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The coming revolution: the use of drones in plant conservation

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Although the origin of Unmanned Aircraft Systems (UASs)—commonly known as "drones"—can be traced to the early 20th century (Dalamagkidis *et al*., 2012), they became popular to the general public after September 11 terrorist attacks as a result of their use in intelligence and military operations. In recent years, however, plenty of civilian uses have emerged. Drones are currently used or tested in search-and-rescue missions, for surveillance (e.g. to patrol borders), to produce high-resolution maps, for fire detection, for crop monitoring, as a transportation system (for example for delivering goods and medicines), and even for filmmaking. Drones are also increasingly used in scientific research, with special emphasis on the fields of meteorology (Richardson, 2014), geology (Marris, 2013), archaeology (Wade, 2014), and biology (Ogden, 2013; Schiffman, 2014).

Uses of drones in biology are manifold, mostly related to forestry and wildlife management. Regarding forestry, uses include forest monitoring, forest cover mapping, pest monitoring (and pest control), fire control, and illegal harvesting of timber (see Paneque-Gálvez *et al*., 2014 for a review). Drones are also increasingly used in many aspects of wildlife management and conservation. They have been proved to be very useful in fighting poachers, being employed at present to control elephant, rhino, and tiger poaching in Africa (Lunstrum, 2014; Marks, 2014; Mulero-Pázmány *et al*., 2014), India (Hussain, 2013) or Nepal (WWF, 2012). Drones have also been used to monitor several "flagship" animal species worldwide, such as flamingos in United Arab Emirates (Swan, 2014), orangutans in Sumatra (Koh & Wich, 2012), or sperm whales in New Zealand (NOAA, 2013). Recently, drones have been employed as an additional sampling tool for the Lake Merritt (California, USA) Bioblitz, carried out in early 2014 (Thaler, 2014).

At present the use of drones in plant species conservation remains, however, virtually unexplored; our revision of both academic and non-academic literature has failed to find any reference to applications related to the conservation of rare and/or endangered plants. Drones might be a great aid for conservation biologists who study plant species that occur in inaccessible or complicated terrain, e.g. steep cliffs and caves. Drones equipped with sensors and cameras represent a safe and cheap alternative to hiring professional climbers or to using manned planes or helicopters. With just a brief glance at the *The Wall of the Dead: A memorial to fallen naturalists* (Coniff, 2011*a*, *b*), one may realize how big is the potential of drones to save human lives (or simply to avoid injuries). In addition to saving costs and human lives, drones may increase efficiency in research, especially in tasks such as species surveys, censuses, and monitoring. A single mission with a "first-generation" drone (typically of 15 min) may allow taking hundreds of photos and georeferencing dozens of individuals (Fig. 1A, B). "Second-generation" drones—capable of much longer flights (see below)—and equipped with real-time video cameras will substantially reduce the time needed for reconnaissance level-surveys. Another advantage of drone usage is that undesirable effects of trampling and habitat disturbance can be avoided; this is particularly important when the target species is located within a protected area (where special care is required), or when the target species co-occurs with other endangered species; drones may also prevent the accidental trampling of the target species, a common negative impact when monitoring activities are carried out (J. López-Pujol, pers. obs.).

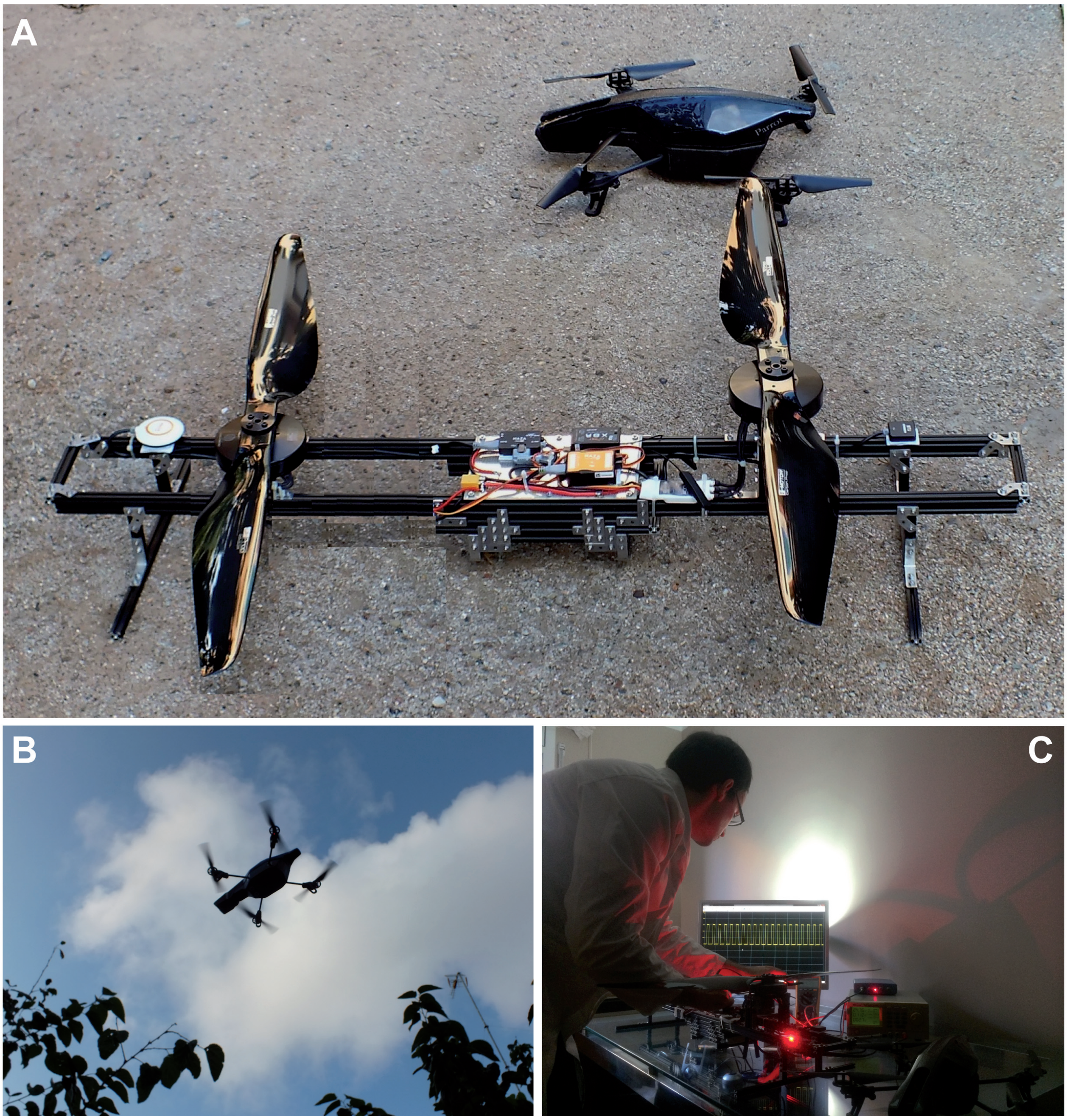

Figure 1. (A), in the foreground, our prototype of second-generation drone; in the background, a "typical" first-generation drone; (B), flight test with the first-generation drone to evaluate its ability to carry out censuses of plant populations; our drone proved to be far more versatile than binoculars and/or naked eye in observing and counting the number of individuals in inaccessible places; (C), C. Sánchez-Bou working on the development of our prototype of second-generation drone.

Drones used in biology are usually quadrotor-propelled UASs. Although much more versatile than fixed-wing drones due to their capability to remain stationary (see below), they have very limited flight times. Although literature shows flight times up to or over 25 minutes and payloads up to 2 kg (Paneque-Gálvez *et al*., 2014), flight times actually shrink to 15 minutes with moderate payloads (see also Luo *et al*., 2014). In addition, these first-generation drones are only capable of taking off and flying under very stable anticyclone meteorological conditions, with no wind and no turbulences. Since wind conditions may change a few meters above the floor, safe flights are only warranted up to 30 m from the ground. Moreover, radio frequency coverage limits drone operation to about 100 m in direct vision; if there are several obstacles between the drone and the operator, the flight range could be reduced to just a few tens of meters. The alternative to multi-rotor drones, the fixed-wing drones—those propelled by a single motor and relying on wings to keep them in the air—can reach longer flight times expanding their operating range to several kilometres (Koh & Wich, 2012; Paneque-Gálvez *et al*., 2014). However, their payloads are lower than multirotor drones, which may compromise the performance of the video camera and other sensors that can be carried. Moreover, fixed-wing drones are not capable of stationary flights, which is a requirement for most of the uses envisaged for plant species conservation.

The first author of this letter (C. Sánchez-Bou) is developing a second-generation quadrotor drone (Fig. 1A, C) under the scientific advice of the second author (J. López-Pujol) which will overcome some of the shortcomings mentioned above. Our prototype has been designed specifically to meet our goals in plant conservation through a series of key improvements. First, it carries more efficient electric rotors with improved thrust and high-lift propellers, which deliver a much higher thrust-to-weight ratio compared to the extant drones. These new features will at least double actual flight times and allow carrying professional payloads. Second, our prototype's standard payload will be composed of a high-definition video camera with high-resolution optical zoom to allow professional video and photography capturing. With an optical zoom, a close approach to the plant is not required to capture high-quality images, thereby saving power and reducing the risk of collision. A 3D electronically-controlled mechanical structure (a gimbal) will keep the camera focused on the object of interest irrespective of the drone's flight course (thus, avoiding the effects of pitch, roll, or yaw). Third, our prototype uses a GPS-aided, precise flight controller which, coupled with a low-drag fuselage and the advanced propulsion system explained above, will provide stable flights in mild windy conditions (until now, quadrotor drones were able to fly only in non-wind conditions). Finally, the traditional radio controller will be complemented with two additional radio frequency systems. One of them will be a high power Wi-Fi transceiver with high-gain antennas, whereas the second consists of a 3G/4G modem; both systems increase radio frequency coverage—especially where 3G/4G coverage is available, while permitting the reception of real-time data (such as images, GPS data and on-board sensors telemetry) and achieving a more precise control of the aircraft.

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