

Distribution, morphology and phenology of *Anthrenus nipponensis* Kalik & Ohbayashi (Coleoptera: Dermestidae)

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ABSTRACT

Little is known about the eastern Palaearctic species *Anthrenus nipponensis*, a member of the Palaearctic *A. pimpinellae* species complex. In the current study, a morphometric examination of specimens held in the Natural History Museum, London, is carried out. *A. nipponensis* is larger and narrower than most other species belonging to the complex. The unusual shape of the antennal club is illustrated and discussed. The male genitalia are small but of comparable size to several other *Anthrenus* species relative to body length. The accuracy of published drawings of *A. nipponensis* aedeagi is discussed. The literature is searched for records of *A. nipponensis* to produce a geographical and phenological distribution. The species is distributed across Japan, the Korean peninsula, north-eastern corner of China, and the south-eastern tip of Russia. The adult flight season peaks during the second half of May. Details on the life history are included.

Keywords: *Anthrenus nipponensis*, literature, morphometrics, genitalia, Eastern Palaearctic

INTRODUCTION

The family Dermestidae (Coleoptera) is poorly known. A possible reason for this is the antipathy that many entomologists hold towards the group as a result of the damage that a small number of *Anthrenus* Geoffroy, 1762, spp. inflict on dry insect collections (Holloway & Pinniger 2020; Holloway & Bakaloudis 2021). The main species responsible for the destruction of insect collections is *A. verbasci* Linnaeus, 1767, but the activities of this species, plus on occasions others such as *A. sarnicus* Mroczkowski, 1963 (Armes 1988), *A. coloratus* Reitter, 1881 (Nardi & Háva 2019), and *A. flavipes* Leconte, 1854 (Holloway & Bakaloudis 2021), tarnishes the reputation of the entire family. Only a small number of entomologists worldwide study Dermestidae, hence the limited scope of our knowledge.

The number of described Dermestidae species just exceeds 1700 (Háva 2021). The genus *Anthrenus* is large, including over 260 species that are split into ten subgenera, although Kadej (2018) using larval characteristics found evidence that only one sub-genus, *Anthrenus* s. str., is monophyletic, the remaining sub-genera forming a single polyphyletic group. Most publications with information on *Anthrenus* consist of faunistic studies and brief descriptions of new species. The life histories of *Anthrenus* spp. as pests of stored products have been extensively studied (e.g., Hinton 1945; Rees 2004), but beyond that the number of in-depth studies is currently limited. A notable exception is Beal (1998), with Kadej, Háva & Kalík (2007a); Kadej (2018); Scheers (2020); Hermand & Holloway (2020), and Holloway *et al.* (2020a) providing other recent examples of studies that go beyond the simple reporting of collections.

Within the subgenus *Anthrenus* s. str. are species belonging to the Palaearctic *A. pimpinellae* complex. It had long been suspected that the complex contained many species falling under the name *A. pimpinellae* Fabricius, 1775 (Kalik, mentioned in Hoebeke, Wheeler, & Beal 1985; Beal 1998). Now it is clear that Kalik and Beal were correct. Kadej, Háva & Kalík (2007a) described three new species, Kadej & Háva (2011) a further three species, and Holloway (2019, 2020, 2021) yet three more species, bringing the number of valid taxa in the complex to 23. The representative member of the *A. pimpinellae* complex in Japan was considered to be *A. pimpinellae latefasciatus* Reitter, 1892, but work carried out by Kalik, recorded in Kalik & Ohbayashi (1985), found that *A. pimpinellae latefasciatus* bore no resemblance to European *A. pimpinellae* and raised the taxon to *A. latefasciatus* Reitter, 1982. Kalik & Ohbayashi (1985) studied Japanese specimens in more detail and established that the genital structure differed from that observed in *A. latefasciatus*. Kalik & Ohbayashi (1985) named this new species *A. nipponensis* Kalik & Ohbayashi, 1985. There is no evidence that *A. latefasciatus* exists in Japan (Háva 2021). Two thorough papers have been produced on the recognition of *A. nipponensis* (Kalik & Ohbayashi 1985; Kadej, Háva & Kalík 2007b), but beyond these little is known about this far eastern Palaearctic species.

The Natural History Museum, London, (NHM) holds a significant collection of *Anthrenus* species offering the opportunity to study some species in depth, including a collection of 23 individuals of *A. nipponensis*. In the current study we review published data on *A. nipponensis* to consider geographic distribution and use the NHM specimens to carry out a morphological study to further our understanding of size and form in this taxon.

MATERIAL AND METHODS

The NHM *A. nipponensis* specimens were placed in a solution of 2% acetic acid for five days to soften and allow their removal from staging prior to dissection. Dissection was carried out under a Brunel BMSL zoom stereo LED microscope and involved detaching the abdomen from the rest of the insect using two entomological pins. The soft tergites were then peeled away from the harder ventrites to expose the genitalia. For males, the aedeagus was detached from the ring sclerite, and then sternite IX was detached from the ring sclerite and the aedeagus. Images of male and female habitus, both upper and under sides, were captured at $\times 20$ magnification using a Canon EOS 1300D camera mounted on the BMSL microscope. Images of aedeagi and sternite IX were captured at $\times 100$ magnification for measurement using the EOS 1300D camera mounted on a Brunel monocular SP28 microscope. After dissection, all body parts were mounted on card. The antennae were teased out and images were taken at $\times 63$ magnification through the BMSL microscope. All images were fed through Helicon Focus Pro version 6.8.0 focus-stacking software. Morphometric measurements were made using DsCap.Ink Software version 3.90.

Measurements taken

Body length (BL): distance from anterior margin of pronotum to the apex of the elytra; Body width (BW): maximum distance across the elytra; Antennal club length (AL): length of the last three antennomeres; Antennal club width (AW): maximum width across the terminal antennomere; Paramere length (PL): distance from the

anterior end of the parameres to the apex of the parameres; Sternite IX length (SL): distance from the tip of one anterior horn to the tip of the posterior margin.

Literature search and mapping

A literature search was carried out for information on location of *A. nipponensis* specimens taken, published morphometric data, and life history. Specimen locations were mapped using ArcMap 10.5.1. The minimum bounding geometry tool was used to illustrate minimum range. Statistical analysis was carried out using Minitab version 19.1.1.

RESULTS

Examples of the *A. nipponensis* habitus (dorsal aspect), antennal club, aedeagus, and sternite IX are shown in Figs 1–4.

Morphometrics

The 23 *A. nipponensis* NHM specimens that were dissected had been collected in Harbin Northern China, 31.v.1952 (n=9♂♂, 14♀♀) (see Holloway 2019; Holloway *et al.* 2020). All data were normally distributed and homoscedastic. Male body length (BL)=2.939±0.237mm (mean±standard deviation); female BL=3.313±0.318mm. Male BL differed significantly from female BL ($t_{21}=3.02$, $p=0.007$). 95% of male BL would be expected to fall between 2.4–3.5mm (study sample minimum/maximum=2.608 and 3.294mm, respectively). 95% of female BL would be expected to fall between 2.6 and 4.0mm (study sample minimum/maximum=2.946 and 3.873mm, respectively).

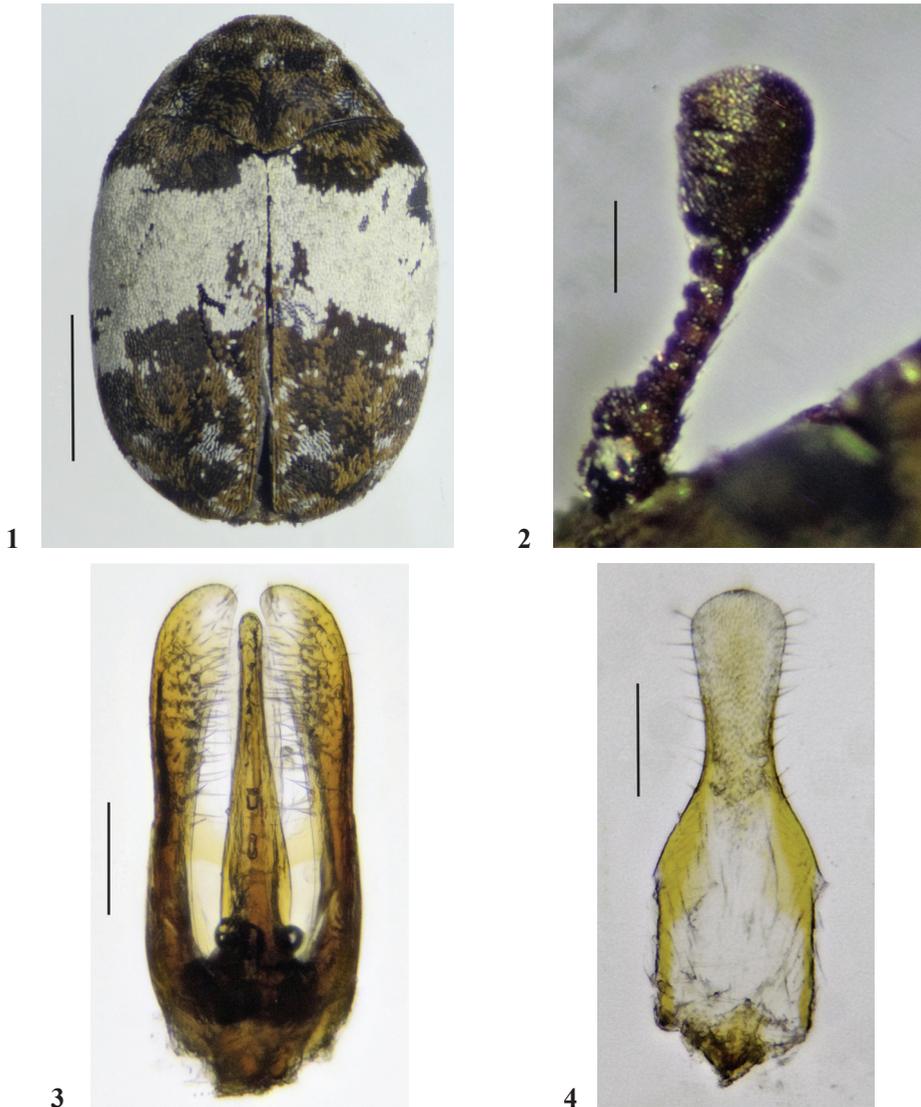
Body width/body length (BW/BL) was calculated as a measure of body shape. Male BW/BL=0.659±0.008 (mean±standard deviation); female BW/BL=0.666±0.011. Male BW/BL did not differ significantly from female BW/BL ($t_{21}=1.56$, ns [not significant]). Combining the two data sets (mean=0.664±0.011), 95% of all values would be expected to fall between 0.644–0.686 (study sample minimum/maximum=0.647 and 0.683, respectively), so *A. nipponensis* is relatively narrow (Fig. 1). As a measure of variability, the coefficient of variation (standard deviation/mean * 100%)=1.6%.

The *A. nipponensis* antennal club has a small protrusion on the ventral outer corner giving the club an angular appearance (Fig. 2). Both sexes display this feature. Male antennal club length (AL)=164±9µm (mean±standard deviation); antennal club width (AW)=129±9µm were significantly smaller than female antennal clubs AL=175±8µm; AW=137±6.5µm (AL $t_{16}=2.68$, $p=0.016$, AW $t_{16}=2.1$, $p=0.051$). Whilst these differences might be expected through allometry, the shape of the antennal club (mean AL/AW=1.27±0.04) did not differ between the sexes ($t_{16}=0.63$, ns).

The *A. nipponensis* aedeagus is shown in Fig. 3 and sternite IX is shown in Fig. 4. Mean paramere length (PL)=380±13µm. Mean paramere length/Body length (PL/BL)=0.13±0.0076. Mean sternite IX length (SL)=417±24µm.

Life History

Beal (1998) argues that any species belonging to the *A. pimpinellae* complex outside of Europe is not likely to be *A. pimpinellae*, in particular species from eastern Palaearctic. Yokoyama (1929, in Hinton 1945) describes the life history of *A. pimpinellae latefasciatus* from Japan, which we now know was most probably *A. nipponensis* and not *A. latefasciatus* (see Kalik & Ohbayashi 1985; Háva 2021). This being the case, *A. nipponensis* usually has one generation a year (occasionally a two-year cycle) (Yokoyama 1929). *Anthrenus nipponensis* is very common in sparrow (*Passer Brisson 1760 sp.*) nests, where it feeds on feathers, dead nestlings, and the remains of insects (Yokoyama 1929). Yokoyama (1929) also describes *A. nipponensis* as an occasional pest of woollens in Japan.



Figs 1–4. — *Anthrenus nipponensis* structures: 1, habitus (scale bar=1mm); 2, antennal club (scale bar=100 μ m); 3, aedeagus (scale bar=100 μ m); 4, sternite IX (scale bar=100 μ m).

Distribution and Phenology

We found a total of 162 *A. nipponensis* specimens reported in the literature, although some of these had been collected as batches from the same location and on the same date. All collection locations are mapped in Fig. 5: most records are from Japan, principally Honshu, but also Kyushu. There are also records from the Korean Peninsula, and NE China. Overall, the records suggest a relatively restricted distribution.

Twenty-six *A. nipponensis* specimens (or batches of specimens) were associated with collection dates (Fig. 6). By far the largest number of records came from the

month of May with most specimens being collected between the middle and end of May. The earliest record was 30th April (Japan) and the latest 26th June (also Japan).

DISCUSSION

Comparative morphology

Anthrenus nipponensis was first recognized as a discrete taxon and described by Kalik & Ohbayashi (1985). Their description of the species is detailed, but there are anomalies associated with their drawing of the aedeagus. In our current study, the aedeagus was imaged perfectly flat whereas the drawing in Kalik & Ohbayashi (1985) might be of an aedeagus in which the parameres are folded forwards (or backwards) creating a flat-topped, hooked profile. One of us (GJH) has noted that some species, such as *A. latefasciatus*, have very thin aedeagal parameres that tend to bend at the tip whilst drying – producing a hooked appearance. In the current study, we were careful to avoid using aggressive chemicals, such as potassium hydroxide (KOH), when cleaning the aedeagus, to ensure that delicate elements remained undamaged. Kalik & Ohbayashi (1985) do not describe how the aedeagus was prepared prior to drawing, but it is possible that their preparation process deformed the parameres. In addition, other important paramere features, such as setal distribution, and the shape and extent of the pale windows, were not drawn – either because they were considered of little significance or because they were damaged.

The drawing of the *A. nipponensis* aedeagus by Kalik & Ohbayashi (1985) suggests that the median lobe falls well short of the tips of the parameres, something that Fig. 3 illustrates not to be the case in the specimens we studied. However, Kalik & Ohbayashi (1985) noted that the tip of the median lobe is expanded and as shown in our Fig. 3.

Kadej, Háva & Kalík (2007a, b) also drew the *A. nipponensis* aedeagus and noted the structure and distribution of the setae, and the bulb-shaped tip to the median lobe but were not able to illustrate the size and extent of the pale windows in the parameres. Holloway (2019, 2020, 2021) and Holloway *et al.* (2020) have shown the significance of the shape and extent of these windows in species differentiation. Kadej, Háva & Kalík (2007a) demonstrated the importance of male sternite IX structure in species definition and produced a drawing of this structure in *A. nipponensis*. Their drawing does not resemble our image shown in Fig. 4 and suggests that they drew a sternite IX in which both anterior horns had folded inwards.

So much work on Dermestidae consists of faunistic studies and descriptions of new species that we know very few species in any detail, except, that is, for the pest species of stored products (Hinton 1945; Rees 2003). Previous studies have found that both external and internal morphometrics can be useful identification guides to *Anthrenus* spp. (Holloway & Bakaloudis 2020; Holloway *et al.* 2020; Holloway, Bakaloudis & Foster 2021). The male and female sample sizes used in the current study are modest, but large enough to produce new data and generate statistically significant differences, the morphometrics carrying standard deviations that allow expected size ranges to be estimated.

The current study confirms that *A. nipponensis* is large relative to many other *Anthrenus* species with 95% of specimens likely to have body length (BL) falling between 2.4 and 4.0mm, with occasional specimens longer than 4.0mm. The range

of BL values recorded here concurs very well with those observed by Kalik & Ohbayashi (1985) (2.3–4.1mm) and Kadej, Háva & Kalík (2007a) (2.8–4.0mm). Few *A. amandae* Holloway, 2019, and *A. pimpinellae* exceed 3.0mm in body length (Holloway & Bakaloudis 2020), whilst *A. isabellinus* Küster, 1848, rarely exceeds 3.5mm (Holloway *et al.* 2020). Of the 23 species of the *A. pimpinellae* complex, only two species, *A. goliath* Saulcy, in Mulsant & Rey, 1868, and *A. corona* Holloway, 2021, are larger than *A. nipponensis* (Kadej, Háva & Kalík 2007a; Holloway 2021).

For *A. nipponensis*, mean BW/BL=0.664 indicating that this is a narrow species. BW/BL indicates body shape and for all Dermestidae studied so far, this character is consistent within species with a coefficient of variation usually between 1% and 2% (in this study 1.6%). It is also a character that reliably varies between some species and thus can be used to differentiate among certain species under field conditions. *Anthrenus amandae* and *A. pimpinellae* are also narrow species (BW/BL ~0.68) whilst *A. isabellinus* has broader, more rounded sides (BW/BL ~0.73). The average BW/BL for the maximum and minimum BW and BL values from Kalik and Ohbayashi (1985) and Kadej (2007b) is 0.66, which agrees well with the figure we obtained here for *A. nipponensis*.

The *A. nipponensis* antennal club (Fig. 2) displays a sharp angle at the outer ventral corner, which protrudes slightly as a small point or knob. The shape of the *A. nipponensis* antennal club has been noticed elsewhere (Kalik & Ohbayashi 1985). An angular antennal club is not unique to *Anthrenus nipponensis* (e.g., *A. pimpinellae* shows a slight angle (see Holloway *et al.* 2020)), but no other *Anthrenus* species within the *A. pimpinellae* complex displays quite the extent of knob protrusion as in *A. nipponensis*. Kadej, Háva & Kalík (2007b) also noted and illustrated the angular club shape but maintained that it was displayed only by males and not by females. This is not accurate as both males and females have similar antennal club shape.

The *A. nipponensis* aedeagal structure is shown in Fig. 3. The average paramere length (PL) is 380µm. Of the other *Anthrenus* species so far measured, *A. pimpinellae* and *A. chikatunovi* Holloway, 2020, have similar PL: 366µm (Holloway & Bakaloudis 2020) and ca. 400µm (Holloway 2020), respectively. However, as the average BL of *A. pimpinellae* is 2.58mm, the ratio PL/BL for *A. pimpinellae*=0.143 compared with 0.13 for *A. nipponensis*, whilst PL/BL for *A. chikatunovi* is about 0.133. *Anthrenus isabellinus* PL is about 540µm (Holloway *et al.* 2020) giving a PL/BL value of nearly 0.18, very much larger than *A. nipponensis*. *Anthrenus corona* is a large *Anthrenus* species (BL=4.434mm, 1 specimen) with a large aedeagus (PL=572µm) (Holloway 2021), but because BL is so large, PL/BL=0.129, very similar to *A. nipponensis*. From the data available so far, it appears that *A. nipponensis* PL relative to BL is similar to *A. corona* and *A. chikatunovi*, and 10% smaller than *A. pimpinellae*. *Anthrenus isabellinus* has a PL/BL value nearly 40% larger than *A. nipponensis*. As more data become available it will be clearer if there are groups of species with similar PL/BL values.

Life history

There is very little *A. nipponensis* life history information available. Yokoyama (1929) appears to be the only study on this topic. The finding that *A. nipponensis* can breed on feathers, wool, and dead insects does not differentiate the taxon from many

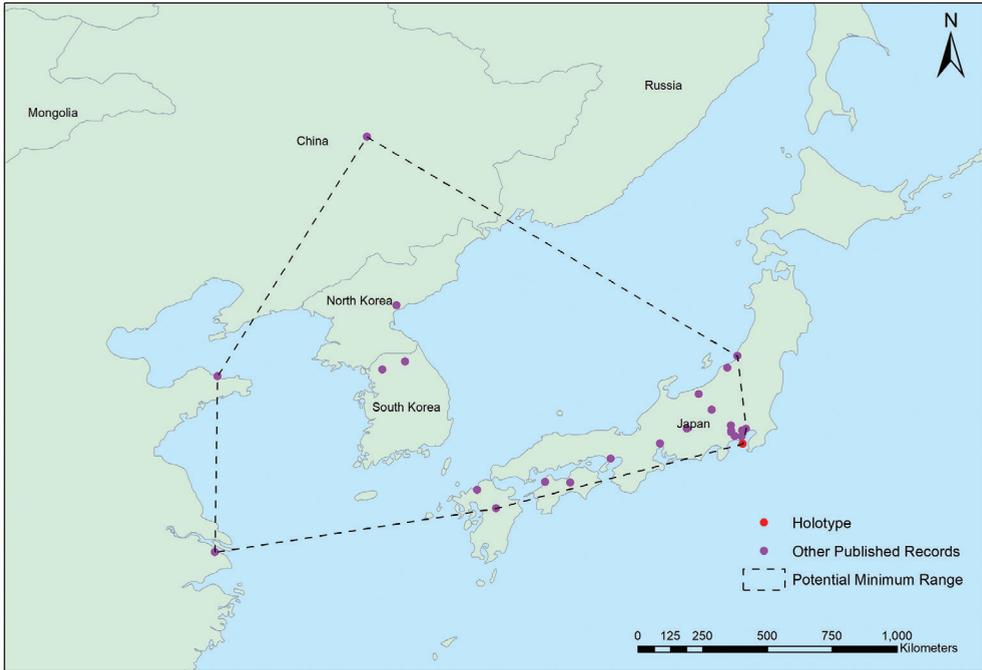


Fig. 5. — Global distribution of *A. nipponensis* from published data.

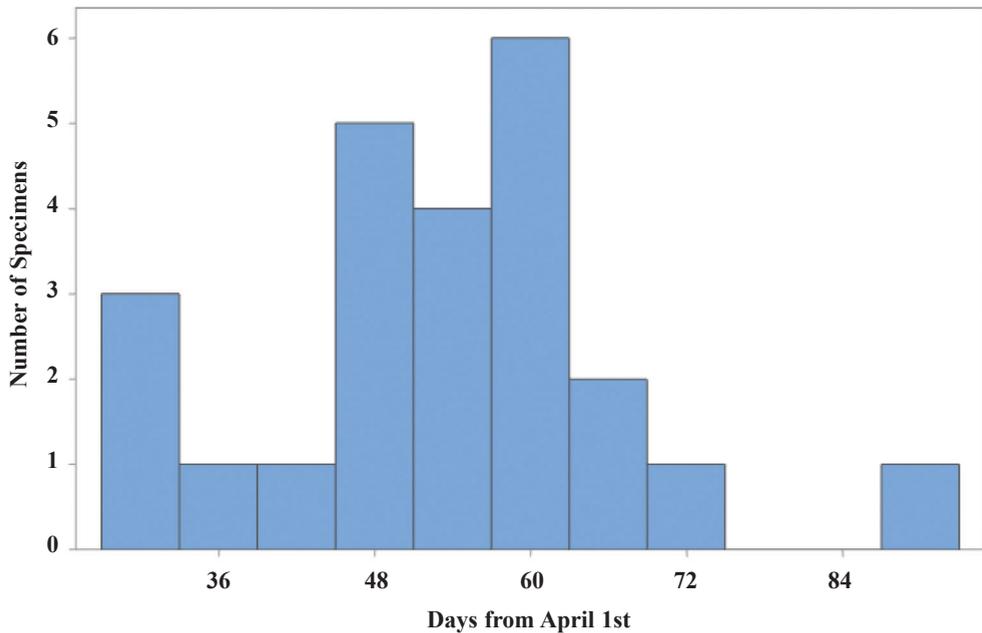


Fig. 6. — Phenogram of adult *A. nipponensis* activity from published collection dates.

other species of *Anthrenus* (Hinton 1945). Certainly, some *Anthrenus* species specialize on α -keratin (mammal), such as *A. flavipes* (Holloway & Bakaloudis 2021), whilst others focus on β -keratin (feathers) such as *A. amandae* (Holloway & Bakaloudis 2020), but these food sources could be so abundant that they do not constitute a limiting resource. More life history work needs to be carried out to establish what the limiting factors might be that generate competition and drive speciation and diversification in the *A. pimpinellae* complex (Walter, Hulley & Craig 1984).

Distribution and phenology

Some countries have well-developed recording schemes, such as the United Kingdom (NBN Atlas 2021), Germany (Benisch 2021), and Poland (BIOMAP 2021), and within these schemes the country-wide distributions and sometimes the phenologies of a few *Anthrenus* species are shown. Data scattered across faunistic studies can be useful though, if they are synthesized to provide an overview of distribution and adult activity. Our mapped points in Fig. 5 are contained within a convex hull showing where *A. nipponensis* is to be found. The distribution stated for *A. nipponensis* by Háva (2021) is Northern China, North Korea, Japan, and Russia (Kitay). Fig. 5 agrees with this statement (with the inclusion of South Korea), but the figure illustrates a relatively tight distribution rather than the wide distribution that could be interpreted from Háva (2021). *Anthrenus nipponensis* appears on the Chinese list of *Anthrenus* species (Kadej & Háva 2015; Háva 2019; Herrmann & Háva 2019), but this has rather limited value in describing distribution when the country is as large as China.

Associated with many of the literature-based records are collection dates (supplemented with further museum data in the current study). Fig. 6 suggests that most adult activity occurs from mid to late May. The authors are not aware of comparative material from the eastern Palearctic for any other *Anthrenus* species, although similar phenograms have been produced for some European *Anthrenus* species. Adult *A. angustefasciatus* Ganglbauer, 1904, are most active in Belgium in late May/early June (Scheer 2020). Benisch (2021) also shows phenograms for several *Anthrenus* species. In Germany, records for *A. angustefasciatus* and *A. scrophulariae* Linnaeus, 1758, peak in late May, whilst *A. pimpinellae* peaks a little later on in late May/early June (Benisch 2021). All these species peak at about the same time in Europe as *A. nipponensis* does in eastern Asia, but not all *Anthrenus* species are most active at the same period of time: *A. fuscus* (for example) peaks later in July (Benisch 2021).

Overview

The present study has provided more extensive, accurate information on *A. nipponensis* and has, at the same time, illustrated inaccuracies in some of the data in the published literature. Accurate identification and subsequent taxonomy depends on reliable species descriptions. Holloway (2020, 2021) and Holloway & Bakaloudis (2020) demonstrated how the discovery of new species is facilitated when phenotypically similar species are accurately described. The Palearctic *A. pimpinellae* complex is considered difficult and only through very recent work are we beginning to iron out long-standing misconceptions and misunderstandings. Even so, there remain some poorly understood species (e.g., *A. goliath*), and it is most likely that as these species are better studied more new species could come to light.

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