First record of the tropical bed bug *Cimex hemipterus* (Fabricius, 1803) (Hemiptera, Cimicidae) in Norway

MORTEN HAGE, ANDERS AAK, MARI STEINERT & BJØRN ARNE RUKKE *

Hage, M., Aak, A., Steinert, M. & Rukke, B.A. 2022. First record of the tropical bed bug *Cimex hemipterus* (Fabricius, 1803) (Hemiptera, Cimicidae) in Norway. *Norwegian Journal of Entomology* 69, 201–206.

The tropical bed bug *Cimex hemipterus* (Fabricius, 1803) is reported for the first time in Norway. Both morphological characters and DNA barcoding were used to identify a specimen collected in Lillehammer, Innlandet County, Norway. This hematophagous insect is a common nuisance pest in the tropics and can be expected to show an occasional indoor appearance in Norway in the future. A brief risk assessment is conducted, and some aspects related to pesticide resistance and efficient pest control are discussed.

Key words: Hemiptera, Cimicidae, *Cimex hemipterus*, *lectularius*, indoor pest, ectoparasite, nuisance, DNA barcoding, IPM.

Morten Hage, Norwegian Institute of Public Health – Department of Pest Control. P.O. Box 222 Skøyen, NO-0213 Oslo, Norway. E-mail: morten.hage@fhi.no

Anders Aak, Norwegian Institute of Public Health – Department of Pest Control. P.O. Box 222 Skøyen, NO-0213 Oslo, Norway. E-mail: anders.aak@fhi.no

Mari Steinert, Norwegian Institute of Public Health – Department of Pest Control. P.O. Box 222 Skøyen, NO-0213 Oslo, Norway. E-mail: mari.steinert@fhi.no

** Bjørn Arne Rukke, Norwegian Institute of Public Health – Department of Pest Control. P.O. Box 222 Skøyen, NO-0213 Oslo, Norway. E-mail: bjornarne.rukke@fhi.no*

** Corresponding author*

Introduction

In Norway, the heteropteran family Cimicidae includes the bat bug (*Cimex pipistrelli* complex), the swallow bug (*Cimex* (= *Oeciacus*) *hirundinis* Lamarck, 1816) and the common bed bug (*Cimex lectularius* L., 1758). Their evolutionary origin and exact taxonomical status are under investigation with modern DNA-based methods, and the bat bug probably consists of multiple species (Balvín *et al.* 2012, Balvín *et al.* 2015, Roth *et al.* 2018, Roth *et al.* 2019). The Cimicidae are hematophagous ectoparasitic insects feeding on birds and mammals (Usinger 1966), and *C. lectularius* is the only human-associated species previously recorded in Norway (Roth *et al.* 2018). *C. lectularius* has been an increasing nuisance pest in Norway for almost two decades, and, except for a drop during the COVID-19 pandemic, its infestation rate appears to have stabilized at a level of approximately 3000 control cases per year (NIPH 2022, Rukke *et al.* 2022). These observations match the global resurgence of bed bug infestations (Doggett *et al.* 2018). The worldwide growth of the bed bug nuisance is strongly related to travel and pesticide resistance,

and it encompasses both *C. lectularius* and the tropical bed bug *Cimex hemipterus* (Fabricius, 1803) (Dang *et al.* 2017, Doggett *et al.* 2018, Akhoundi *et al.* 2020). Several first records and a survey of infestations in 15 European countries indicate an increased prevalence and broader distribution of *C. hemipterus* in recent years (Gapon 2016, Vinnersten 2017, Masini *et al.* 2019, Golub *et al.* 2020, Balvín *et al.* 2021, Chebbah *et al.* 2021). In line with these European observations, we report the first finding of *C. hemipterus* in Norway.

The species/material

***Cimex hemipterus* (Fabricius, 1803)**

INNLANDET (OS), Lillehammer: Lillehammer (EIS 54) 20. August 2021, 1♂, leg. Ane Julie Aaslie (Anticimex), det. Bjørn Arne Rukke, coll. NIPH.

C. hemipterus is morphologically quite similar to *C. lectularius*, but it has a more slender appearance (Balvín *et al.* 2021) and is on average slightly longer (Usinger 1966, Vinnersten 2017). Distinct morphological characters used to separate the two species are: 1) the pronotum of *C. hemipterus* is less than 2.5 times as wide as long at the middle, while the pronotum of *C. lectularius* is more than 2.5 times as wide as long, and 2) the paragenital sinus (adult females only) is a deep, narrow cleft in *C. hemipterus*, whereas in *C. lectularius* this is a somewhat more open and shallower cleft (Usinger 1966). One population of *C. hemipterus* in Guangzhou, China, has been found to have a width-to-length ratio of the pronotum of 2.6, and therefore molecular identification should be conducted for identification of the two species if a specimen is close to the cutoff ratio of 2.5 (Zhang *et al.* 2021).

Additional characters that are useful in distinguishing the two species are the shape of the bristles found on the anterior sides of the pronotum and the last abdominal segment. The edge of the bristles of *C. hemipterus* appear smooth compared to the uneven or jagged edge in *C. lectularius* (Usinger 1966). The tibial pads of *C. hemipterus* are also hairy when compared to the *C. lectularius* (Kim *et al.* 2017), but such identification requires large magnification and benefits from comparison with reference material.

In August of 2021, the Section for Pest Control at the Norwegian Institute of Public Health (NIPH) received a male bed bug specimen found in a private home in Lillehammer city. The specimen was discovered when unwrapping a small rug purchased from a local retailer. Due to deviant appearance from *C. lectularius*, the on-site pest controller sent the specimen to NIPH for identification. It was identified as an adult male of *C. hemipterus* using the identification key in Usinger (1966). The specimen's bristles on the anterior sides of the pronotum and the last abdominal segment of the *C. hemipterus* had edges that were smooth instead of uneven or jagged. The width-to-length ratio of the pronotum was measured to be 2.2. In comparison, a reference specimen from a *C. lectularius* stock culture at NIPH had a ratio of 2.9 (Figure 1).

The morphological characteristics pointing at *C. hemipterus*, were confirmed by DNA barcoding. We sent the *C. hemipterus* specimen in addition to a C. lectularius specimen from our laboratory stock culture for barcoding. DNA was extracted from the left hind leg of the specimens using E.Z.N.A tissue kit (Omega Bio-Tek Inc., Norcross, USA). The samples were amplified using the LepF1 and LepR1 primers (Hajibabaei *et al.* 2006). Amplicons were thereafter purified and sequenced using traditional Sanger sequencing. The resulting COI sequences (GenBank accession nr: *C. hemipterus* - OM700201 and *C. lectularius* - ON911370) were mapped to the BOLD database for specimen identification (http://www.boldsystems.org/index.php/IDS_OpenIdEngine). This returned a solid match with > 99.62 % sequence similarity to *C. hemipterus* in the database (top 50-matches), whereas it provided an 81.76 % match with our reference specimen of *C. lectularius*.

Discussion

The distribution of bed bugs is affected by their synanthropic association, but in general, *C.*

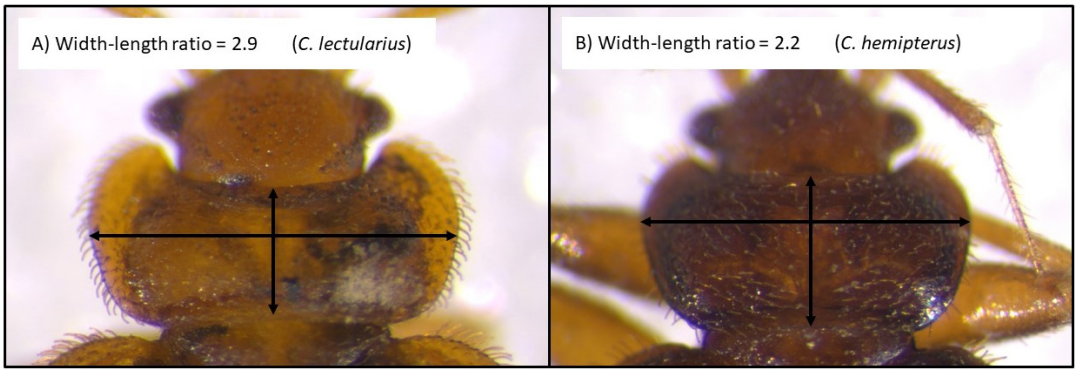

FIGURE 1. Pronotum of **A**) *Cimex lectularius* from a stock culture at the Norwegian Institute of Public Health (originally collected in Oslo, Norway) and **B**) *Cimex hemipterus* collected in Lillehammer, Norway. Arrows show the width-length ratios of the specimens pronotum used in species identification. Photo: Anders Aak and Bjørn Arne Rukke.

hemipterus is more commonly found within the 30° north and south latitudes, while *C. lectularius* primarily occurs in temperate regions. The two species co-exist in parts of Africa, Middle- and South America, the Middle East, Asia, and Australia. International travel and increased globalization most likely have influenced the historical global distribution pattern (Doggett *et al.* 2018, Akhoundi *et al.* 2020). Further, these dispersal mechanisms may be augmented by the development of pesticide resistance in both species (Dang *et al.* 2017, Romero 2018). The rapid dispersal between countries and continents with ample opportunities to establish indoors may promote concurrent appearances of the two species in the future, as seen with recent dispersal of *C. hemipterus* into temperate regions in the European countries (Gapon 2016, Vinnersten 2017, Masini *et al.* 2019, Balvín *et al.* 2021, Chebbah *et al.* 2021).

The *C. hemipterus* recorded in Lillehammer city was not from an established population, but the observation adds to the list of Norwegian cimicids (Roth *et al.* 2018). In Sweden, *C. hemipterus* is considered an established species, but only a handful observations have been reported among tens of thousands of bed bug infestations during the last 10 years (Vinnersten 2017). The low abundance of *C. hemipterus* relative to *C. lectularius* is comparable to Norway as Sweden has twice the amount of people and a higher incidence of bed bugs per capita (Vinnersten 2017, NIPH 2022). The biology and appearance of the two species are very similar, and *C. hemipterus* may have been overlooked in both countries. However, examination of museum specimens, submitted samples to NIPH and records in national data portals show no previous records of *C. hemipterus* in Norway (Roth *et al.* 2018, Artsdatabanken 2022, GBIF 2022, NIPH 2022). *C. hemipterus* has also been observed in Finland (Vinnersten 2017, Roth *et al.* 2018), but to our knowledge not in the other Nordic countries of Denmark and Iceland.

The aim for the pest control companies, managers and governmental bodies is to protect indoor environments from colonization of bed bugs and eradicate all known infestations. Bed bugs are difficult to keep at bay, as efficient dispersal abilities and cryptic behavior often allow them to stay ahead of the control efforts. Introductions through tourism may give *C. hemipterus* temporary residence in Norway, and pest control technicians should be on the alert if bed bugs appear differently (Balvín *et al.* 2021) or if infestation and insect behavior deviate from normal situations (Gapon 2016, Kim *et al.* 2017, Golub *et al.* 2020). The methods of Integrated Pest Management (IPM) used to control *C. lectularius* also apply to *C. hemipterus* (Romero *et al.* 2017, Doggett *et al.* 2018). Thus, precise species identification is probably of subordinate importance for the efficiency of control efforts. Efficient control typically combines several

methods (Bennett *et al.* 2016, Romero *et al.* 2017, Wang *et al.* 2018), such as heat treatment of apartments, rooms, objects or local bed bug aggregations (Benoit 2011, Puckett *et al.* 2013, Rukke *et al.* 2015, Loudon 2017, Kells 2018, Rukke *et al.* 2018), the use of desiccant dust alone or in combination with mobility stimulants (Benoit *et al.* 2009b, Akhtar & Isman 2016, Singh *et al.* 2016, Aak *et al.* 2016, Rukke *et al.* 2021), insect pathogenic fungi (Barbarin *et al.* 2017, Aak *et al.* 2018, Rukke *et al.* 2021) and freezing of infested objects (Benoit *et al.* 2009a, Olson *et al.* 2013, Rukke *et al.* 2017). Pesticide resistance is likely to be prevalent in *C. hemipterus* (Dang *et al.* 2017), and therefore control efforts should focus on non-poisonous methods. As for *C. lectularius*, building-wide inspections and control efforts should always be considered as infestations in single rooms may spread to adjacent rooms or housing units (Cooper *et al.* 2015, Bennett *et al.* 2016). Regarding control of *C. hemipterus*, it is important to note that the improved climbing abilities compared to *C. lectularius* (Kim *et al.* 2017) and differentiated responses to aggregation signals (Dery *et al.* 2021), may interfere with efficient use of interceptor traps for detection and evaluation purposes. In addition, *C. hemipterus* may have a lower reproductive potential, compared to *C. lectularius* (Araujo *et al.* 2009, How & Lee 2010b, Matos *et al.* 2017) and eradication may therefore be easier.

Norway is at the extreme end of the expected geographical distribution of *C. hemipterus* (30° north and south latitudes), and bedroom temperatures during Norwegian winters typically range between 18–20°C. *C. hemipterus*' preference for higher temperatures (How & Lee 2010a) can be a factor restricting this "tropical culprit" from becoming an endemic nuisance in Norway. Whether or not we will encounter *C. hemipterus* again is an open question, but increased awareness of this species is recommended.

Acknowledgements. Dr. Steffen Roth and Dr. Arnulf Soleng provided valuable comments on the manuscript. Dr. Jarl Andreas Anmarkrud, M.Sc. Audun Schrøder-Nielsen and Professor Arild Johnsen organized the DNA barcoding and provided valuable comments on the technical description. Mrs. Ane Julie Aaslie from Anticimex made the precise initial observation of the specimen and submitted it to NIPH.

References

Aak, A., Hage, M., Rukke, B.A. 2018. Insect pathogenic fungi and bed bugs: behaviour, horizontal transfer and the potential contribution to IPM solutions. *Journal of Pest Science* 91, 823–835.

Aak, A., Roligheten, E., Rukke, B.A., Birkemoe, T. 2016. Desiccant dust and the use of CO2 gas as a mobility stimulant for bed bugs: a potential control solution? *Journal of Pest Science* 90, 249–259.

Akhoundi, M., Sereno, D., Durand, R., Mirzaei, A., Bruel, C., Delauney, P., Marty, P., Izri, A. 2020. Bed bugs (Hemiptera, Cimicidae): Overview of classification, evolution and dispersion. *International Journal of Environmental Research and Public Health* 17, 4576.

Akhtar, Y., Isman, M.B. 2016. Efficacy of diatomaceous earth and a DE-aerosol formulation against the common bed bug, *Cimex lectularius* Linnaeus in the laboratory. *Journal of Pest Science* 89, 1013–1021.

Araujo, R.N., Costa, F.S., Gontijo, N.F., Goncalves, T.C.M., Pereira, M.H. 2009. The feeding process of *Cimex lectularius* (Linnaeus, 1758) and *Cimex hemipterus* (Fabricius, 1803) on different bloodmeal sources. *Journal of Insect Physiology* 55, 1151–1157.

Artsdatabanken, 2022. *Artsobservasjoner. Rapportsystem for arter*, Trondheim, Norway. Available from: https://www.artsdatabanken.no/ (2022) [accessed 30.VI.2022].

Balvín, O., Munclinger, P., Kratochvil, L., Vilimova, J. 2012. Mitochondrial DNA and morphology show independent evolutionary histories of bedbug *Cimex lectularius* (Heteroptera: Cimicidae) on bats and humans. *Parasitology Research* 111, 457–469.

Balvín, O., Roth, S., Vilimova, J. 2015. Molecular evidence places the swallow bug genus *Oeciacus* Stal within the bat and bed bug genus *Cimex* Linnaeus (Heteroptera: Cimicidae). *Systematic Entomology* 40, 652–665.

Balvín, O., Sasínková, M., Martinú, J., Nazarizadeh, M., Bubová, T., Booth, W., Vargo, E.L., Štefka, J. 2021. Early evidence of establishment of the tropical bedbug (*Cimex hemipterus*) in Central Europe. *Medical and Veterinary Entomology* 35, 462–467.

Barbarin, A.M., Bellicanta, G.S., Osborne, J.A., Schal, C., Jenkins, N.E. 2017. Susceptibility of insecticide-

resistant bed bugs (*Cimex lectularius*) to infection by fungal biopesticide. *Pest Management Science* 73, 1568–1573.

Bennett, G.W., Gondhalekar, A.D., Wang, C., Buczkowski, G., Gibb, T.J. 2016. Using research and education to implement practical bed bug control programs in multifamily housing. *Pest Management Science* 72, 8–14.

Benoit, J.B. 2011. Stress tolerance of bed bugs: a review of factors that cause trauma to *Cimex lectularius* and *C. hemipterus*. *Insects* 2, 151–172.

Benoit, J.B., Lopez-Martinez, G., Teets, N.M., Phillips, S.A., Denlinger, D.L. 2009a. Responses of the bed bug, *Cimex lectularius*, to temperature extremes and dehydration: levels of tolerance, rapid cold hardening and expression of heat shock proteins. *Medical and Veterinary Entomology* 23, 418–425.

Benoit, J.B., Phillips, S.A., Croxall, T.J., Christensen, B.S., Yoder, J.A., Denlinger, D.L. 2009b. Addition of alarm pheromone components improves the effectiveness of desiccant dusts against *Cimex lectularius*. *Journal of Medical Entomology* 46, 572–579.

Chebbah, D., Elissa, N., Sereno, D., Hamarsheh, O., Marteau, A., Jan, J., Izri, A., Akhoundi, M.2021. Bed bugs (Hemiptera: Cimicidae) population diversity and first record of *Cimex hemipterus* in Paris. *Insects* 12, 578.

Cooper, R., Wang, C., Singh, N. 2015. Mark-release-recapture reveals extensive movement of bed bugs (*Cimex lectularius* L.) within and between apartments. *Plos One* 10, e0136462.

Dang, K., Doggett, S.L., Veera Singham, G., Lee, C.Y. 2017. Insecticide resistance and resistance mechanisms in bed bugs, *Cimex* spp. (Hemiptera: Cimicidae). *Parasites & Vectors* 10, 318.

Dery, M., Lee, C.Y., Choe, D.H. 2021. Differential responses to aldehyde pheromone blends in two bed bug species (Heteroptera: Cimicidae). *Chemoecology* 31, 397–403.

Doggett, S.L., Miller, D.M., Lee, C.Y., 2018. *Advances in the biology and management of modern bed bugs*. 439 pp. John Wiley & Sons Ltd, Oxford.

Gapon, D.A. 2016. First record of the tropical bed bug *Cimex hemipterus* (Heteroptera: Cimicidae) from Russia. *Zoosystematica Rossica* 25, 239 –242.

GBIF 2022.*GBIF Global Biodiversity Information Facility*, Copenhagen, Denmark. Available from: www.gbif.org (2021) [accessed 30.06.2022].

Golub, V.B., Aksenenko, E.V., Soboleva, V.A., Kornev, I.I. 2020. New data on the distribution of the tropical bed bug *Cimex hemipterus* and the western conifer seed bug *Leptoglossus occidentalis* (Heteroptera: Cimicidae, Coreidae) in the European part of Russia. *Russian Journal of Biological Invasions* 11, 97–100.

Hajibabaei, M., Janzen, D.H., Burns, J.M., Hallwachs, W., Hebert, P.D. 2006. DNA barcodes distinguish species of tropical Lepidoptera. *Proceedings of the National Academy of Sciences of the United States of America* 103, 968–971.

How, Y.F., Lee, C.Y. 2010a. Effects of temperature and humidity on the survival and water loss of *Cimex hemipterus* (Hemiptera: Cimicidae). *Journal of Medical Entomology* 47, 987–995.

How, Y.F., Lee, C.Y. 2010b. Fecundity, nymphal development and longevity of field-collected tropical bedbugs, *Cimex hemipterus*. *Medical and Veterinary Entomology* 24, 108–116.

Kells, S.A. 2018. Non-chemical control, pp. 257–272 in: Doggett, S. L., Miller, D. M., Lee, C. Y. (Eds.), *Advances in the biology and management of modern bed bugs*. John Wiley & Sons Ltd, Oxford.

Kim, D.Y., Billen, J., Doggett, S.L., Lee, C.Y. 2017. Differences in climbing ability of *Cimex lectularius* and *Cimex hemipterus* (Hemiptera: Cimicidae). *Journal of Economic Entomology* 110, 1179–1186.

Loudon, C. 2017. Rapid killing of bed bugs (*Cimex lectularius* L.) on surfaces using heat: application to luggage. *Pest Management Science* 73, 64–70.

Masini, P., Zampetti, S., Miñón Llera, G., Biancolini, F., Moretta, I., Romani, R., Tramontana, M., Hansel K., Stingeni, L. 2019. Infestation by the tropical bedbug *Cimex hemipterus* (Hemiptera: Cimicidae): first report in Italy. *Journal of the European Academy of Dermatology and Venereology* 34, e28–e30.

Matos, Y.K., Osborne, J.A., Schal, C. 2017. Effects of cyclic feeding and starvation, mating, and sperm condition on egg production and fertility in the common bed bug (Hemiptera: Cimicidae). *Journal of Medical Entomology* 54, 1483–1490.

NIPH 2022. Database and pest control statistics for Norway - 2007 to 2022 (Norwegian Institute of Public Health). *Pest control statistic, educational protocols and official e-mail correspondances*. Available from: www.fhi.no/skadedyr [accessed 01.04.2022].

Olson, J.F., Eaton, M., Kells, S.A., Morin, V., Wang, C. 2013. Cold tolerance of bed bugs and practical recommendations for control. *Journal of Economic Entomology* 106, 2433–2441.

Puckett, R.T., McDonald, D.L., Gold, R.E. 2013. Comparison of multiple steam treatment durations for control of bed bugs (*Cimex lectularius* L.). *Pest Management Science* 69, 1061–1065.

Romero, A. 2018. Insecticide resistance, pp. 273–284 in: Doggett, S. L., Miller, D. M., Lee, C. Y. (Eds.), *Advances in the biology and management of modern bed bugs*. John Wiley & Sons Ltd, Oxford.

Romero, A., Sutherland, A.M., Gouge, D.H., Spafford, H., Nair, S., Lewis, V., Choe, D.H., Li, S., Young, D. 2017. Pest management strategies for bed bugs (Hemiptera: Cimicidae) in multiunit housing: a literature review on field studies. *Journal of Integrated Pest Management* 8, 1–10.

Roth, S., Balvin, O., Siva-Jothy, M.T., Di Iorio, O., Benda, P., Calva, O., Faundez, E.I., Khan, F.A.A., McFadzen, M., Lehnert, M.P., Naylor, R., Simov, N., Morrow, E.H., Willassen, E., Reinhardt, K. 2019. Bedbugs evolved before their bat hosts and did not co-speciate with ancient humans. *Current Biology* 29, 1847–1853.

Roth, S., Coulianos, C.C., Vinnersten, T.P., Roligheten, E. 2018. *Cimex pipistrelli* complex new to Norway and additional records of bed bug species (Cimicidae, Heteroptera) from Norway and Sweden. *Norwegian Journal of Entomology* 65, 118–126.

Rukke, B.A., Hage, M., Aak, A. 2017. Mortality, fecundity and development among bed bugs (*Cimex lectularius*) exposed to prolonged, intermediate cold stress. *Pest Management Science* 73, 838–843.

Rukke, B.A., Roligheten, E., Aak, A. 2022. Procurement competence and framework agreements for upgraded bed bug control [*Cimex lectularius* (Hemiptera: Cimicidae)]. *Journal of Economic Entomology* 115, 240–249.

Rukke, B.A., Salma, U., Birkemoe, T., Aak, A. 2021. Blood deprivation and heat stress increase mortality in bed bugs (*Cimex lectularius*) exposed to insect pathogenic fungi or desiccant dust. *Medical and Veterinary Entomology* 35, 121–128.

Rukke, B.A., Sivasubramaniam, R., Birkemoe, T., Aak, A. 2018. Temperature stress deteriorates bed bug (*Cimex lectularius*) populations through decreased survival, fecundity and offspring success. *Plos One* 13, e0193788.

Rukke, B.A., Aak, A., Edgar, K.S. 2015. Mortality, temporary sterilization, and maternal effects of sublethal heat in bed bugs. *Plos One* 10, e0127555.

Singh, N., Wang, C., Wang, D., Cooper, R., Zha, C. 2016. Comparative efficacy of selected dust insecticides for controlling *Cimex lectularius* (Hemiptera: Cimicidae). *Journal of Economic Entomology* 109, 1819–1826.

Usinger, R.L. 1966. *Monograph of Cimicidae (Hemiptera-Heteroptera)*. The Thomas Say Foundation, Vol. VII. Entomological Society of America, College Park, Maryland, USA.

Vinnersten, T.P. 2017. *Cimex hemipterus* (Fabricius, 1803) en etablerat vägglusart i Sverige (Heteroptera, Cimicidae). *Entomologisk Tidskrift* 138, 67–70.

Wang, C., Eiden, A., Singh, N., Zha, C., Wang, D., Cooper, R. 2018. Dynamics of bed bug infestations in three low-income housing communities with various bed bug management programs. *Pest Management Science* 74, 1302–1310.

Zhang, J., Xia, Y., Wang, C., Han, D., Ren, D., Zheng, J., Xu, X., He, Y., Wang, D. 2021. Morphological and molecular identification of tropical bed bugs from two cities of the Pearl River Delta in China. *Journal of Medical Entomology* 58, 471–474.

Received: 6 April 2022
Accepted: 20 May 2022