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Evidence of leafcutter bees (*Megachile*) using plastic flagging as nesting material

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Abstract. Leafcutter bees (*Megachile* Latreille) occasionally cut anthropogenic plastics in addition to natural leaves used for nest construction. We document new observations of bees cutting yellow and orange plastic flagging and compare the visual reflectance of plastics with that of commonly used leaves. Reflectance patterns showed clear differences between plastics and leaves, suggesting that plastic use is unlikely to be driven by visual similarity and may instead represent opportunistic or maladaptive behavior.

INTRODUCTION

Solitary bees in the genus *Megachile* Latreille play an important role in natural and agricultural pollination (Pitts-Singer & Cane, 2011) and are well known for cutting circular leaf pieces used to construct nest cells (Wilson & Carril, 2015). *Megachile*, in addition to having specific preferences for pollen and nectar sources that vary by species, also show preferences for the types of leaves they use to line their nests (Kambili *et al*., 2017; Sinu & Bronstein, 2018). While the preferences for nesting materials seem to vary by geographic location, broad patterns have been observed, particularly a preference for leaves from plants in the rose family (Rosaceae) (Sinu & Bronstein, 2018). Once a female bee has selected a nesting location, she will repeatedly cut small round circular pieces out of a nearby leaf using her mandibles that she carries back to the nest. A female will use around 11 leaf pieces to construct a single nest cell, in which she deposits pollen and nectar and lays an egg (Eickwort *et al*., 1981; Torretta *et al*., 2012).

Although these bees normally rely on plant material for use in nesting, several recent studies report *Megachile* harvesting plastic waste for nest construction (MacIvor & Moore, 2013; Gess & Roosenschoon, 2017; Allasino *et al*., 2019). These findings have led some authors to speculate that plastic incorporation may represent a novel adaptive behavior in response to anthropogenic change. However, the potential consequences of plastic use remain poorly understood. Plastic-lined nest cells retain moisture, promote

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fungal growth, and have been associated with larval mortality rates approaching 90% (Stephen & Every, 1970).

While *Megachile* are increasingly being observed using plastics, it remains unknown why this is happening. It has been suggested that the increasing use of plastics might be due to limitation of vegetation in some agricultural areas, causing bees to select plastic waste as an "ecologically adaptive trait" (MacIvor & Moore, 2013; Allasino *et al*., 2019). While we hesitate to draw a similar conclusion, it remains unknown what environmental cues, such as color or reflectance, might play any role in nesting material selection.

Reflectance, as it is used here, refers to the fraction of incoming light that a surface reflects back, and it can be described as a wavelength-specific signature across the visible spectrum (here, we quantify reflectance from 400–700 nm). Because bees rely heavily on vision (Chittka & Raine, 2006), differences in surface reflectance can translate into differences in how materials appear to a bee under natural light. Bee color vision is typically mediated by three photoreceptor classes (UV, blue, and green), and bees routinely use visual cues like color, brightness/contrast, and spectral reflectance patterns to locate and discriminate floral resources during foraging (Chittka & Raine, 2006). This visual ecology raises a basic (and previously under-developed) possibility for nest-material choice: if leafcutter bees visually assess candidate materials, then color/reflectance could be one cue among several (*e.g*., availability, texture, thickness, or odor) that might influence plastic cutting, motivating our test of whether commonly used leaves and plastic flagging show similar spectral reflectance.

Here we document two cases of leafcutter bees cutting plastic flagging: yellow plastic flagging in 2009 and orange plastic flagging in 2019. We evaluate whether these plastics resemble natural leaves in spectral reflectance. We hypothesize that the plastic flagging will have similar reflectance to natural leaves, causing the bees to confuse the plastic flagging for their natural nesting materials.

It should be mentioned that a previous version of this paper that only described the observation of leafcutter bee using plastic flagging was published in 2020 in an online journal. Subsequently, the journal lost funding and went under, deleting the website and all papers associated with it. Here, we not only report the observations that were originally published in the now defunct online journal, we also add reflectance data to further investigate this observation.

MATERIAL AND METHODS

Plastic flagging displaying semicircular cutouts characteristic of *Megachile* was collected in Douglas, Arizona, USA on 30 July 2009 (yellow flagging) and 10 September 2019 (orange flagging). Flagging was originally deployed for landscaping purposes. The immediate area contained a redbud (Fabaceae: *Cercis occidentalis* Torr. ex Gray) tree showing minor leafcutting activity. Ornamental rose bushes (*Rosa x hybrid*) were also present in the neighborhood, but it is unknown if these showed evidence of leafcutter bee activity. Nests were not located, and the cutting bees were not collected and therefore could not be identified to species. In addition to the yellow and orange flagging, pink flagging was used on the property but had no evidence of use by bees.

To test the hypothesis that bees may select plastics with leaf-like optical properties, we measured reflectance (400–700 nm) of the orange and yellow flagging cut by bees, as well as pink flagging (both fresh and sun-faded), red and blue plastic tape occasionally used outside, and leaves from three rose varieties (red, lavender, and pink). Reflectance was measured using an Ocean Optics Flame spectrometer with a krypton light source and fiber-optic probe, calibrated to a white standard. Measurements were expressed as relative reflectance (%) compared to a white standard, which represents approximately 100% reflectance across the measured wavelengths. Each sample spectrum therefore represents the proportion of light reflected by the material relative to the white standard.

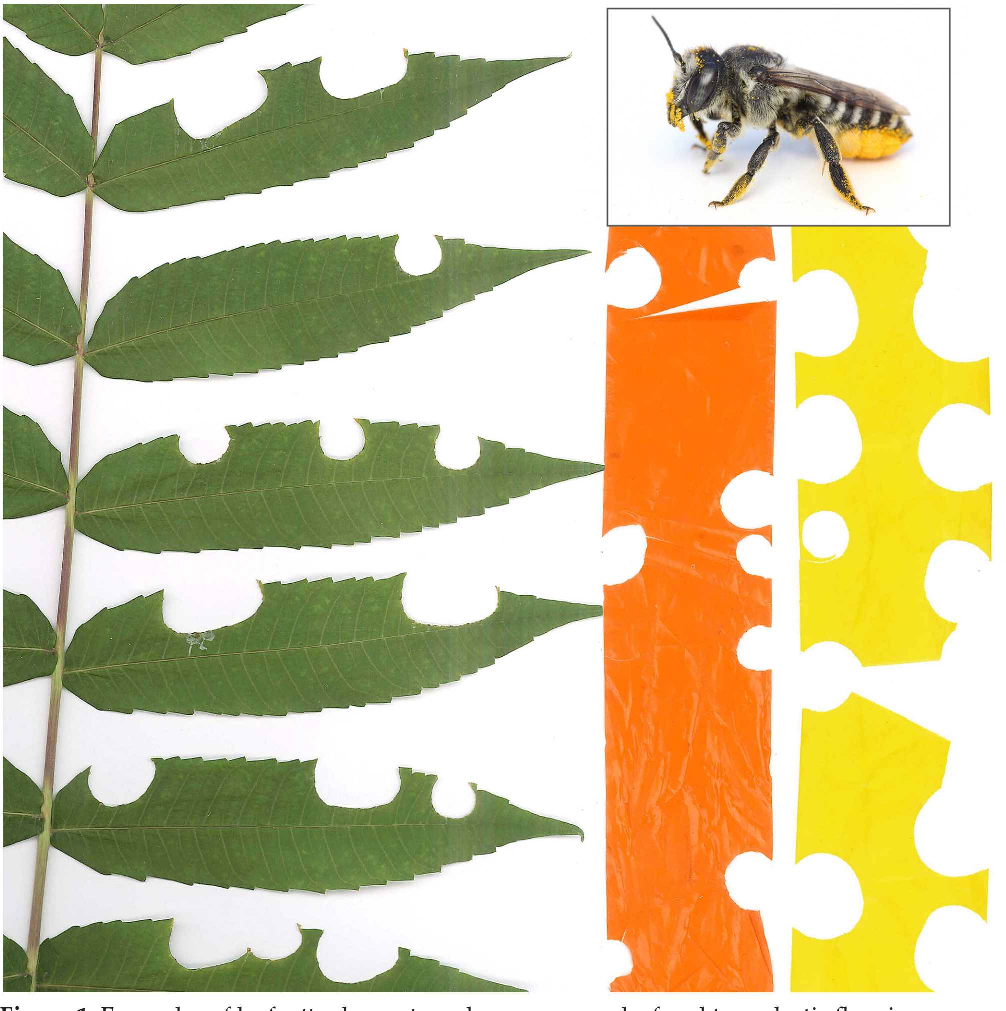

Figure 1. Examples of leafcutter bee cut marks on a sumac leaf and two plastic flagging analyzed in this study.

Each sample was measured three times and averaged, and a 25-point moving average was applied to smooth the curves. Reflectance was measured only from 400–700 nm, corresponding to the visible range recorded by the spectrometer and light source used in this study; ultraviolet wavelengths (<400 nm), although detectable by bees, were not measured due to instrument limitations.

Because the goal of this study was exploratory, assessing whether plastic and leaf materials showed broadly similar reflectance patterns, no formal statistical comparisons were performed. Instead, reflectance curves were visually compared across wavelengths to evaluate overall similarities and differences between plastic flagging and natural leaf materials.

RESULTS AND DISCUSSION

Both yellow and orange flagging showed clear semicircular cut marks nearly identical to those produced by *Megachile* during leaf harvesting, even when observing them under a microscope (Fig. 1). The yellow flagging contained at least 18 distinct cutouts, while the orange flagging had eight semicircles and two partially removed pieces. These quantities indicate that the cutting bee likely harvested enough material to construct one or more nest cells, either entirely from plastic or mixed with natural leaf pieces, consistent with previous reports (MacIvor & Moore, 2013; Allasino *et al.*, 2019).

Contrary to the initial hypothesis that plastic use might be influenced by visual resemblance to natural leaves, our reflectance measurements revealed no similarity between leaf and plastic reflectance. The rose leaves exhibited low reflectance (generally ~10–30%) across the entire 400–700 nm range (Fig. 2), with a small peak at about 520–570 nm, which matches reflectance data from other studies (Bergstrand *et al.*, 2016). In contrast, the yellow and orange plastics showed extremely high, broad reflectance, often exceeding 80–90%, and did not match the shape, magnitude, or wavelength-specific patterns of any leaves measured (Fig. 2). Other plastics (pink, faded pink, red, and blue) also showed curves distinct from those of leaves. Visual comparison of the reflectance data showed clear differences between plastic materials and rose leaves across much of the measured wavelength range. Because the goal of this study was exploratory and based on a limited number of material samples, we did not conduct formal statistical comparisons of reflectance values. However, these results suggest that bees are likely not selecting plastics because they visually mimic foliage.

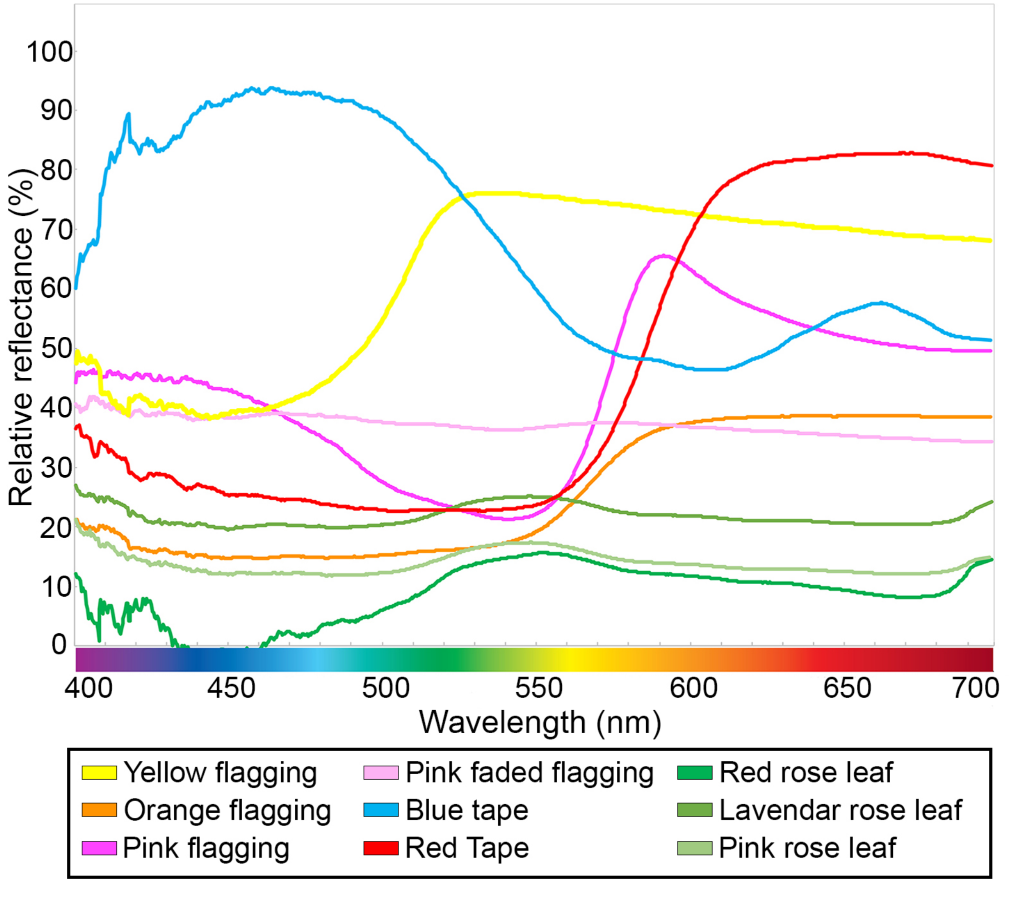

Figure 2. Graph showing the reflectance profiles of the yellow and orange flagging used by bees, rose leaves, and various other materials.

Some leafcutter bees have also been reported to incorporate flower petals into nest construction (*e.g.*, Michener, 2007), suggesting that bees may occasionally select materials with different textures or colors than typical leaf pieces. Although petals were not included in the present analysis and no evidence of petal use by leafcutter bees was observed at the study site, comparing petal reflectance with plastics could provide an interesting avenue for future work.

Given the absence of reflectance similarity, plastic use by *Megachile* is more simply explained as opportunistic or mistaken behavior rather than an adaptive response. This interpretation aligns with the known negative effects of plastic nest substrates, including moisture retention and mold-associated mortality (Stephen & Every, 1970). Reports of plastic-only nest cells frequently document dead larvae, incomplete cells, or cells of uncertain outcome (Allasino *et al.*, 2019), further supporting the view that plastic incorporation is potentially maladaptive.

Although plastic use remains rare, its increasing documentation suggests that plastic waste, including plastic flagging commonly used in ecological and construction settings, continues to present novel hazards to cavity-nesting bees. Because our data show that bees do not appear to be visually "confusing" plastics with leaves, reducing bees' access to plastic materials remains the most straightforward way to prevent their incorporation into nests. We recommend avoiding yellow and orange plastic flagging near habitats with leafcutter bees or replacing plastic materials with biodegradable natural-fiber alternatives that pose lower risks to developing larvae.

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