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NOTES AND COMMENTS

The use of an unmanned aerial vehicle (UAV) to investigate aspects of honey bee drone congregation areas (DCAs)

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Unmanned aerial vehicles (UAVs) are a relatively new method of acquiring scientific data in a variety of applications and although their use has expanded greatly in recent years there has been no evaluation of the use of UAVs in the investigation of honey bee drone congregation areas (DCAs). This scientific note describes the advantages of using a UAV for locating DCAs and investigating DCA boundaries in difficult terrain and adverse wind conditions. A Phantom Vision 2 Unmanned Arial Vehicle video camera drone fitted with an artificial queen bee was used to examine DCAs in a mountainous, bush clad area in the Wellington area of New Zealand. The UAV was able to investigate areas not easily accessible on foot and impassable for vehicles, and was able to investigate areas upwind of the operator. Results suggest that the directionality of a UAV is useful in investigating DCAs and helping to determine their boundaries in areas of difficult terrain in the Wellington area of New Zealand.

Keywords: drone honey bee; *Apis mellifera* L; honey bee mating; drone congregation areas (DCAs); unmanned aerial vehicle (UAV); drone; queen pheromone; (E)-9-oxodec-2-enoic acid (9-ODA)

During the breeding season, western honey bee (*Apis mellifera* L.) drones mate with virgin honey bee queens in flight. Drones are thought to congregate in certain, defined areas called drone congregation areas (DCAs). Several drones will mate with a virgin queen that flies through the area on her mating flight (Gries & Koeniger, 1996). The factors that determine the presence of DCAs or their boundaries are still comparatively unknown (Scheiner et al., 2013). Although not all mating events take place at DCAs, these congregations appear to be important for honey bee reproductive behavior (Koeniger et al. 2005).

Study of DCAs is important because such areas may have practical uses for genetically controlled mating in bee breeding programs and could be used to delimit conservation areas for subspecies of honey bees (Ruttner, 1976). This aspect assumes greater importance in view of the global spread of exotic diseases and the growing resistance to treatments (Aizen & Harder, 2009; Neumann & Carreck, 2010; Oldroyd, 2007).

Finding and determining DCAs is a time consuming business which hinders research into these areas, and carrying out research into the parameters of DCAs once found, can be difficult, especially in remote areas. Radar monitoring has been used in this role, but is expensive, and the effectiveness of this method can be limited by the local terrain, vegetation, and man-made features (Loper, Wolf, & Taylor, 1987). Landscape analysis methods investigated by Galindo Cardona et al. (2012) have also been used in determining the location of DCAs. Most research into the flight behavior of drones in DCAs and DCA boundaries has been conducted using helium balloons or kites holding aloft an artificial queen impregnated with queen pheromone (E)-9-oxodec-2-enoic acid (9-ODA), or dead queens, or tethering live queens to a line (Mortensen & Ellis, 2014; Muerrle, Hepburn, & Radloff, 2007; Ruttner, 1985).

These methods are effective in most cases, but even in ideal conditions, balloons and kites suffer from a lack of directionality. For example, a balloon cannot easily be sent to a particular area over a tree line or river, or over an area of impenetrable bush to locate a DCA or test DCA boundaries, unless the wind is blowing in the right direction. Wind direction therefore often dictates the days on which investigation of certain inaccessible areas can be carried out. Even then, intervening tree lines can often prove a barrier because of the possibility of line entanglement. And even in ideal conditions, balloons and kites cannot be used in certain areas inaccessible on foot or by vehicle due to their distance from access points. Because of these limitations, it was difficult and at times impossible to effectively research some possible DCA locations and possible DCA boundaries in the difficult terrain of the Wellington area of New Zealand using balloons or kites.

For example, I was not able to effectively investigate with balloons two river valley areas which were separated from the main valley area by the river, high tree lines and dense bush (Figure 1). Relying on balloons, I was only able to investigate these areas if the wind was blowing in the right direction, but even then, tree lines often prevented success due to the risk of line

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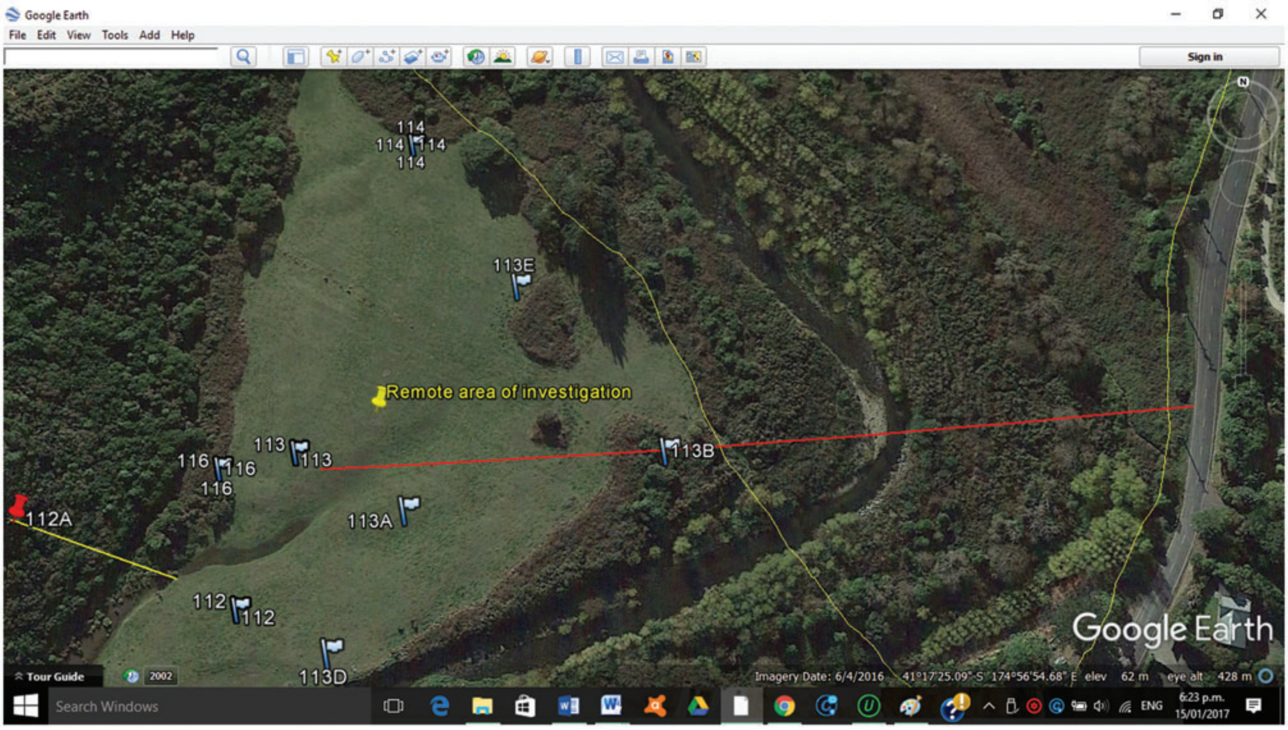

Figure 1. One of the areas investigated by the UAV in the Wainuiomata River Valley that was inaccessible by vehicle and accessible by foot only with great difficulty through dense bush and a fast flowing river.
Note: The red line shows the UAV approach line to the area and is between 250 and 300 m long.

entanglement. Furthermore, with the long line required to drift the balloon to the remote areas, I was then unable to vary the height of the balloon to test for drone reaction at different heights. Another limiting factor was that due to the distances involved in sending a balloon to these areas, and because of intervening vegetation, it was almost impossible to determine drone activity visually, even using binoculars. Only a difficult river crossing and cutting through areas of bush to reach the sites (not legal in National Parks) would have enabled effective use of balloons for this task.

However, using an unmanned aerial vehicle (UAV) equipped with an inbuilt, moveable video camera, I was able to investigate DCAs in an extensive hill and valley area and determine their boundaries. The UAV could be flown over tree lines, rivers and areas of bush that were impassable or inaccessible on foot, regardless of wind direction, and it could stream live video back to the operator and record this activity for later analysis. The rising sides of the valley, covered in dense bush could also be easily investigated. The inbuilt camera recorded the time of appearance of drones, the development of, and disappearance of drone comets, and showed when drone activity began and dropped off in both vertical and horizontal dimensions.

The UAV (Figure 2), can fly up to 15 m per second (54 km/h), in any direction, and it can fly in winds up to 27 km/h, enabling it to fly any conditions in which drone bees fly. It is not affected by strong gusty winds due to its GPS positioning system which prevents it moving in

Figure 2. Phantom 2 Vision UAV rising to investigate any height limit to drone activity.

space unless directed. The rechargeable battery lasts for around 25 min. I attached a 90 cm light wood, cylindrical probe extending out to the front of the machine in line with the video camera. The attachment device weighed about 90 grams in total. (The UAV can carry over a kilogram of extra weight). The extension is designed to keep drone bees and drone comets away from the downdraft of the rotors, although downwash turbulence sometimes appeared to initially confuse the bees as to the nearby source of the pheromone. For the purposes of my investigations, this was not a factor. The queen was made from a small 3×0.5 cm piece of dowel covered in a soft cloth, and attached to the probe by a stiff wire. The artificial queen was impregnated with 1 mg of 9ODA in solution with 0.5 ml acetone.

Using a camera equipped UAV, DCAs can be accurately and rapidly investigated in any conditions in which drone bees fly, and over any terrain. This enables one researcher to rapidly investigate areas not accessible on foot or by vehicle such as river areas, swamps, over tree lines or areas of dense bush; and areas upwind of the operating site. This is not always be possible using kites or balloons. The results so far suggest that this method is useful in investigating DCAs in conditions that would be difficult if not impossible if using balloons and kites. Further investigation into the advantages of using UAVs for this type of research is recommended.

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