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ORIGINAL RESEARCH ARTICLE

Nesting biology and associated insect enemies of the exotic leaf cutter bee *Megachile* (*Eutricharaea*) *concinna* (Hymenoptera: Megachilidae) in Argentina

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The nesting biology of the exotic bee *Megachile* (*Eutricharaea*) *concinna* Smith, 1879 and its negative interactions with other insects were studied. Trap nests made of wood were located in an urban environment in Buenos Aires province, Argentina, and surveyed during 26 months. The lifecycle and the structure of the nest of *M. concinna* are described. We also report six interactions between this bee and native and exotic parasitoids and cleptoparasites. The species *Baryscapus megachilidis* is recorded here for the first time in Argentina.

Biología de nidificación e insectos enemigos asociados a la abeja exótica *Megachile* (*Eutricharaea*) *concinna* (Hymenoptera: Megachilidae) en Argentina

Se estudió la biología de nidificación y las interacciones negativas con otros insectos de la abeja exótica *Megachile* (*Eutricharaea*) *concinna* Smith, 1879. Para este estudio se utilizaron trampas nidos construidas con madera colocadas en un ambiente urbano en la provincia de Buenos Aires, Argentina los cuales fueron seguidos durante 26 meses. Se describe el ciclo de vida y la estructura de los nidos de *M. conncina.* Registramos la presencia de seis interacciones entre esta abeja y parasitoides y cleptoparásitos exóticos y nativos. Se cita además por primera vez la presencia de *Baryscapus megachilidis* en Argentina.

Keywords: leafcutter bee; trap nests; parasitoids; alien bees

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Introduction

Bees of the genus *Megachile* Latreille comprise approximately 1500 described species worldwide, and can be subdivided into 52 subgenera (Michener, 2007). These bees are commonly known as "leafcutter bees" because they cut and use pieces of leaf or petals to build the brood cells inside pre-existing cavities. The "pale leafcutter bee" *Megachile* (*Eutricharaea*) *concinna* Smith is a native species of Africa, presently widespread in the Caribbean and North America and has recently been recorded in Argentina (Alvarez, Lucia, Durante, Pisonero, & Abrahamovich, 2012). In Argentina, there are eight reported species of exotic bees (Alvarez et al., 2012; Roig-Alsina, 2006; Torretta, Medan, & Arahamovich, 2006), but only two of them were deliberately introduced for commercial purposes: *Apis mellifera* L. and *Megachile rotundata* (Fabricius) (Bierzychudek, 2011; Tesón, Dagoberto, Lizarralde, & Loiacono, 1976). The species of bumble bees, *Bombus ruderatus* (Fabricius) and *B. terrestris* L., were introduced into Chile as pollinators, and then spread to Argentina, apparently in a natural way, via the trans-Andean passage in the NW Patagonia (Schmid-Hempel et al., 2014). The remaining species: *Anthidium manicatum* (L.), *Lithurgus huberi* Ducke, *Megachile concinna* (Megachilidae), and *Hylaeus punctatus* Brullé (Colletidae) probably expanded their range from Brazil, or were accidentally introduced (Alvarez et al., 2012; Gonzalez, Engel, Lucia, & Alvarez, 2013; Roig-Alsina, 2006; Silva et al., 2014; Strange, Koch, Gonzalez, Nemelka, & Griswold, 2011).

Only *B. terrestris* and *B. ruderatus* are monitored for their expansion, populations, pathogens, and possible impacts on bees and native flora (Arbetman, Meeus, Morales, Aizen, & Smagghe, 2013; Morales, 2007; Morales & Aizen, 2006; Sanguinetti & Singer, 2014; Schmid-Hempel et al., 2014). According to Goulson (2003), the transmission of parasites or pathogens to native organisms is one possible undesirable effect caused by the introduction of exotic bees. There are numerous examples of pathogens and parasites transported to new regions by alien bees (e.g., Arbetman et al., 2013; Arretz, 1973; Donovan, 1980; Goerzen, Dumouchel, & Bissett, 1990; Schmid-Hempel et al., 2014). In Chile, several natural enemies were introduced along with *M. rotundata* (Arretz, 1973), the most important being *Baryscapus megachilidis* (Burks) (Eulophidae) and *Monodontomerus obscurus* Westwood (Torymidae). Likewise, in Argentina, Arretz and Martinez (1980) mention that during the 1970s, imported nests of *M. rotundata* were infested with *Vitula edmansae* (Packard) (Pyralidae), parasitoids such as *M. obscurus* and *Dibrachys maculipennis* Szelényi (Pteromalidae), dermestid beetles and fungi.

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Currently no information on the establishment, distribution, and impact on the native fauna is known for these natural enemies. Among the many organisms which directly or indirectly destroy solitary bees, the majority are insects, however, the most distinctive complex of parasitic forms is that associated with the bees belonging to the Megachilidae family (Linsley, 1958). The aim of this work is therefore to describe nesting biology of *M. concinna*, as well as its associated insect enemies in a north-eastern locality of Argentine Pampas.

Materials and methods

Study site and trap nesting

This study was conducted in an urban environment at the locality of Berisso (Partido de Berisso) (34°53′12′′S, 57°53′41′′W, 4 m.a.s.l), Buenos Aires province, Argentina. This region belongs to the Pampean biogeographic province (Cabrera & Willink, 1973). The weather in the region is humid temperate, and the cool season extends from May to October, with the mean monthly temperature being <18 °C. Observations on the nesting biology, collections of insect enemies, and bees (*M. concinna*) were obtained from 33 trap nests. Each trap nest was made of individual block of wood (*Pinus* sp., Pinaceae). These blocks were of two different sizes: (a) 70 20 30 mm, each drilled with a single hole 60 mm in depth and with internal diameters ranging from 4 to 6 mm; and (b) 120 20 20 mm with 90 mm in depth, with internal diameters ranging from 6 to 10 mm. The trap nests were attached horizontally in groups of nine sampling boxes to a wall of about 1–1.5 m above the ground totaling 56 traps per year. The observations started on January 2011, when the traps were installed and were inspected weekly until March 2013.

Nest dissections

Each closed nest obtained in the field was transported to the laboratory, and maintained in the trap nest for a period of approximately 15 days. After the nest was open, the cells were removed and then placed individually into plastic vials and were kept in the laboratory at room conditions (15–25 °C). Each brood cell was numbered according to the position within the nest, being the last cell, the nearest to the nest entrance. These cells were checked daily for emergence (except on weekends), species, date, and sex of *Megachile* and parasitoids and cleptoparasites were recorded. Sex ratio of *M. concinna* was estimated as the number of males emerged per females.

Insect enemies study

Associated species were isolated and observed by a Leica S8APO stereomicroscope and photographs were taken with a Leica DFC295 attached to the stereomicroscope. Digital images were mounted using open software CombineZM (Hadley, 2011). The material was mounted using conventional techniques and some specimens were slide-mounted in Canada balsam according to Noyes (1990) for more detailed study. Voucher specimens are deposited in the División Entomología of Museo de La Plata, Argentina (MLP).

Results

Host life cycle

We collected and studied a total of 33 nests (170 cells) of *M. concinna*. The length and diameter of the cells analyzed (n = 11) varied from 6.7 to 9.5 mm ($\bar{X}$ = 8.4 ± 0.83) and 4.5 to 5.5 mm ($\bar{X}$ = 5.1 ± 0.32), respectively. All cells were constructed with pieces of leaves or petals and the number of cells encountered per nest varied from 2 to 10 ($\bar{X}$ = 5.1 ± 1.94; nests studied = 33) (Table 1). A total of 109 bees emerged from these nests: 53 males and 56 females (a sex ratio of 1: 1.05). Bees from nests which were closed in February 2011 emerged from the overwintering diapause between November and mid December 2011, comprising a developmental period of almost 10 months. The overwintering generation starts building its nests in early November, extending up to mid-January. The first bee of the spring–summer generation started to emerge in mid-December up to late-February, when the last one emerged (Figure 1). The length of the developmental stages from the time the nest was closed to the adult emergence was approximately 28–42 days ($\bar{X}$ = 33; n = 17). Males were mainly located on the last cells of the nest, and they emerged mostly one or two days before the females. Nevertheless, in six cases (nests 3, 6, 11, 18, 21, and 25), males and females emerged in the course of one day, and in four nests (23, 24, 27, and 29), there were no live adults.

Mortality

We recorded approximately 34% of mortality. In 14.1%, the cells did not reach full development, the cause of mortality being unknown. The main mortality in brood cells appeared, however, to have been caused by other associated insect: 34 cells of 20 nests (20 and 60.6%, respectively) were attacked by the following species: *Coelioxys* sp. (Hymenoptera: Megachilidae), *M. obscurus*, *B. megachilidis*, *Eusiphona vittata* Sabrosky (Diptera: Milichiidae), *Anthrax oedipus* Fabricius (Diptera: Bombyliidae) and *Nemognatha nigrotarsatus* (Fairmaire and Germain) (Coleoptera: Meloide) (Table 1). Insect enemies were divided into two main groups:

1-parasitoids

The specimens of *M. obscurus* (Torymidae) (Figures 3 and 11) were only found in one cell (nest 29), 10 adults of this species emerged approximately one month after

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Table 1. Nesting period of *Megachile concinna*, emergence of adults and insect enemies recorded along two years in Berisso, Argentina.

Nest	Nesting period	Cells (*n*)	Cells attacked	*Megachile concinna*	*Monodontomerus obscurus*	*Baryscapus megachilidis*	*Anthrax oedipus*	*Eusiphona vittata*	*Nemognatha nigrotarsatus*	*Coelioxys* sp.	Dead offspring
1	II-2011/ 12-XI-2011	3	0	12-XI-2011: 2♀(I, III)							1larva* (II)
2	II-2011/ 20-XII-2011	3	0	20-XII-2011: 1♀(I)							1larva†(III) 1♀(II)
3	10–15-XI-2011/ 14-XII-2011	6	0	14-XII-2011: 1♂ (VI) 5♀ (I-V)							
4	10–15-XI-2011/ 16-XII-2011	5	0	16-XII-2011: 3♂(III-V) 17-XII-2011: 2♀(I,II)							
5	10–15-XI-2011/ 20-XII-2011	6	0	20-XII-2011: 3♂(IV-VI) 22-XII-2011: 3♀(I-III)							
6	19-XI-2011/ 26-XII-2011	5	0	26-XII-2011: 2♂(V,VI) 3♀(I-III)							
7	24-XI-2011/31-XII-2011	7	2	26-XII-2011: 2♂(IV,III) 31-XII-2011: 2♀(II, I)						31-XII-2011: 2♂(VII,V)	1larva* (VI)
8	27-XI-2011/4-I-2012	4	1	4-I-2012: 1♂(II) 5-I-2012: 2♂(I,IV)				3-I-2012: 6 adults (III)			
9	27-XI-2011/ 5-I-2012	6	4 (3¥)	5-I-2012: 2♀(I,III)				3-I-2012: 10 adults and 3 dead pupae (II)	Dead pupa (IV)		
10	31-XI-2011-/10-I-2012	7	4¥	10-I-2012: 2♀(III,II) 11-I-2012: 1♀(I)					19-XII-2012: 1 adult (IV)		
11	1-XII-2011/5-I-2012	8	1	5-I-2012: 5♂ (VIII,VII,III-V)				Dead pupae (VI)			2♀ (II,I)
12	6-XII-2012/9-I-2012	6	1	9-I-2012: 2♂(VI,IV) 3♀(I-III)				Dead pupae (V)			
13	8-XII-2011/11-I-2012	5	1	10-I-2012: 1♂(V) 11-I-2012: 3♀(I-III)				8 Dead pupae(IV)			
14	28-XII-2011/ 25-I-2012	3	2	25-I-2012: 1♂(III)			1-II-2012: 1 adult (II) 2-II-2012: 1adult (I)				
15	28-XII-2011/ 25-I-2012	4	2	25-I-2012: 2♂ (III,IV)			2 Dead pupae (II,I)				
16	28-XII-2011/ 25-I-2012	4	0	25-I-2012: 4♂ (I-IV)							
17	28-XII-2011/ 29-I-2012	5	1	29-I-2012: 4♂(II-IV)			1 adult (I)				
18	31-XII-2011/ 28-I-2012	4	1	28-I-2012: 2♂ (III,IV)				30-XI-2012: 1 adult 12-XII-2012:1 adult and dead pupae (I)			1♂(II)
19	31-XII-2011/ 1-II-2012	6	0	1-II-2012: 1♂(VI) 5♀(I-V)							
20	1–5-I-2012/ 6-II-2012	3	0	6-II-2012: 2♀ (II, III)							1pupa♀† (I)
21	1–5-I-2012/ 1-II-2012	6	0	1-II-2012: 1♂(VI) 4♀(II-V)							1♀(I)

(*Continued*)

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Table 1. (*Continued*).

Nest	Nesting period	Cells (*n*)	Cells attacked	*Megachile concinna*	*Monodontomerus obscurus*	*Baryscapus megachilidis*	*Anthrax oedipus*	*Eusiphona vittata*	*Nemognatha nigrotarsatus*	*Coelioxys* sp.	Dead offspring
22	5-I-2012/ 10-II-2012	5	2	10-II-2012: 1♀ (II)			19–21-II-2012: 2 adults (I, IV)				1larva*(V) 1pupa♀ (III)
23	7-I-2012	2	0								1 larva*(II) 1pupa♀ (I)
24	10-I-2012	4	2			29-I-2012: (57♂42♀) (II) (44♂21♀)(I)					2larvae* (III,IV)
25	11-I-2012/ 13-II-2012	9	2	13-II-2012: 2♂(VII, V) 2♀(IV,II)		10-II-2012: (4♂25♀) (parasitoidizing *M. concinna*) (III) 10-II-2012 (10♀) (parasitoidizing *E. vittata*)(I)		10-II-2012: 7 adults (I)			3larvae* (VI,VIII,IX)
26	11-I-2012/ 17-II-2012	10	1	15-II-2012: 1♂(IX) 16-II-2012: 1♂(X)1♀(I) 17-II-2012: 3♀(IV, V, VIII) 19-II-2012: 1♀(VII) 19–21-II-2012: 2♀(II, VI)				16-II-2012: 10 adults (III)			
27	12-I-2012	3	1			25-I-2012: (2♂46♀) (I)					2larvae* (II,III)
28	I-2012/ 19–21-II-2012	5	1	19–21-II-2012: 1♀(II)		3-III-2012: (21♂4♀) (I)					2larvae* (IV, V) 1pupa♀ (III)
29	I-2012	3	2		7-III-2012: (6♂4♀) (II)	7-III-2012: (4♂37♀)(III)					1♀(I)
30	10-XII-2012/ 10-I-2013	4	2	9-I-2013: 1♂(IV) 10-I-2013: 1♂(III)			17-I-2013: 1 adult (II)		1–3-II-2013: 1 adult (I)		
31	XII-2012/ 20-I-2013	4	1	19-I-2013: 1♂(IV) 20-I-2013: 1♂(III) 1♀(II)			25-I-2013: 1 adult (I)				
32	I-2013/ 16–17-II-2013	9	0	14-II-2013: 4♂(VI-IX) 15-II-2013: 3♀ (II, III, V) 16–17-II-2013: 1♀(I)							1 larva* (IV)
33	I-2013/ 16–17-II-2013	6	0	16–17-II-2013: 4♂ (III-VI) 1♀(II)							1pupa♀ (I)
		n = 170	*n* = 34	♀56 ♂53	4♀6♂	185♀ 132♂	7 adults	35 adults	2 adults	2♂	

Notes: Nesting period is given as the day on which the bee closed the nest until the emergence of the last adult of leafcutter bee. Latin numerals in parentheses represent the position of the cell within the nest.
*Larvae mummified; †Killed before opening of the cell; ¥Destroyed by *N. nigrotarsatus*.

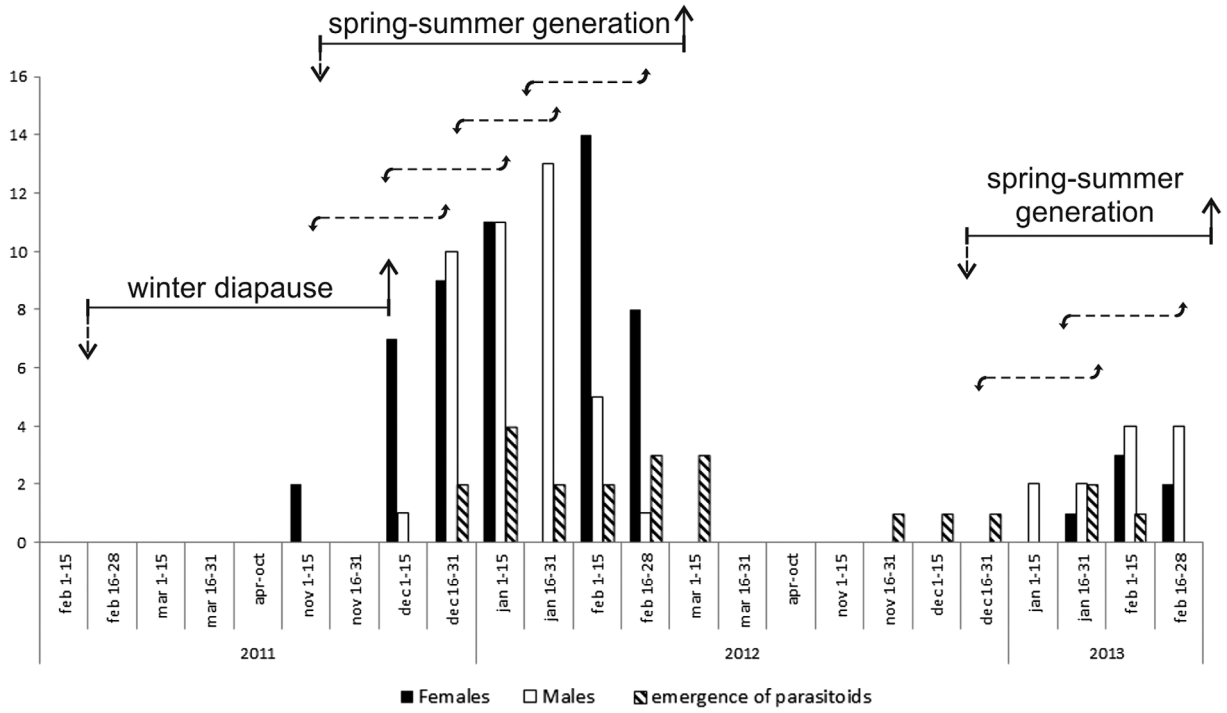

Figure 1. Emergence of *Megachile concinna* and insect enemies from trap nests in Berisso, Argentina.
Notes: Up arrow: adult emergence of *M. concinna*; down arrow: closed nest of *M. concinna*.

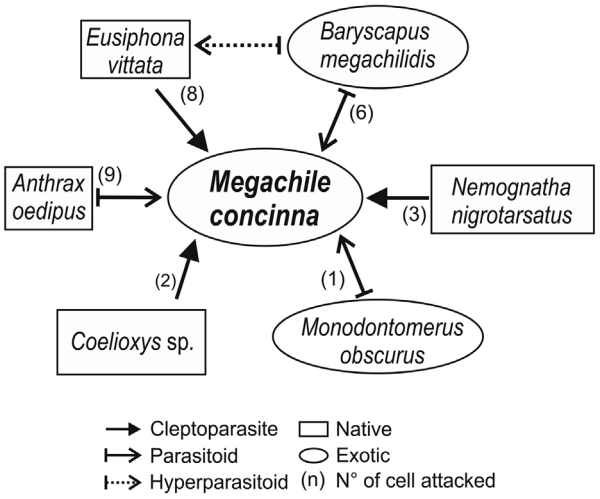

Figure 2. A schematic model exhibiting the interactions between *M. concinna* and insect enemies in Berisso, Argentina.

the nest was closed (Table 1). *B. megachilidis* (Eulophidae) (Figures 8 and 9) was found in seven cells from five nests (4.1% and 15.15%). The adults of this species emerged 13–35 days after the nests were closed, and between 25 and 99 adults emerged per cell ($\bar{X}$ = 51; n = 6) (Table 1). In one brood cell, there were found a puparium of *E. vittata* parasitized by *B. megachilidis*; it is a case of hyperparasitoidism. From this puparium, emerged nine adults of *B. megachilidis*. On the other hand, the bee fly *A. oedipus* (Figures 4 and 10) parasitoidized nine cells of six nests (5.3 and 18.2%). The adults of this species emerged 35–45 days after the parasitized nest was closed (Table 1). In most cases, the adults of *A. oedipus* emerged between 7 and 11 days after the host emergence. Only one adult of *A. oedipus* developed from each broad cell.

2-Cleptoparasites

We found the fly *E. vittata* (Figure 5) attacking eight cells of eight nests (4.7 and 24.2%). The adults of this species emerged 30–37 days and, exceptionally, 11 months after the nests were closed (Table 1). In each cell, we found between 6 and 13 puparia of this species ($\bar{X}$ = 8.8; n = 5) (Figure 14). *N. nigrotarsatus* was found in three nests; the number of cells attacked is difficult to determine because the larvae of *N. nigrotarsatus* (Figures 12 and 13), before being transferred to the vials, can feed from more than one cell (nest 19). The adults (Figure 6) of this species emerged from two months to one year after the nests were closed (Table 1). The bee *Coelioxys* sp. (Figure 7) was found attacking only two cells in the same nest (nest 7). Two males emerged 37 days after the nests were closed (Table 1) and at the same time as *M. concinna*. This bee attacked the most external cells, and only one adult developed from the cell.

Discussion

This study recorded the life cycle, nest architecture, and parasitoids associated with *M. concinna* in Argentina. Our findings about the life cycle are similar to that obtained

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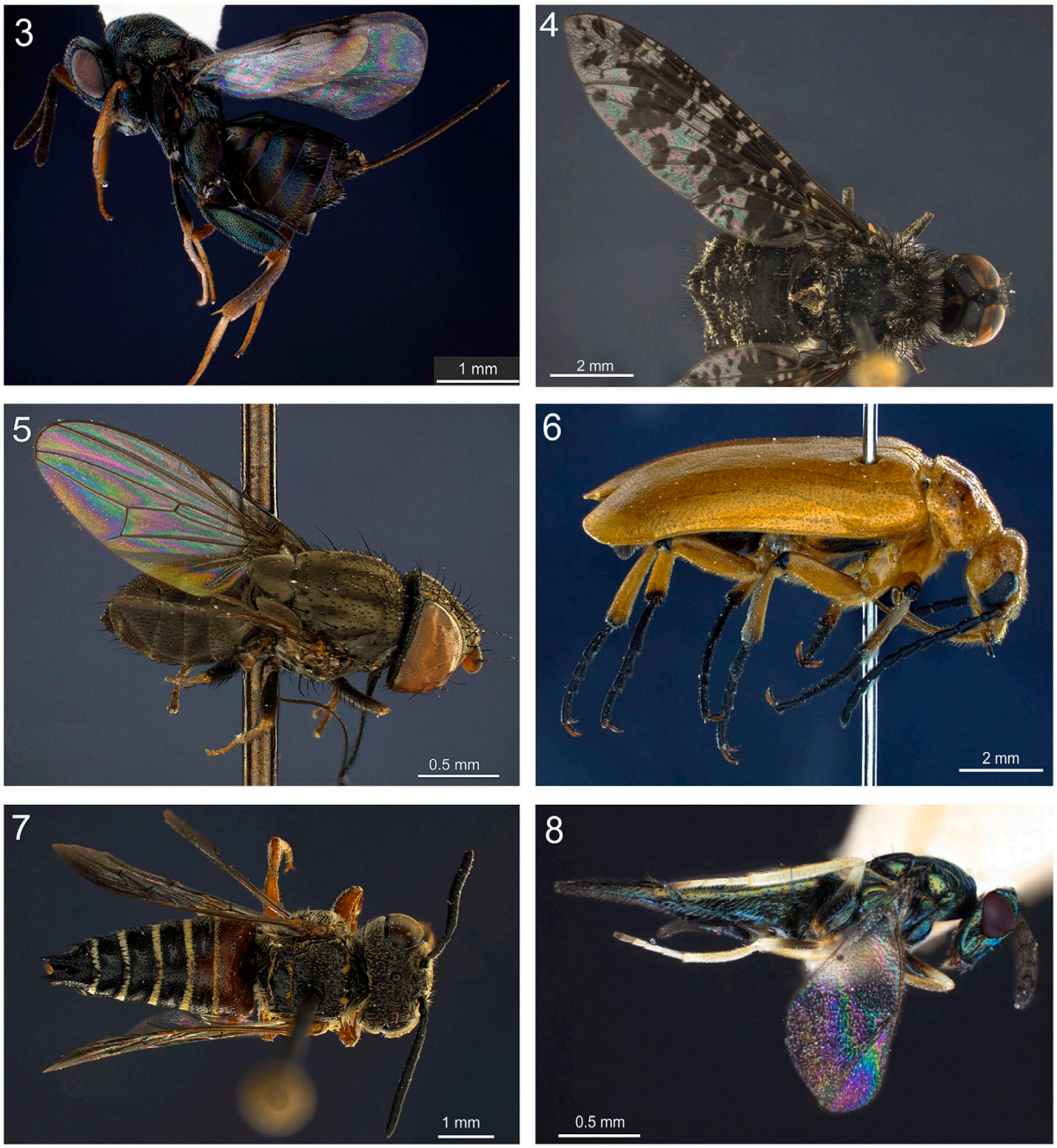

Figures 3–8. Insects associated with nests of *M. concinna* in Berisso, Argentina. (3) *M. obscurus*, body of female in lateral view; (4) *Anthrax oedipus* in dorsal view; (5) *Eusiphona vittata* in lateral view; (6) *Nemognatha nigrotarsatus* in lateral view; (7) male of *Coelioxys* (*Acrocoelioxys*) sp. in dorsal view and (8) *Baryscapus megachilidis* in lateral view.

by Butler and Richie (1965) and Krombein (1967) in USA. The nests that were provisioned at the end of the summer and that overwintered, emerged around 10–11 months later (from the middle to late spring). The total cell ratio per nest was a little higher than the data obtained by Alvarez et al. (2012) and Raw (2007), but the differences can be assigned to the length of the trap nest, as was mentioned by Butler and Wargo (1963) who obtained up to 15 cells in long straws. Our data indicate a bivoltine lifecycle for *M. concinna* in Argentina. The overwintering generation emerged from middle to late spring and started building their nests, extending this period until middle summer (Table 1). The first bee of the spring–summer generation emerges in early summer, and the last in late summer (Figure 1). Due to the short development time that this species has (28–42 days), this bee could have one more generation in the summer (Figure 1). Butler and Richie (1965) established a similar development length of 26–44 days at 18–35 °C. Our data within those of Alvarez et al. (2012) allow us to conclude that this species is established in the north-east of Buenos Aires, but the number of specimens collected in

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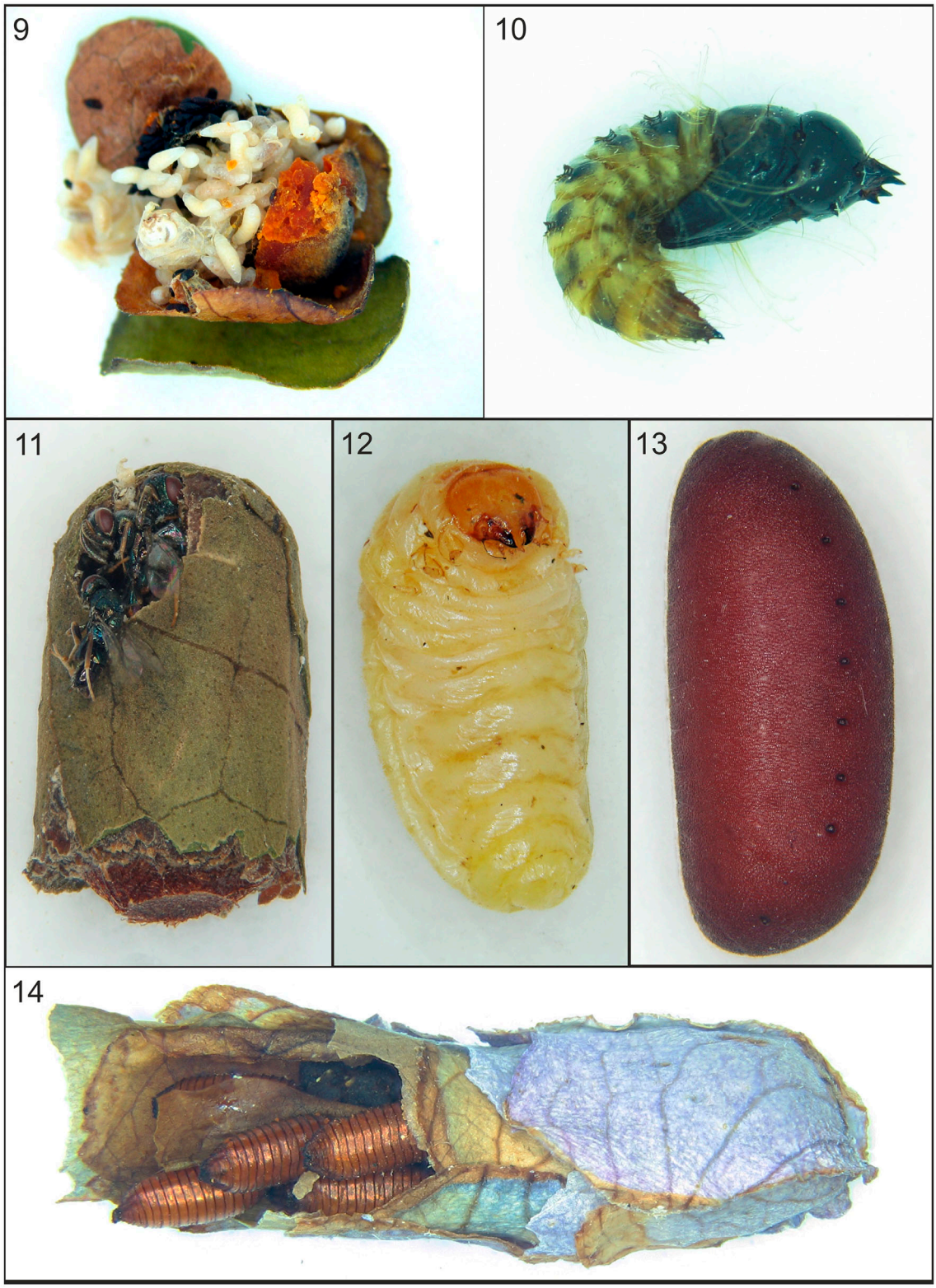

Figure 9–14. Adults and immature stages of insects associated to nest of *M. concinna* in Berisso, Argentina. (9) brood cell of *M. concinna* parasitoidized for *B. megachilidis*; (10) pupa of *A. oedipus*; (11) adult of *M. obscurus* emerging of brood cell of *M. concinna*; (12–13) larva and pupa (coarctate type) of *N. nigrotarsatus*; (14) pupae of *E. vittata* in brood cell of *M. concinna.*

peri-urban areas is still relatively scarce. Therefore, we consider following Colautti and MacIsaac (2004), that *M. concinna* in Argentina can be classified as a localized and numerically rare exotic species (Stage III species). Future surveys should focus to evaluate the true invasive potential of this species.

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All parasitoids or cleptoparasites recorded in this study were found affecting immature stages (larvae-pupae) in brood cells of *M. concinna*, four species of presumably native: *E. vittata*, *A. oedipus*, *N. nigrotarsatus*, and *Coelioxys* (*Acrocoelioxys*) sp. attacked nests of the megachilid on multiple occasions (Figure 2). Two exotic parasitoids *B. megachilidis* and *M. obscurus* attacked *M. concinna*. In one case, *B. megachilidis* was found attacking the native cleptoparasite *E. vittata* behaving as hyperparasitoid of *M. concinna* (Figure 2); this is the first record for *B. megachilidis* for hosts not *Megachile*. Butler and Wargo (1963) reported in mass rearing a high percentage of parasitoidism of *B. megachilidis* (up to 42%), in contrast to our data (3.53%). This could be due to two reasons: because this parasitoid is an exotic species in Argentina and probably still has a low population, or because the aggregations of traps nests can influence the parasitism rates (Linsley, 1958). The average of emergence of *B. megachilidis* per cell mentioned by Butler and Wargo (1963) (53 parasitoids per cell) is similar to the one we obtained ($\bar{X}$ = 51, ±27.45, n = 307).

The origin of the *M. obscurus* collected here is uncertain. They could be insects that have been introduced along with *M. rotundata*, and which subsequently became established, or could have been accidentally co-introduced with *M. concinna*. One of the main findings of this study is that two exotic parasitoids (*M. obscurus* and *B. megachilidis*) breed efficiently within *M. concinna* nests. Thus, *M. concinna* could be a potential driver for their persistence and expansion outside their original ranges. This non intentional introduction could therefore threaten native species, so future studies are necessary to confirm whether *B. megachilidis* and *M. obscurus* really attack native *Megachile* species. Butler and Richie (1965) found a species of bombylid, *Anthrax cintalapa* Cole, as parasitoid of *M. concinna* in Arizona and California (USA). In Argentina, this guild was occupied by a similar species of bombylid, *A. oedipus*, a species widely distributed in the Neotropics.

The complex of insect enemies cited for *M. concinna* in USA consists of six species: *A. cintalapa*, *Coelioxys moesta* Cresson, *Nemognatha lurida* (LeConte), *B. megachilidis*, *Monodontomerus aeneus* (Fonscolombe), and *Trogoderma.* We found a similar assemblage associated with this bee: *E. vittata*, *B. megachilidis*, *A. oedipus*, *N. nigrotarsatus*, *M. obscurus*, and *Coelioxys* sp. We can establish that the fauna of insects that attack *M. concinna* in the USA and Argentina is composed of species, mostly belonging to the same genera. More biological studies are needed to monitor the spread of exotic species and thus understand and assess their impact on native fauna of bees. In addition, these studies could help to understand their negative interactions with native and exotic insects.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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