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Observations of the nest structure of *Osmia inermis* (Hymenoptera: Megachilidae) from Newfoundland, Canada

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ABSTRACT

A nesting aggregation of *Osmia inermis* (Zetterstedt) (Hymenoptera: Megachilidae), discovered in rural Newfoundland, was excavated in August 2006 and measurements were made on the cocoons. In total, 169 cocoons containing pupae (85 ♀, 77 ♂) and prepupae were present in the aggregation. Except for seven cocoons containing larvae, all others contained pupae that, in most cases, were melanized. Cocoons containing female pupae were significantly larger (in width, length and cap diameter) than those containing male pupae. The size difference of the cocoon was reflected in a size difference in the pupae themselves, with females being significantly larger than the males. No incidence of parasitism was observed. Observation of pollen from pollen loafs remaining in the nest and from fecal pellets showed *Vaccinium angustifolium* to be the most important pollen source. This plant is also the most abundant flowering ericaceous shrub in the habitat during the time when the bees are foraging for pollen. The literature indicates that *Osmia inermis* is parsivoltine in other jurisdictions. However, observations of *Osmia inermis* from Newfoundland suggest that this species is likely univoltine. This is the first record of this species from Newfoundland.

RÉSUMÉ

Une nichée grégaire d'*Osmia inermis* (Zetterstedt) (Hymenoptera: Megachilidae) découverte à Terre-Neuve en zone rurale fut excavée en août 2006 et des mesures furent recueillies sur les cocons. Au total, 169 cocons renfermant des pupes (85 ♀, 77 ♂) et des prépupes s'y retrouvaient. À l'exception de sept cocons renfermant des larves, tous contenaient des pupes, dans la plupart des cas mélanisées. Les cocons renfermant des pupes femelles étaient significativement plus grands (en largeur, longueur et diamètre de la capsule) que ceux qui renfermaient des pupes mâles. La différence de taille chez les cocons était reflétée dans une différence de taille chez les pupes, les femelles étant significativement plus volumineuses que les mâles. Aucun parasitisme ne fut constaté. L'observation du pollen provenant de pelotes fécales et de pains de pollen demeurant dans le nid démontra que la source principale du pollen était *Vaccinium angustifolium*. Cette plante est l'éricacée arbustive la plus abondante au sein de l'habitat pendant la période où les abeilles sont à la recherche de pollen. La littérature indique qu'*Osmia inermis* est parsivoltine sous d'autres juridictions. Cependant, les observations d'*Osmia inermis* à Terre-Neuve suggèrent que cette espèce est probablement univoltine. Ceci représente le premier signalement de cette espèce à Terre-Neuve.

INTRODUCTION

The diversity of bees worldwide and their importance as pollinators has been well documented (Michener 2007). Because of the relative ease of observing and collecting adult bees, their morphology and forage behaviour have been studied for many species. However, in most instances bees nest in the ground and in other cryptic locations (e.g., under rocks or in the pithy stems of herbaceous plants), resulting is less knowledge of nest structure and behaviour for most species. Often the discovery of a bee nest is by chance. Determining nest structure and nesting habits of bees offers many insights to levels of sociality (Sakagami and Michener 1962), provides useful taxonomic information (Knerer and Atwood 1966), and has been used for construction of phylogenetic relationships between bee taxa (Bosch et al. 2001).

The bees of the family Megachilidae show diverse nesting habits (O'Toole and Raw 1999), but typically they construct a linear series of natal cells in a variety of substrates including soil, under or on rocks surfaces, on and in stems, in the

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nest of other bees and wasps, and in tunnels in wood left by wood-boring beetles. Even a snail shell is known to serve as a nest habitat for some species (O'Toole and Raw 1999).

The island of Newfoundland is the most easterly landmass in North America and its bee fauna reflects both its isolation from mainland North America and its climatic conditions. Presently, at least 47 species occur in Newfoundland and Labrador in 6 families (Appendix 1). Three of the bees on the list, *Bombus impatiens*, *Apis mellifera*, and *Megachile rotundata* have been introduced. *Bombus impatiens* and *Megachile rotundata* have not become established and *Apis mellifera* may be found around areas where people keep these bees but no feral *Apis mellifera* are known in NL. The adjacent region of mainland North America has almost 200 species recorded in 6 families (Sheffield et al. 2003; Sheffield et al. 2008). The eastern part of Newfoundland typically has a climate that is considerably moderated by the ocean that surrounds it. Its summers are cool (daily average temperature at Holyrood in June 11.9 °C) albeit short, with the earliest spring flowers showing in late May or early June. Newfoundland winters are cool with an average daily temperature in February of -3.9 °C but the cool temperatures extend to make a long season (see Appendix 2).

Osmia inermis (Zetterstedt) is an uncommon bee that has an holarctic distribution and is regarded as a boreal-alpine species. In Britain, it occurs only in the highland region of Scotland at elevations above 260 m (Else and Edwards 1996). On continental Europe it is known from northern Finland south to northern Spain and east to Greece (Warncke 1988) but is restricted to montaine areas. They are known to construct their nests under rocks (Sandhouse 1939) where several females may construct a few hundred cells from masticated leaf material (Cane and Sipes 2006). *Osmia inermis* has been recorded mainly from the north-eastern parts of North America from Labrador and Quebec in the north down to New York state; east to Nova Scotia and west to Wisconsin (Sandhouse 1939; Mitchell 1962; Sheffield et al. 2003).

The purpose of this paper is to describe the nest structure and habits of *Osmia inermis* for the first time from island of Newfoundland.

METHODS

Study location: The nest was found in June of 2006 and located about 10 m from the side of a secondary road in rural Newfoundland (47°25'46.29"N, 53°18'15.81"W) near the community of Colliers; 167 m in elevation. The nest was left undisturbed until 12 August 2006 when it was excavated.

Mensural characteristics: Upon excavation of the nest, the cocoons were removed and the length and width of each was measured (0.01 mm) using digital calipers. Each cocoon was then excised and the pupae removed, sexed based on number of antennae segments (12 for females, 13 for males), and the head width between the compound eyes was measured using a standard eyepiece micrometer at 8X magnification. Comparison of the means of measured variables between male and female bees was by a Student's t-test. Pollen from three provisions were placed on microscope slides and identified using the key provided by Crompton and Wojtas (1993).

RESULTS

The habitat that the nest was located in had a dry rocky soil with very shallow litter layer and large boulders distributed among the sparse coniferous trees (see Figure 1). The dominant coniferous tree species included larch (*Larix laricina* (Du Roi) K. Koch (Pinaceae)) with a smaller number of the balsam fir *(Abies balsamea* (L.) Mill. (Pinaceae)), black spruce (*Picea mariana* (Mill.) B.S.P. (Pinaceae)) and trailing juniper *(Juniperus horizontalis* Moen. (Cupressaceae)). Some mountain alder (*Alnus crispa* (Ait.) Pursh (Betulaceae)) was also located in the disturbed areas along the roadside. The entire area was dominated by ericaceous shrubs (Ericaceae) which included: lowbush blueberry (*Vaccinium angustifolium* Ait.), sheep-laurel (*Kalmia angustifolia* L.), Labrador tea (*Rhododendron groenlandicum* (Oeder) K.A. Kron & W.S. Judd, and rhodora (*Rhododendron canadense* (L.) Torr.). Ground pine clubmoss (*Lycopodium clavatum* L. (Lycopodiaceae)) and reindeer lichen (*Cladonia rangiferina* (L.) Nyl. (Cladoniaceae)) were also common in the area.

The nesting aggregation was found on the underside of a discarded heat shield from a vehicle catalytic converter (dimensions were 27 cm x 24 cm) (Figure 2). The nest was composed of three greenish to rust red mounds of masticated leaf material (Figure 2). There were some empty cocoons which were assumed to be from a previous year.

At the time that the nest was excavated, four adult female bees were collected from around the nest. In total, 169 cocoons where excavated from the nesting mass, plus three cells with pollen provisions but no larvae. Most of the cocoons contained pupal bees in varying degrees of melanization: 85 female pupae and 77 male pupae. Seven cocoons contained mature larvae and no pollen provisions were present. In two instances, cocoons contained a fully grown, intact bee larva along with two other larvae in the cocoon but no parasitism was

Figure 1. Habitat where *Osmia inermis* nest was located in eastern Newfoundland, Canada.

Figure 2. Nest of *Osmia inermis* located under discarded vehicle heat shield. Note adult female on top of middle mound. The white substance is powder applied before shield was turned over.

evident from the excised cocoons. Three of seven cocoons with larvae in them had shriveled, dark colored larvae.

The cocoons were dark brown to tan in color and oval in shape. There was a significant size difference in the cocoons with the female cocoons significantly larger than males (Table 1). Length and width of cocoons that had male pupae in them were significantly smaller than those that had female pupae (Table 1). At the anterior end there was a cap with a rounded nipple that was made up of loose fibers that appeared white. Michener (2007) suggested that the white cap of cocoons is incompletely filled in silk fibers that probably function for gas exchange. The diameter of the cap varied between male and female cocoons (Table 1). In addition, the size difference in cocoons was mirrored in the size of the pupae contained on the inside. Female pupae had a significantly wider head capsule than male pupae (Table 1). There was no significant difference in the size of the cocoons from different locations throughout the nest mass.

The fecal pellets were localized at one end of the cell. They retained their shape with a smooth surface and were round in cross-section. Some were straight while others slightly reflexed, 1.11 mm in length (SD = 0.258 mm, n = 17) and 0.36 mm in width (SD = 0.032 mm, n = 17) and are truncate at the tips. The color of the pellets was gray and different from the color of the provision.

The most common pollen grains contained in pollen loafs and fecal pellets were from *Vaccinium angustifolium*.

DISCUSSION

This is the first record of *Osmia inermis* occurring on the island of Newfoundland. While, in Scotland and mainland Europe, this species occurs mainly in montane regions, in Newfoundland the nest of *Osmia inermis* was located at 167 m above sea level and only 6.5 km from the shoreline. In Newfoundland the adult bees can be found early in June until the mid August while in Nova Scotia, the flight period is May and June (C. Sheffield, York University (YU), personal communication); in Scotland from late May until the end of July (Else and Edwards 1996); and April-May (lower latitudes) and July-August (higher latitudes) in the Swiss Alps (A. Mueller, ETH Zurich, personal communication). The late start to the flight period and its extending to mid August in Newfoundland is probably the result of the extended cool temperatures that the east coast of Newfoundland experiences during the summer as compared to mainland North America and elsewhere which results in a delay of flowering of native plants and subsequent late appearance of *Osmia inermis*. It also results in slowed development and the observed prolonged adult life span extending into mid August. It is interesting that the similarity of extended flight time with *Osmia inermis* in the Swiss Alps may be reflective of the similar cooler temperatures that may be experienced there.

Table 1. Measurement data for cocoons from an *Osmia inermis* nest aggregation located on the Avalon Peninsula, Newfoundland and Labrador, Canada. Comparison of means was by a Student's t-test.

Character (mm)	Female		Male		*p*
	mean	SD (n)	mean	SD (n)	
cocoon length	9.07	0.461 (81)	7.79	0.515 (75)	<0.001
cocoon width	5.38	0.245 (80)	4.47	0.329 (75)	<0.001
cocoon cap diameter	3.38	0.339 (73)	2.80	0.389 (72)	<0.001
pupal head width	3.45	0.110 (71)	2.81	0.167(72)	<0.001

The *Osmia inermis* nesting aggregation that was excavated in Newfoundland was similar to the nest described by Else and Edwards (1996) from Scotland; they uncovered large clusters of cells under stones which they assumed was the work of several females. Four adult bees were collected from around the nest and it is probable that other adult bees may have been involved in the construction of the nest mass but were not collected or observed on the day that excavation took place.

In Newfoundland, this bee species appears to be dependant primarily on the Ericaceae. When the bees are foraging in Newfoundland, *Vaccinium angustifolium, Kalmia angustifolia* and *Ledum groenlandicum* are common in the habitat and outnumber all of other flowering plants. Where Stubbs et al. (1992) found 10% of the pollen in pollen loads in Maine was from *Salix* (Salicaceae), no *Salix* pollen was located in Newfoundland bees, most likely due to the fact that *Salix* sp. in Newfoundland normally is finished blooming by the time the bee is foraging (H.E. Mann, Sir Wilfred Grenfell College (SWGC), personal communication). In Nova Scotia, adults are associated with *Vaccinium angustifolium* (C. Sheffield, YU, personal communication) while *Osmia inermis* in Scotland depends on the pollen from Birds-Foot Trefoil, *Lotus corniculatus* (Leguminosae) (Else and Edwards 1996). Since the flower morphology between these plant families are so very different, *Osmia inermis* should probably be considered an "eclectic" oligolege. This is consistent with other species of *Osmia* that are indisputably eclectic oligoleges (Cane and Sipes 2006). Unlike traditional oligoleges, bees that are termed eclectic oligoleges use pollen host genera belonging to widely separated clades (e.g., different families, even different orders) (Cane and Sipes 2006).

The term parsivoltine was coined by Torchio and Tedebino (1982) to describe bees species that have individuals of a brood completing their development in one or two years. *Osmia inermis* from Scotland showed a parsivoltine life history where a portion of the brood delayed their development and pupated in the second summer (Else and Edwards 1996). Smith (1851) also observed a large nest of *Osmia parietina* (later corrected to *Osmia inermis*) in Scotland in late November that had fully formed adults and developing larvae. Torchio and Tedebino (1982) showed that parsivoltism resulted in skewed sex ratios. However, it is not a life history that appears to be used by *Osmia inermis* from Newfoundland. The sex ratio of *Osmia inermis* pupae in Newfoundland was very close to equilibrium. In addition, if *Osmia inermis* was parsivoltine we would have expected to observe a portion of the nesting population as larvae when it was excavated in August. However, only 4 of 169 cocoons had larvae but with no provisions and 3 cocoons contained dead, shriveled larvae. Two of the seven cocoons contained more then one larvae (up to 3 in one case). I did not consider this as parasitism as the *Osmia* larvae were intact and fully grown.

It was proposed that large year to year fluctuations in weather and/or resources explain observed parsivoltine life histories (Torchio and Tedebino 1982). Intuitively, in such a situation one would expect an organism to be better off if it were to produce offspring that requires differing times to reach maturity. This would allow some offspring to survive unfavorable years and to reproduce when conditions and resources are more favorable (Torchio and Tedebino 1982). It is interesting to note that in Newfoundland during

May and June, there are often sudden periods of poor weather (cold temperatures, frost and even snow) that curtail bee activity and often kill developing flowers, thus depriving bees of forage suggesting that we should expect *Osmia inermis* populations to be parsivoltine. However, Torchio and Tededino (1982) determined that fluctuation in environmental conditions or resources was not the determining factor of the parsivoltine life history observed but instead that genetic polymorphism in developmental times of individual bees was a more accurate explanation producing the parsivoltism. Thus, based on the nest structure and composition at the time of excavation *Osmia inermis* in Newfoundland appears to be univoltine and not parsivoltine.

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Appendix 1. Bee species recorded from Newfoundland and Labrador up to June 2009. Data from D.J. Larsen, Memorial University, (unpublished) and original observations.

Family	Genus	Species
Apidae	*Bombus*	*borealis* Kirby 1837
	Bombus	*frigidus* Smith 1854
	Bombus	*melanopygus* Nylander 1848
	Bombus	*mixtus* Cresson 1878
	Bombus	*polaris* Curtis 1835
	Bombus	*sylvicola* Kirby 1837
	Bombus	*ternarius* Say 1837
	Bombus	*terricola* Kirby 1837
	Bombus	*vagans bolsteri* Franklin 1913
	Bombus	*impatiens* Cresson 1863**
	Psithyrus	*ashtoni* (Cresson 1864)
	Psithyrus	*fernaldae* (Franklin 1911)
	Apis	*mellifera* Linnaeus 1758*
Andrenidae	*Andrena*	*carolina* Viereck 1909
	Andrena	*clarkella* (Kirby 1802)
	Andrena	*frigida* Smith 1853
	Andrena	*milwaukeensis* Graenicher 1903
	Andrena	*nigrihirta* (Ashmead 1890)
	Andrena	*nivalis* Smith 1853
	Andrena	*rufosignata* Cockerell 1902
	Andrena	*thaspii* Graenicher 1903
	Andrena	*wilkella* (Kirby 1802)
Anthophoridae	*Nomada*	*valida* Smith 1854
	Nomada	*composita* Mitchell 1962
	Nomada	*cuneata* (Robertson 1903)
	Nomada	*cressonii* Robertson 1893
Halictidae	*Dialictus*	spp
	Lasioglossum (*Evylaeus*)	*foxii* (Robertson 1895)
	Lasioglossum (*Evylaeus*)	*quebecensis* (Crawford 1907)
	Lasioglossum (*Evylaeus*)	*truncatus* (Robertson 1901)
	Lasioglossum (*Evylaeus*)	*rufitarse* (Zetterstedt 1838)
	Lasioglossum	*cattellae* Ellis 1913
	Halictus	*rubicundus* (Christ 1791)
	Sphecodes	*solonis* Graenicher 1911
Colletidae	*Hylaeus*	*basalis* (Smith 1853)
	Hylaeus	*annulatus* (Linnaeus 1758)
	Hylaeus	*modestus* Say 1837
Megachilidae	*Megachile*	*centuncularis* (Linnaeus 1758)
	Megachile	*frigida* Smith 1853
	Megachile	*gemula gemula* Cresson 1878
	Megachile	*melanophaea* Smith 1853
	Megachile	*relativa* Cresson 1878
	Megachile	*rotundata* (Fabricius 1793)**

Appendix 1 (cont'd). Bee species recorded from Newfoundland and Labrador up to June 2009.

Family	Genus	Species
	Osmia	*bucephala* Cresson 1864
	Osmia	*caerulescens* (Linnaeus 1758)
	Osmia	*inermis* (Zetterstedt 1838)
	Osmia	*proxima* Cresson 1864

* Not surviving as feral colonies. Ocurring only in tended hives.
** Introduced for blueberry pollination. Not established.

Appendix 2. The averaged daily temperature at Holyrood, Newfoundland and Labrador, Canada (47° 27.000'N; 53° 6.000'W)(data obtained from Environment Canada Holyrood, online).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Daily Average (°C)	-3.2	-3.9	-0.9	3.1	7.4	11.9	16.3	16.8	13.1	8.5	4.0	-0.4
Daily Maximum (°C)	0.9	0.4	3.1	6.9	12.0	17.0	21.4	21.3	17.4	12.3	7.6	3.3
Daily Minimum (°C)	-7.2	-8.2	-4.9	-0.8	2.7	6.8	11.8	12.1	8.7	4.7	0.5	-4.1