Original article

Field use of an incubation box for improved emergence timing of *Osmia lignaria* populations used for orchard pollination

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Abstract – Wintered populations of blue orchard bees, *Osmia lignaria*, may require incubation to time emergence to crop bloom. In this study, bee nests were placed in an almond (California) and an apple (Utah) orchard under two incubation treatments: in wood blocks and field incubation boxes. Loose cocoons were also placed in the boxes. Incubation boxes had heating units (set to max. temperature = 22 °C) to increase or prolong daytime temperatures to higher than ambient ($\geqslant$ 14 °C higher in Utah). Bee emergence was monitored, and temperatures were recorded. The incubation boxes allowed for faster accumulation of heat units compared to wood blocks. Bees survived well under all conditions (> 90% emergence). Compared to bees in wood blocks, females in incubation boxes required three days less in CA and eight days less in Utah for 50% emergence. Results show the utility of heated incubation boxes for shortening *O. lignaria* emergence time, helping to synchronize bee emergence with bloom initiation.

Megachilidae / *Osmia lignaria* / blue orchard bee / incubation / pollination

1. INTRODUCTION

The blue orchard bee, *Osmia lignaria* Say (Hymenoptera: Megachilidae), is a cavity-nesting solitary bee that occurs throughout most of the United States and into southern Canada (Rau, 1937; Mitchell, 1962). This bee species is an efficient pollinator of flowers of fruit trees in the rose family (Rosaceae). Pollination proficiency is due to the bee's natural emergence in the spring, preference for the nectar and pollen of fruit tree flowers, and promiscuous foraging behavior (Torchio, 1976, 1985, 1987; Bosch and Kemp, 2001, 2002). One problem that has hindered pollination is that fruit trees, especially almonds, bloom early in the spring when temperatures can still be cool enough to inhibit pollinator

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foraging activity (Torchio, 1976). *Osmia lignaria* adults fly under overcast skies and at lower temperatures (12 °C) than honey bees (Bosch and Kemp, 2001; see also Vicens and Bosch, 2000), and this allows fruit producers using this species to obtain good yields in years with poor weather during bloom (Bosch et al., 2006).

Osmia lignaria is a univoltine species. Adult bees overwinter in their cocoons, and when exposed to warm spring temperatures, will emerge within a few days and take flight (Bosch and Kemp, 2001). Commercial management of *O. lignaria* includes maintaining them in artificial nesting cavities and subjecting them to defined temperature regimes during winter and spring to facilitate emergence of adults in synchrony with fruit tree bloom (Bosch et al., 2000; Bosch and Kemp, 2003, 2004). With proper management, *O. lignaria*

populations can be sustained and increased, thus allowing an orchardist to maintain a supply or surplus of pollinators (Torchio, 1976, 1985, 1987; Bosch and Kemp, 2001, 2002; Bosch et al., 2006). *Osmia lignaria* can be used alone for fruit tree pollination, or in addition to honey bees, *Apis mellifera* L.

Coordinating the emergence of bees with the onset of fruit tree bloom requires an understanding of both bee and tree developmental physiology. Management of *O. lignaria* requires that adults are wintered for sufficiently long periods (e.g., about 200 days at 4 °C for populations from northern Utah) (Bosch and Kemp, 2003). Then in the spring, if the maximum daily temperatures reach 20 °C, adult bees will emerge from nests in approximately one week without supplemental incubation (Bosch and Kemp, 2001). At lower orchard temperatures (10–15 °C), male emergence proceeds quickly, but female emergence is much slower. Depending on fruit species and cultivar, however, bloom occurs when the temperatures in the orchard are 8–17 °C (Faust 1989; Nyéki and Soltész, 1996). Thus, daily temperatures may allow for accumulation of heat units and progression of bloom in fruit trees, while female bee emergence is arrested or very slow. A consequence of slow, asynchronous bee emergence is that some *O. lignaria* adults may still be in their cocoons when the earliest, most productive bloom occurs (Delaplane and Mayer, 2000). For example, almonds and cherries have fruit-setting capacities as high as 50%, and fruit yields may be suboptimal if some bloom finishes before pollinator foraging ensues (Kester and Griggs, 1959; McGregor, 1976; Thompson, 1996; Delaplane and Mayer, 2000).

If the timing of fruit tree blossom is ahead of bee emergence, *O. lignaria* nests containing wintered adults can be incubated under artificial conditions indoors, and the emerged adults can be collected in containers and released in the orchard (Torchio, 1981, 1982a, b; Bosch and Kemp, 2001). However, females released as emerged adults express higher pre-nesting dispersal (Torchio, 1984, 1985), thus diminishing female nest establishment and bee reproduction in the orchard. To circumvent this problem, we designed a field incubation box that allows *O. lignaria* populations to be heated within their nesting shelter. We predicted that the heating of the boxes (to 20–22 °C) early in the day would allow bees to accumulate more heat units than populations left at ambient temperatures, and thereby females would emerge sooner and over a shorter duration.

In this study, we describe and field-test a prototype of an incubation box for use with *O. lignaria* populations in apple and almond orchards. These two crops bloom at different times and are located in different geographic regions, and thus are exposed to different weather conditions that could affect the timing of orchard bloom and bee emergence. Our first objective was to compare emergence rates in nests incubated at ambient temperatures and in incubation boxes, and to ascertain whether earlier bee emergence and shorter durations of emergence can be obtained without increasing mortality.

Previous studies have used daily checks of loose cocoons (extricated from their nests) inserted in nesting cavities or placed individually in glass vials to monitor emergence (Bosch and Kemp, 2000; Bosch et al., 2000). This method allows for quick monitoring of emergence from the cocoon, but it is unclear whether, upon emergence from the cocoon, females stay in the nest cavity for a certain time period before flying away from the nest. Females may remain in the nest to await certain environmental conditions, to allow time for physiological processes to occur, or perhaps to imprint upon nesting cues. Thus, a second objective of this study was to compare emergence rates from the cocoons with departure rates out of the nest.

2. MATERIALS AND METHODS

2.1. Bee populations

Study populations were the progeny of northern Utah bees flown in 2003 in almond and apple orchards in California and Utah, respectively. The bees were flown in the regions in which their progeny would be released in the subsequent year (2004) to assure that the new generations could be

held under defined, appropriate conditions and durations during the winter. Parent populations of bees nested in paper drinking straws (15 cm long and 8 mm in diameter) inserted in holes drilled in wood blocks. Nests obtained in CA containing diapausing adults were brought to the ARS Bee Biology & Systematics Laboratory in Logan, UT, and placed in cold storage (4–5 °C) on 29 July 2003 for 201 days. The nests from UT were placed in cold storage in the laboratory on 18 September 2003 for 205 days. For both populations, during the winter period, X-radiography was used to assess the number and sex of live adults inside the nests so that experimental treatments could be allotted similar numbers of female bees, which was the only sex monitored for emergence in this study.

Once almond bloom was imminent in California, the managed population of CA-raised bees were placed into portable coolers and driven back to an almond orchard in Modesto, CA for release on 16 February 2004. Likewise, upon the onset of apple bloom in North Logan, UT, the UT-raised bees were driven a short distance to an apple orchard for release on 10 April 2004.

2.2. Shelters and nesting materials

In both the CA and UT orchards, bee nests were distributed among five wooden shelters, in which the bees were placed in the field incubation box (FIB) or in unheated wood blocks (described below). The shelters were placed so that an open side faced southeast to facilitate the gathering of early morning sunlight and its warmth (Bosch and Kemp, 2001).

In California, the shelters were constructed of a vertical sheet of plywood (122 cm × 122 cm) with two horizontal shelves (20 cm in depth; situated approx. 0.8 m and 1 m from the ground), with other plywood panels forming two sides and a roof (60 cm in depth). Each shelter was elevated approximately 1 m off the ground by attaching it to metal fence posts. The shelters were situated along one row of trees in a 15-acre almond orchard and were spaced 100 m from each other.

Five-sided, box-shaped plywood shelters (61 × 61 × 61 cm) were used in Utah. The sides of the boxes had horizontal cut-outs for ventilation. They were elevated ~1.5 m off of the ground using fence posts and were placed in a 3-acre apple orchard. Shelters were set evenly across several rows of apple trees with ~30 m of space between them.

2.3. Field incubation box (FIB)

The FIB (patent application submitted) was designed specifically for this study (Fig. 1). The FIB has an inner compartment for holding whole nests in paper straws or loose cocoons and for buffering bees from direct contact with a heating unit. This inner compartment is constructed of black, high-density polycarbonate (Laird Plastics, Salt Lake City, UT) insulated by a Styrofoam box. An electric heat blanket (Gordo Sales, Inc., Layton, UT) is positioned on the bottom of the Styrofoam box and is in contact with the outside bottom of the inner box (Fig. 1). Temperature inside the box is controlled with a custom-made thermostat set to turn off at 21–22 °C for this study; no low temperature threshold was implemented. During the study as needed, batteries (12 V) that powered the heat blankets were recharged during the night with a battery charger, or during the day with a solar panel (40 × 23 cm, Model SX10M, 30 V maximum, BP Solar International Inc., Frederick, Maryland). Preliminary tests in which temperatures were monitored inside the FIBs (without bees) that were placed outdoors and in laboratory incubators showed that the arrangement of equipment in the FIBs allowed for even heating throughout the inner box compartment. Emerged bees could leave the FIB via a clear, vinyl tube (1.9 cm in outer diameter and 1.6 cm in inner diameter) that extends from the bottom of the FIB. Boar bristles at the distal end of the exit tube inhibited bees from re-entering the FIB once they had left (Fig. 1).

2.4. Experiments

For addressing the first objective of comparing female bee emergence at ambient temperature and emergence at elevated temperatures, two incubation treatments were devised: nests in wood blocks (ambient), and nests in FIBs (heated). Each treatment was replicated in the five shelters.

Nests in wood blocks: Nests (in paper straws) containing a total of about 30 females were inserted into the holes of each of the five wood blocks. The wood blocks (15 × 15 cm) had 49 holes (15 cm long and 8 mm in diameter) drilled into one face that served as an artificial nesting device into which straws containing overwintered nests could be inserted (Torchio, 1982a).

Nests in FIB: Nests containing a total of about 30 females were adhered to sticky boards (approx. 20 × 26 × 0.25 cm plastic sheet covered
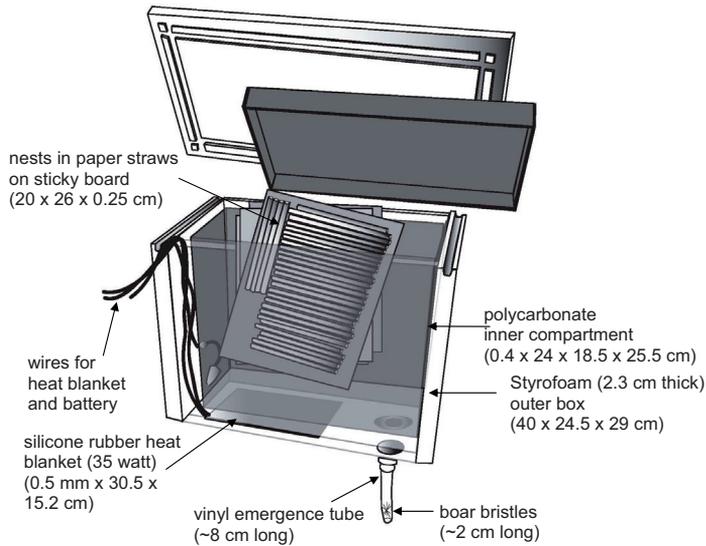
Figure 1. Field incubation box for nests of *Osmia* in straws.

by inverted masking tape). The straws were tightly packed against each other so that emerging bees were not exposed to sticky areas of the boards. The boards were placed on their edges into each of the five FIBs (Fig. 1), allowing air to move in spaces between the boards for even heating of the nests. The heaters in the incubation boxes were switched on manually each morning (0630–0900 MST) and turned off each evening (1700–1800 MST).

Nests in wood blocks and nests in FIBs also were used to address the second objective of this study, i.e. to compare emergence rates of adults from the cocoons and rates of departure from the nests. As mentioned, previous studies have used loose cocoons individually placed in glass vials to monitor emergence. For this reason, an additional 30 female cocoons were removed from nest cells and individually placed in 5 mL glass vials. The vials were attached to sticky boards, which were also included in FIBs.

2.5. Data collection

At the onset of orchard bloom, bees were placed into the FIBs and blocks. All nests had previously been slit longitudinally so that, once in the morning and once in the early evening, all bees were checked for survival and emergence from (1) the cocoon and (2) the nest. Examining the bees twice per day gave

a more detailed portrayal of emergence, with some bees out of the cocoon but still in the nest in the morning, and then having flown away by the afternoon. In the CA orchard, emergence was monitored from 17 to 27 February 2004. A few females had not emerged by 27 February, and thus their emergence could not be recorded. In UT, emergence was monitored from 11 April to 6 May 2004, a timeframe that allowed for the fate of all bees to be determined.

HOBO dataloggers (Onset Computer Corp., Bourne, Massachusetts) were used to record temperature continuously in the FIBs, in the wood blocks (using a probe placed inside a nesting cavity to one half of the length), and inside the shelter (not in direct sunlight) where the FIB and wood block resided. In CA, due to the HOBOs failure to function properly, temperature data were recorded for only the last days of the study, from 23 to 27 February. In UT, temperatures were recorded throughout the emergence period, and thus degree-day accumulation could be calculated for this time period from the daily temperatures (see below).

2.6. Statistical analysis

Data from the UT and CA studies were analyzed separately. Degree-days were calculated for UT temperature data using the website: http://www.ipm.ucdavis.edu/WEATHER/

ddretrieve.html, with 5 °C as the base temperature. The base temperature of 5 °C was chosen because if *O. lignaria* overwintering adults are held in a cooler just below this temperature (~4.5 °C) for longer than 200 days, males will begin to emerge without increasing the temperature (unpubl. data.).

Chi-square tests of independence using contingency tables were used to compare the frequency of emerged and dead bees in loose cocoons in FIBs, nests in FIBs, and nests in wood blocks. Paired T-tests were used to compare: (1) mean time to emerge from the cocoons and mean time to depart from the nests between treatments (i.e., nests in FIBs and nests in wood blocks); (2) mean time to emerge from the cocoons and mean time to depart from the nests within each treatment; and (3) mean time to emerge from the loose cocoons in FIBs and mean time to depart from the nests in FIBs.

3. RESULTS

3.1. Mortality

Most bees (90–99%) placed out in the UT and CA orchards survived (Tab. I). Chi-square analysis revealed a significant difference in survival among all treatments (in FIBs or in wood blocks) or locations of bees (loose cocoons or nests) in the UT orchard. Paired comparisons revealed a significantly higher survival of bees in the nests in wood blocks (98.7%) compared to survival of bees in nests in FIBs (90.3%). Survival of bees in the wood blocks was not significantly different from survival of bees in the loose cocoons in FIBs (95.2%). FIB temperatures in one of the five UT replicates exceeded 41 °C on three days. Nine bees from nests in FIBs and seven bees from cocoons in FIBs died in this replicate.

In CA, no significant differences were found between the survival of bees in nests in wood blocks, nests in FIBs, and loose cocoons in FIBs (Tab. I).

3.2. Temperature and bee emergence in Utah

The average minimum temperatures in UT were similar in the FIBs, in the wood blocks and inside the shelters (ambient) (Fig. 2).

Table I. Mean percent of surviving *Osmia lignaria* females according to incubation treatments (in FIBs or in wood blocks) and locations of bees (in loose cocoons or in nests) (replicated 5 times with ~30 females per replicate) in an orchard in Utah and in California. Significant differences were found in survival frequency in Utah only: among all treatments/locations ($\chi^2 = 10.36$, d.f. = 2, $P < 0.01$); between nests in wood blocks and nests in FIBs ($\chi^2 = 8.45$, d.f. = 1, $P < 0.005$).

Utah	
Treatment/Location	% Live (± SE)
Loose cocoons in FIB	95.2 ± 4.8
Nests in FIB	90.3 ± 6.6
Nests in block	98.7 ± 0.8
California	
Treatment/Location	% Live (± SE)
Loose cocoons in FIB	97.0 ± 1.4
Nests in FIB	97.9 ± 1.4
Nests in block	96.0 ± 1.2

However, average maximum and average mean temperatures were higher in the FIBs than in the wood blocks and within the shelters. Average maximum temperatures inside the FIBs exceeded the set temperature of 22 °C.

In the FIBs, degree-days were accumulated at a faster rate than in the wood blocks (Fig. 3). By the 20th day of the study, 155 degree-days were accumulated in the FIBs, while only 110 degree-days were accumulated in the wood blocks (Fig. 3). Average 50% female cumulative emergence from the cocoons occurred by day 4 in nests in FIBs and by day 12 in nests in wood blocks (Fig. 4). Mean time for 50% departure from the nest was 4 days in nests in FIBs and 13 days in nests in wood blocks (Fig. 4). The mean number of days until emergence from the cocoons in the nests was significantly lower in nests in FIBs than in nests in wood blocks (7.8 ± 2.8 and 11.6 ± 3.8 days, respectively) (Tab. II). Similarly, bees in nests in FIBs took significantly less time to leave the nest than bees in nests in wood blocks (8.2 ± 2.7 and 12.8 ± 3.6 days, respectively) (Tab. II). Within treatment, no significant difference was found in time to emerge from the cocoon and time to leave the nests
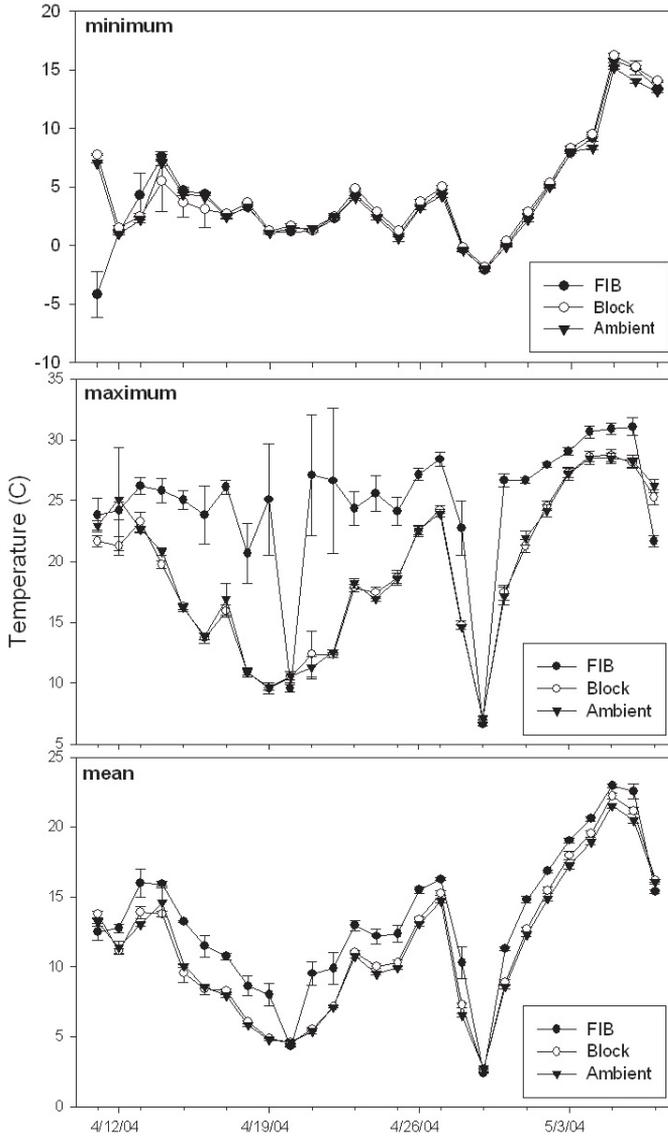
Figure 2. Daily average minimum, maximum and mean temperatures within bee nesting shelters (ambient), inside wood blocks, and inside field incubation boxes (FIBs) in a Utah apple orchard. Values are means ± SE of five replicates.

in FIBs (Tab. II), whereas a significant difference was found in time to emerge from the cocoon and time to leave the nest in wood blocks (11.6 ± 3.8 and 12.8 ± 3.6 days, respectively) (Tabs. II). There was also no significant difference in the mean number of days for emergence from the loose cocoons and departure from the nests in FIBs (Tab. II).

3.3. Emergence in California

In the CA orchard, no accumulation of degree-days during the emergence period was calculated due to temperature logger failure. Fifty percent cumulative emergence from the cocoon occurred by day 3 in nests and loose cocoons in FIBs and by day 6 in nests in blocks
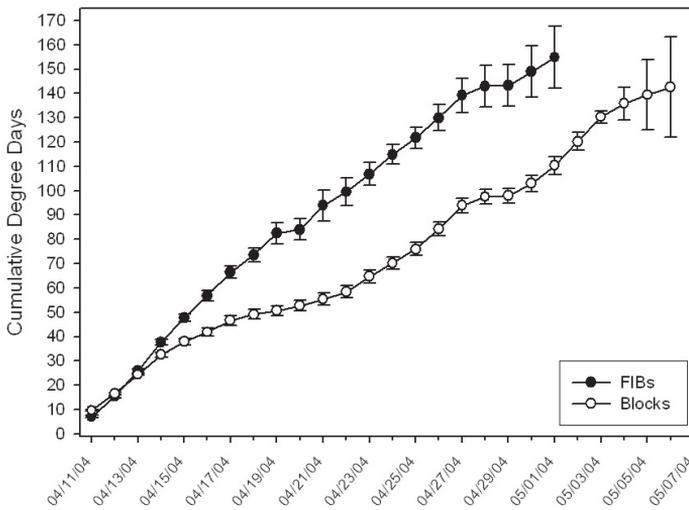
Figure 3. Cumulative degree-days (base 5 °C) by date (until all female bees had emerged) in field incubation boxes (FIBs) and in wood blocks in a Utah apple orchard. Values are means ± SE of five replicates.

Table II. Comparison between and within treatments of mean number of days (Range, Mean ± SE) using paired T-tests (d.f. = 4) for *Osmia lignaria* females to emerge from their cocoons (e) and depart from their nests (d) (replicated five times with ~30 females per replicate).

Utah					T	P-Value
e: Cocoons in FIBs	(2–21, 7.8 ± 2.8)	vs.	e: Cocoons in Blocks	(2–26, 11.6 ± 3.8)	3.12	0.035
d: Nests in FIBs	(2–21, 8.2 ± 2.7)	vs.	d: Nests in Blocks	(2–26, 12.8 ± 3.6)	3.89	0.018
e: Cocoons in FIBs	(2–21, 7.8 ± 2.8)	vs.	d: Nests in FIBs	(2–21, 8.2 ± 2.7)	2.10	0.104
e: Cocoons in Blocks	(2–26, 11.6 ± 3.8)	vs.	d: Nests in Blocks	(2–26, 12.8 ± 3.6)	6.84	0.002
e: Loose cocoons	(2–28, 7.4 ± 3.1)	vs.	d: Nests in FIBs	(2–21, 8.2 ± 2.7)	1.29	0.267
California					T	P-Value
e: Cocoons in FIBs	(1–10, 4.8 ± 0.3)	vs.	e: Cocoons in Blocks	(2–11, 5.9 ± 0.4)	2.66	0.056
d: Nests in FIBs	(2–21, 5.0 ± 0.3)	vs.	d: Nests in Blocks	(2–26, 7.1 ± 0.3)	5.50	0.005
e: Cocoons in FIBs	(1–10, 4.8 ± 0.3)	vs.	d: Nests in FIBs	(2–21, 5.0 ± 0.3)	0.74	0.499
e: Cocoons in Blocks	(2–10, 5.9 ± 0.4)	vs.	d: Nests in Block	(2–26, 7.1 ± 0.3)	8.41	0.001
e: Loose cocoons	(1–11, 5.2 ± 0.5)	vs.	d: Nests in FIBs	(2–21, 5.0 ± 0.3)	0.33	0.757

(Fig. 5). Similar differences were obtained when these two treatments were compared for departure of bees from the nest (Fig. 5).

The average number of days for emergence from the cocoons appeared to be fewer for bees in nests in FIBs than in nests in wood blocks, but this difference just failed significance (4.8 ± 0.3 and 5.9 ± 0.4 days, respectively) (Tab. II). Time to leave the nests was significantly lower for females in nests in FIBs

than in nests in wood blocks (5.0 ± 0.3 and 7.1 ± 0.3 days, respectively) (Tab. II). For the nests in FIBs, there was no significant difference in time to emerge from the cocoon and time to depart from the nest (Tab. II). However, for nests in wood blocks, there was a significant difference in time to emerge from the cocoon and time to leave the nest (5.9 ± 0.4 and 7.1 ± 0.3 days, respectively) (Tab. II). No significant difference was found in the mean
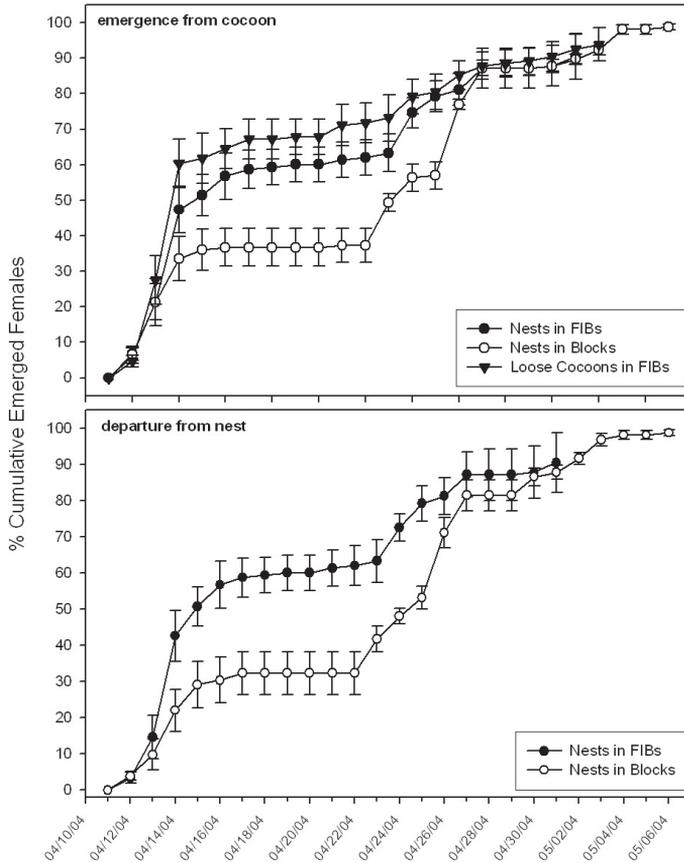
Figure 4. Cumulative *Osmia lignaria* female emergence from cocoons (top) and departure from the nest (bottom) in nests in wood blocks, and nests and loose cocoons in field incubation boxes (FIBs) in a Utah apple orchard. Values are means ± SE of five replicates.

number of days for emergence from the loose cocoons and departure from the nests in FIBs (Tab. II).

4. DISCUSSION

The blooming period of rosaceous fruit trees is brief and dependent on cultivar and weather. When using *O. lignaria*, speed and synchrony of emergence are important factors for obtaining the most efficient pollination and successful bee reproduction. One approach, demonstrated here, is to enhance the synchrony of bee foraging and fruit tree bloom through the use of FIBs for shortening the

emergence time of *O. lignaria* females in the field.

The use of FIBs was beneficial for three reasons: (1) it enhanced bee emergence; (2) it did not increase bee mortality, except in one replicate; (3) it prevented females from re-nesting in old nests.

(1) FIBs warmed the bees earlier in the day and kept them warm for a longer period of the day compared to bees in wood blocks. In the Utah orchard, 50% departure from the nests in FIBs was obtained by day 4, compared to day 13 in the wood blocks. In Utah, it was demonstrated that degree-days accumulated more quickly in the heated FIBs than in the wood blocks, although the relationship between the accumulation of heat units and
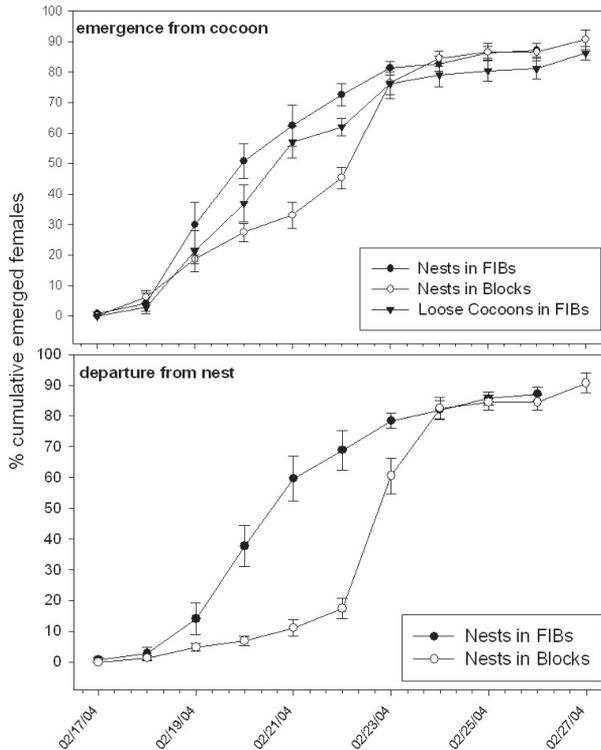
Figure 5. Cumulative *Osmia lignaria* female emergence from cocoons (top) and departure from the nest (bottom) in nests in wood blocks, and nests and loose cocoons in field incubation boxes (FIBs) in a California almond orchard. Values are means ± SE of five replicates.

cumulative female emergence is not clear from our data. It is known that female emergence proceeds very slowly at temperatures below 20 °C (Bosch and Kemp, 2001), but the relationship between temperature and bee emergence time is not yet completely understood.

In the California orchard, 50% departure from the nests in the FIBs was obtained by day 4, compared to day 6 in the wood blocks. The emergence time at ambient temperatures (i.e., in the wood blocks) in California was about half the duration of emergence time at ambient temperatures in Utah. Average spring temperatures in central and southern California are naturally warmer than in Utah (http://www.ncdc.noaa.gov/oa/ncdc.html), and the warmer California temperatures may have helped to expedite bee emergence from their nests in blocks. Thus, the impact of FIBs might be greater in regions where the

climatic conditions are less favorable for bee emergence, such as in Utah.

(2) We did not intend to heat the bees to more than 20–22 °C during the day, or to provide nocturnal warmth. However, overheating was recorded, and in one FIB in the UT orchard, the high temperature (~40 °C) was probably lethal to some bees. It is not clear if excessive FIB temperatures represent inaccuracy of the thermostats or the combined effects of solar heating plus insulation of the FIBs. The high survival obtained in the nine other shelters proves that the proper use of the FIB did not harm the bees. Previous laboratory studies have found increased mortality in bees incubated at constant 30 °C (Bosch and Kemp, 2001), and, therefore, efforts must be made to include a safeguard against the overheating of the FIBs. Such safeguards might include having light-colored FIBs and positioning them

within the shelter to avoid exposure to direct sunlight.

(3) The emergence tube of the FIB allowed for 100% of the emerged bees to readily leave the shelter, while it completely excluded them from re-entering the FIB and re-nesting in their old straws (Bosch and Kemp, 2001). Keeping the bees out of the FIB forced them to establish nests in new nesting materials (supplied within the shelters) rather than in old cavities. Female blue orchard bees sometimes show a preference to nest in old nesting materials (Torchio, 1984), but the use of new nest material would help to decrease the incidence of microbial pathogens and parasites remaining in old nests. We are beginning to understand what chemicals from old nests serve as cues to females in the process of selecting a nest cavity (Pitts-Singer, 2007). These chemicals might be incorporated to artificial nest materials to enhance female establishment and thus help in maintaining sustainable populations of *O. lignaria* for orchard pollination.

It was also interesting to find that, upon emergence from the cocoons, females did not immediately leave the nests. However, differences between time to emerge from the cocoons and time to leave the nests (~0.5 day for nests in FIBs, ~1 day for nests in wood blocks) were not dramatic, and were only significant for bees in blocks. Within the FIBs, there was no significant difference in the time to emerge from loose cocoons and time to leave the nests. Thus, monitoring bee emergence from loose cocoons (Bosch and Kemp, 2000, Bosch et al., 2000) provides a good estimate of departure time from nests when bees are incubated in FIBs, but may underestimate departure time from nests when bees are incubated at ambient temperatures.

Female emergence in the field might have been further shortened by incubating nests throughout the night. Laboratory studies have shown that after about 200 days of overwintering at 4 °C, females take an average of four days to emerge from cocoons when incubated at constant 20 °C or 22 °C (Bosch and Kemp, 2000, 2003). A possible concern with 24-hour incubation is that night emergence might disrupt mating activity, which often takes place shortly after female emergence.

However, most individuals in laboratory studies emerge during the morning and early afternoon.

Following departure from the natal nests, female bees need 1–2 days to feed, mate, and select a nesting cavity before they begin activities that facilitate pollination (Bosch and Kemp, 2001). An additional strategy to improve synchronization of bee foraging with fruit tree bloom is to provide alternative pollen-nectar sources at the beginning of the blooming period, when orchard bloom is still scarce. This method has been successfully implemented by Maccagnani et al. (2007) for *O. cornuta* in pear orchards. We believe that a combination of both approaches (use of FIBs and alternative flower sources) will enhance both fruit tree pollination and bee reproduction and thus contribute to the successful management of *Osmia* populations at a commercial scale.

Utilisation au champ d'une boîte d'incubation pour améliorer la date d'émergence des populations d'*Osmia lignaria* utilisées pour la pollinisation des vergers.

Osmia lignaria / Megachilidae / incubation / pollinisation / étude au champ

Zusammenfassung – **Feldversuche zur Nutzung einer Brutbox zur Verbesserung des Schlüpfzeitpunkts von *Osmia lignaria* Populationen in der Bestäubung von Obstpflanzungen.** Die Blaue Mauerbiene *Osmia lignaria* Say ist eine in Nordamerika heimische höhlenbrütende solitäre Biene. Für Obstgärten mit Rosaceen ist sie ein effizienter Bestäuber. Den Winter verbringen die Blauen

Mauerbienen als Adulte, aber noch in ihren Kokons, aus denen sie mit Einsetzen der warmen Frühjahrstemperaturen innerhalb weniger Tage schlüpfen und ausfliegen. Bei entsprechendem Management können die Populationen an Blauen Mauerbienen in Obstgärten erhalten und sogar gesteigert werden. Ein Problem für den Einsatz dieser Bienen in der Bestäubung von Obstgärten stellt jedoch die frühe Blütezeit dar, bei der oft noch so niedere Temperaturen herrschen, dass sie die Aktivität der Bienen begrenzen. Unsere Studie geht dieses Problem an und hierzu führten wir Feldversuche mit einer Freilandbrutbox (FIB) durch (Abb. 1). Hauptziel war es, die Schlupfzeitpunkte von Bienen, die in solchen Brutboxen gehalten wurden, mit denen von Bienen zu vergleichen, die unter Normaltemperaturen in Holz nisteten. Vor allem wollten wir sehen, ob die Bienen früher schlüpfen und eine niedrigere Mortalität aufweisen. Ein zweites Ziel war es, die Schlüpfzeitpunkte aus den Kokons mit dem Zeitpunkt des Verlassens der Brutnester in Verbindung zu setzen.

Nester der Blauen Mauerbiene wurden in zwei Obstpflanzungen (einer Mandelpflanzung in Californien und einer Apfelpflanzung in Utah) entweder in Brutboxen oder in Holzblocknestern ausgebracht. In die Brutboxen wurden zudem lose Kokons in Glasröhrchen gegeben. Während des jeweiligen Beobachtungszeitraums registrierten wir die Temperatur (Abb. 2, 3) und die Schlüpfzeitpunkte (Abb. 4, 5). Beim Vergleich der Schlüpf- und Überlebensraten von Bienen aus Brutboxen und Holzblöcken (Tab. I, II; Abb. 4, 5) zeigte sich folgendes. In den Brutboxen wärmten die Nester schneller auf und wurden für einen längeren Zeitraum pro Tag warmgehalten. Dies resultierte in einem früheren Schlupf aus den Kokons und in einer früheren Ausflugszeit (Tab. II). Ausser in einem Fall, in dem die Temperatur in der Brutbox bis auf 41 °C gestiegen waren, konnten wir keine Unterschiede in den Mortalitätsraten verzeichnen. Der Einsatz von Brutboxen erwies sich auch als erfolgreich, wenn es darum ging, die Wiederbenutzung alter Nester zu reduzieren.

Unsere Ergebnisse zeigen, dass der Einsatz von Brutboxen ein effizientes Verfahren darstellt, um die Schlüpfzeitpunkte zu verkürzen und damit den Einsatz von *Osmia lignaria* in der Bestäubung zu verbessern, insbesondere solange die Wetterbedingungen noch variabel und unvorhersehbar sind.

Megachilidae / *Osmia lignaria* / Blaue Mauerbiene / Brutbox / Bestäubung

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