck, 1759	Z9-14Ac	Subchev et al. 1990, J. Appl. Ent.
<i>Agrochola macilenta</i> Hübner, 1809	Z11-16Ac	Subchev et al. 1986a, Ecology
<i>Agrotis segetum</i> (Denis & Schifferrmüller) 1775	Z9-14Ac + Z7-12Ac (4:1)	Subchev et al. 1986c, Ecology
<i>Amphipyra pyramidea</i> (Linnaeus, 1758)	Z11-16Ac	Subchev et al. 1986a, Ecology
<i>Anarta trifolii</i> Hufnagel, 1766 (= <i>Discestra trifolii</i> )	Z11-16Ac	Subchev 1981, Ecology
	Z11-16Ac + Z11-16OH	Subchev 1985c, Ecology
	Z11-16Ac + Z5-16Ac (100:1)	Subchev et al. 1987a, Fol. Biol.
<i>Apamea monoglypha</i> (Hufnagel, 1766)	Z11-16Ac + Z7-12Ac	Subchev et al. 1986a, Ecology
<i>Apamea sordens</i> (Hufnagel, 1766)	Z11-16Ac + Z11-16OH + Z11- 16Al	Subchev et al. 1986a, Ecology
* <i>Atethmia ambusta</i> (Denis & Schifferrmüller) 1775	Z7-14Ac + Z5-14Ac	Subchev et al. 1995a, J. Appl. Ent.
* <i>Atypha pulmonaris</i> (Esper, 1790)	Z11-16Ac + Z11-16OH	Subchev et al. 1986a, Ecology
* <i>Calliergis ramosa</i> Esper, 1786 (= <i>Callierges ramosa</i> )	Z11-16Ac + Z11-16Al	Subchev et al. 1986a, Ecology
<i>Chersotis multangula</i> Hübner	Z11-16Ac + Z5-10Ac (10:1)	Subchev et al. 1990, J. Appl. Ent.
* <i>Conistra rubiginea</i> (Denis & Schifferrmüller) 1775	Z11-16Ac + Z11-16Al; Z11- 16Ac + Z11-16OH + Z11-16Al <sub>d</sub>	Subchev et al. 1986a, Ecology
* <i>Conistra veronicae</i> (Hübner, 1813)	Z7-12Ac	Subchev et al. 1990, J. Appl. Ent.
<i>Cosmia trapezina</i> (Linnaeus, 1758)	Z11-16Al	Subchev et al. 1986a, Ecology
<i>Diachrysia chrysitis</i> (Linnaeus, 1758)	Z5-10Ac + Z7-10Ac (10:1)	Subchev 1995, Proceedings Third Nat. Sci. Conf. Ent.

Family, taxon	Compounds (ratio)	Reference
<i>Diachrysia stenochrysis</i> (Warren, 1913) (= <i>Diachrysia tutti</i> )	Z5-10Ac + Z7-10Ac (1:50)	Subchev 1995, Proceedings Third Nat. Sci. Conf. Entomol
* <i>Diarsia brunnea</i> (Denis & Schiffermüller) 1775	Z11-16Ac	Subchev et al. 1986a, Ecology
* <i>Diloba caeruleocephala</i> (Linnaeus, 1758)	Z8-13Ac	Subchev et al. 2000b, J. Appl. Entomol.
* <i>Euplexia lucipara</i> (Linnaeus, 1758)	Z11-16Ac + Z11-16Al	Subchev et al. 1986a, Ecology
* <i>Eupsilia transversa</i> Hufnagel, 1766	Z11-16OH	Subchev et al. 1986a, Ecology
<i>Euxoa hastifera</i> Donzel, 1848	Z5-10Ac + Z7-12Ac (1:1)	Subchev et al. 1990, J. Appl. Ent.
<i>Hoplodrina ambigua</i> (Denis & Schiffermüller) 1775	Z11-16Ac + Z7-12Ac (100: 1 - 100:30)	Subchev et al. 1987a, Fol. Biol.
<i>Jodia croceago</i> (Denis & Schiffermüller) 1775	Z11-16Ac	Subchev et al. 1990, J. Appl. Ent.
<i>Lacanobia blenna</i> Hübner	Z11-16Ac+Z11-16Al+Z11- 16OH (10:1:3)	Tóth et al. 1986, Ent. Exp. Appl.
<i>Lacanobia oleracea</i> Linnaeus, 1758 (= <i>Mamestra oleracea</i> )	Z11-16-trifluoroacetate	Subchev et al. 1989, C. R. Acad. Bulg. Sci.
<i>Lacanobia oleracea</i> Linnaeus, 1758 (= <i>Mamestra oleracea</i> )	Z11-16-trifluoroacetate	Subchev et al. 1989, C. R. Acad. Bulg. Sci.
<i>Lacanobia suasa</i> (Denis & Schiffermüller) 1775 (= <i>Mamestra suasa</i> )	Z11-16Ac	Subchev 1981, Ecology
	Z11-16Ac + Z7-12Ac (100: 30)	Subchev et al. 1987, Fol. Biol.
<i>Lacanobia w-latinum</i> Hufnagel, 1766	Z11-16Ac	Subchev 1981, Ecology; Subchev et al. 1986a, Ecology
	Z11-16Ac + Z11-16OH + Z11- 16Al	Subchev et al. 1986a, Ecology
<i>Lithophane ornitopus</i> Hufnagel, 1766	Z9-14Ac + Z9-14 Al (10:5; 10:1)	Subchev et al. 1990, J. Appl. Ent.
<i>Mamestra brassicae</i> Linnaeus, 1758	Z11-16Ac + Z11-16Al; Z11- 16Ac+Z11-16 formate	Subchev & Stoilov 1984, C. R. Acad. Bulg. Sci.;
	Z11-16Ac + Z7-12Ac (100:20); Z11-16Ac + Z9-14Ac (100:0.1)	Subchev et al. 1987, Fol. Biol.
<i>Mesapamea secalis</i> (Linnaeus, 1758)	Z11-16Ac + Z11-16OH	Subchev et al. 1986a, Ecology
<i>Mesoligia furuncula</i> (Denis & Schiffermüller) 1775 (= <i>Oligia furuncula</i> )	Z11-16Ac + Z11-16Al; Z11- 16Ac + Z11-16OH + Z11-16Al	Subchev et al. 1986a, Ecology
	Z11-16Ac + Z11-16Al (10: 1 or 10:3)	Tóth et al. 1986, Ent. Exp. Appl.
<i>Mythimna conigera</i> (Denis & Schiffermüller) 1775	Z11-16Al	Subchev et al. 1986a, Ecology
<i>Mythimna pallens</i> Linnaeus, 1758	Z11-16Ac + Z11-16Al	Subchev et al. 1986a, Ecology
* <i>Mythimna vitellina</i> Hübner, 1808	Z11-16Ac + Z11-16Al	Subchev et al. 1986a, Ecology
<i>Noctua albipuncta</i> Denis & Schiffermüller, 1775 (= <i>M. albipuncta</i> )	Z11-16OH + Z11-16Al	Subchev et al. 1986a, Ecology
<i>Noctua orbona</i> Hufnagel, 1766	Z7-12Ac	Subchev et al. 1990 J. Appl. Ent.
<i>Ochropleura plecta</i> Linnaeus, 1761	Z11-16Ac	Subchev 1981, Ecology
	Z11-16Ac + Z11-16Al (100: 1 and 100:3)	Tóth et al., 1986 Ent. Exp. Appl.
<i>Oligia latruncula</i> (Denis & Schiffermüller) 1775	Z11-16Ac	Subchev et al. 1986a, Ecology

Family, taxon	Compounds (ratio)	Reference
<i>Oria musculosa</i> Hübner, 1808	Z11-16Ac	Subchev 1981, Ecology
<i>Orthosia cerasi</i> Fabricius, 1775 (= <i>O. stabilis</i> )	Z11-16Al	Subchev et al. 1986a, Ecology
<i>Orthosia gracilis</i> (Denis & Schiffermüller) 1775	Z11-16Ac	Subchev et al. 1986a, Ecology
* <i>Orthosia populeti</i> Fabricius, 1781	Z11-16Ac + Z11-16Al	Subchev et al. 1986a, Ecology
<i>Polia nebulosa</i> Hufnagel, 1766	Z11-14Ac + Z9-14Ac + E11-14Ac (100:3:10)	Subchev & Tóth 2006, Plant Sci.
<i>Scotochrosta pulla</i> (Denis & Schiffermüller) 1775 (= <i>Egira pulla</i> )	Z9-14Ac	Subchev et al. 1990 J. Appl. Ent.
* <i>Thalpophila matura</i> (Hufnagel, 1766)	Z11-16Ac	Subchev et al. 1986a, Ecology
<i>Tholera cespitis</i> (Denis & Schiffermüller) 1775	Z11-16Al	Subchev et al. 1986a, Ecology
<i>Trachea atriplicis</i> (Linnaeus, 1758)	Z11-16Ac + Z11-16OH + Z11-16Al	Subchev et al. 1986a, Ecology
	Z11-16Ac + Z11-16OH + Z11-16Al (10:1:1)	Subchev 1992, C. R. Acad. Bulg. Sci.
<i>Xestia c-nigrum</i> (Linnaeus, 1758) (= <i>Amathes c-nigrum</i> )	Z7-14Ac	Subchev et al. 1996, J. Appl. Entom.
<i>Yigoga signifera</i> (Denis & Schiffermüller) 1775 (= <i>Ochropleura signifera</i> )	Z9-14Ac + Z9-14OH (1:1)	Subchev et al. 1990, J. Appl. Ent.
<b>Notodontidae</b>		
<i>Thaumetopoea pityocampa</i> (Denis & Schiffermüller) 1776	Y11Z13-16Ac	Subchev et al. 1994, Pheromones
<b>Plutellidae</b>		
* <i>Ypsolophus asperella</i> (Linnaeus, 1761) (= <i>Ypsolopha asperella</i> )	Z11-16Ac	Subchev et al. 1986a, Ecology
* <i>Ypsolophus ustella</i> (Clerck, 1759)	Z11-16Al	Subchev et al. 1986a, Ecology
<b>Pterophoridae</b>		
* <i>Amblyptilia acanthadactyla</i> (Hübner, 1813)	Z11-16Ac	Subchev 1981, Ecology
<b>Pyralidae</b>		
<i>Etiella zinckenella</i> (Treitschke, 1832)	Z11-14Ac + E9-14Ac (100:3)	Subchev & Tóth 2006, Plant Sci.
<i>Myelois cribrella</i> Hübner, 1796	Z11-16Ac	Subchev 1981, Ecology
<b>Sesiidae</b>		
<i>Synanthedon tipuliformis</i> (Clerck, 1759)	E2Z13-18Ac + E3Z13-18Ac (100:3)	Szöcs et al. 1991, Ent. Exp. Appl.
<b>Tortricidae</b>		
<i>Cnephasia oxyacanthana</i> (Herrich-Schäffer, 1851)	E10-12Ac + E9-12Ac (100:10)	Subchev et al. 1998b, Acta zool. Bulg.
<i>Gypsonoma aceriana</i> (Duponchel, 1842)	E10-12Ac	Subchev et al. 2005a, Acta Ent. Bulg.
<i>Neosphaleroptera nubilana</i> (Hübner, 1796-1799)	Z5-10Ac	Subchev et al. 1990, J. Appl. Ent.