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EYES IN THE SKY: **DRONES PROVING THEIR VALUE IN PLANT CONSERVATION**

The National Tropical Botanical Garden in Hawaii is implementing new technologies to support its important plant conservation work

Introduction:

Drone; Unmanned Aerial Vehicle (UAV); Small Unmanned Aircraft System (sUAS). Whatever you may decide to call them, they have an undeniable presence. While there are many instances of drones causing problems, this article is aimed at highlighting the positive effects the technology can have in plant conservation. As with many other emerging technologies, drone technology is progressing at a startling rate. This has led to drones with increased functionality at a reduced cost. These changes are creating excellent opportunities for both small and large organizations to apply UAV tools to complex conservation problems. The National Tropical Botanical Garden (NTBG) has been doing extensive testing and development to implement these new technologies.

Discovery: *Hibiscadelpus woodii*

Originally discovered in 1991 by NTBG Research Biologist Ken Wood, the amazing *Hibiscadelphus woodii* (Malvacae) was known from only four individuals. The species was described by Dr. David Lorence and Dr. Warren Wagner in 1995 and given the name *Hibiscadelphus woodii*, in honor of its discoverer. Over the next two decades, scientists at NTBG would give their all to protect this species.

Kalalau Valley is known to be the most floristically diverse valley in the entire Hawaiian archipelago, and the *H. woodii's* extreme habitat along the rim meant it was only accessible via rappelling on ropes. Three of the individuals were killed in 1998 when the highly-eroded landscape around them came tumbling down. The lone remaining plant survived until it was found deceased in 2011. The species was lost. In fact, the entire genus was almost extinct, with only one of seven known *Hibiscadelphus* still extant.

In early 2018, NTBG submitted a proposal to the Mohamed bin Zayed Species Conservation Fund specifically aimed at finding the "thought-to-be-extinct" *Hibiscadelphus woodii*. This species was selected because the steep habitat had been nearly impossible to survey and drones were unlocking these hard to reach areas. Thankfully the application was accepted, and with the new funding we expanded our drone toolkit.

Above: Using drones for inventory - Wilkesia hobdyi *(Ben Nyberg)*
Top: Drones for discovery – looking for Hibiscadelphus *in the Kalalau valley (Ben Nyberg)*

Field surveys commenced during the extremely wet summer of 2018, which led to many challenges. Misty and rainy conditions severely limited our survey days and damaged the equipment. In January of 2019, the weather started improving and our work resumed. A steep, long downhill hike leads to the very edge of the Kalalau cliffs where we launch the drone. From that location, the quadcopter descended an additional 250-350 meters. One drone battery provides approximately 25 minutes of flight, which allows collection of 40-50 photographs. After multiple flights, we had checked the main area of interest with no apparent *H. woodii*.

Binoculars aided in the selection of a secondary survey area, one valley over and much further down the surface. Indicator species, such as the silvery *Nototrichium sandwicense* hinted at an intact native cliff system. The drone descended into position but windy, misty conditions made plant identification difficult. I collected many photos hoping to catch a glimpse of the small yellow flower.

Post-processing of the imagery was underway back in the computer lab at NTBG's Botanical Research Center. As I slowly checked through the images without a sighting, disappointment was setting in. The process is extremely time consuming and tedious, but occasionally there are sparks of excitement. That spark came when I saw an interesting plant in the lower right corner of photo #228. I had never seen the *Hibiscadelphus* in person, so I quickly contacted Ken to ask for his help in identification.

We examined herbarium specimens and historic photos from the original discovery. When we revisited the drone photo on my computer, the mood soon became joyous. We had rediscovered *Hibiscadelphus woodii*!

Excitement and energy gave way to focus and determination. Additional surveys were needed to confirm the identification. Three consecutive days were rained out, but the on fourth day, the drone assisted in relocating the individual we had originally sighted plus an additional two individuals. High-resolution video was captured to assess potential access routes, but the cliffs are simply too sheer and dangerous for humans to reach the plants. Future work is planned with the goal of finding additional populations in more accessible locations so the plant material can be collected and brought into *ex situ* conservation.

Discovery: Limahuli Valley

Due to difficulty with regulations and permitting, our initial drone testing began in NTBG's Limahuli Garden and Preserve. This valley is over 1,000 acres and is managed almost exclusively by our staff. It provided a location on private property with limited air traffic and wide variety of rare plants. While Kalalau may be the most-biodiverse valley in the state, Limahuli is a close second. A series of vertical rock spires are a distinguishing feature of the area, that until recently had never been surveyed. As the surveys commenced, we immediately started uncovering rare plant populations. The Plant Extinction Prevention Program (PEPP) manages species with fewer than 50 individuals remaining and drones aided in the discovery of three species they work on. We were able to identify and map 75 *Plantago princeps* var *anomala* (Plantaginaceae, previously known from only 25 individuals) and over 200 *Euphorbia eleanoriae* (Euphorbiaceae, previously known from 40 individuals). These Kauai endemics were both new records for the valley and the findings significantly expanded their known habitat.

Hibiscadelphus woodii *(Ken Wood)*

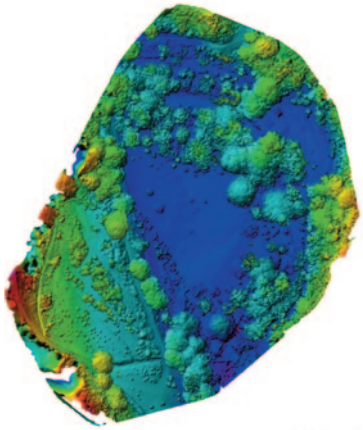
In the Garden- imagery and mapping:

Botanical gardens may vary in size or location, but almost all gardens rely on accurate and up-to-date maps. A common and extremely valuable application of remote flying aircrafts is the high-resolution on-demand imagery they produce. Prior to drones, comparable data sets would be expensive and time-consuming to create. This new technology can provide hundreds of acres of imagery and digital elevation models in a matter of hours. NTBG has found the output products helpful in mapping living collections, surveying damage from natural disasters, analysis of terrain for garden expansion, digitizing garden features and producing high quality paper maps.

Inventory and monitoring: *Wilkesia hobdyi*

Wilkesia hobdyi (Asteraceae) offers another intriguing case for the use of drones. This species grows in dry coastal cliff habitat and is distinctive in its size and color. The IUCN Red List for *W. hobdyi* estimated a total population of 750-809 individuals, which placed it in the Critically Endangered category. A concerted effort has been made to visit each known population and early results have been staggering. In-depth survey and counting has revealed at least 6,000 individuals. New populations have been documented in three locations, two of which are areas where it has not been found before; directly ocean-facing and on dry south facing slopes.

Imagery



Digital Elevation Model

Left: Ken Wood surveying with binoculars (Ben Nyberg)
Below left: Drones for discovery – Limahuli Valley (Ben Nyberg)

The Future:

NTBG is prioritizing the further development of drone technology to create a comprehensive plant conservation toolkit.

- Ongoing research with the University of Sherbrooke is aimed at customizing sampling mechanisms to remotely collect plant material such as seeds or cuttings. This setup will allow us to reach unreachable plants.
- AI and machine-learning have the potential to significantly reduce the time spent in the lab. post-processing photographic data. With proper training, these complex software solutions can identify individual plants and tabulate the information.
- Drones rely on a solid satellite lock to maintain their spatial awareness. Many locations that we survey have limited GPS reception, meaning the flights can be difficult, inaccurate and dangerous. There is work underway to find navigation systems that will function in these challenging environments.

While drones are currently proving to be effective tools, evolution of the technology has the potential to provide ground-breaking results for botanical conservation.

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As part of these counts we have employed a new system in which a pilot and observer (with spotting scope) position themselves across the valley from the plants. With an improved vantage point, the observer directs the UAV into areas where plants occur to collect photos and GPS points. Once the photos are post-processed and mapped, the data can be used to guide seed collection of the species. Specific seed-bearing plants are selected and tie-in locations identified from the photos. The collector can then rappel directly down to the individual, effectively taking all guesswork out of the equation, while increasing both efficiency and safety.

Inventory and monitoring: *Pritchardia flynnii*

Drones allow botanists to cover large areas in limited time. A great example of this is our surveys for *Pritchardia flynnii* (Arecaceae, Loulu palm). *Pritchardia* is a genus of fan palms endemic to tropical Pacific islands with an extremely diverse group in the Hawaiian Islands. Due to its distinct look and size in the canopy, it makes a great candidate for mapping with drones. I highlight this species to illustrate the expansive area that can be surveyed in just one day. On August 8, 2018, NTBG staff were able to cover two square kilometers (500 acres) of steep and challenging terrain while mapping 158 *Pritchardia flynnii* trees. All photos that are collected include high-resolution GPS points allowing for mapping and navigation to specific individuals. Traditional field survey would have taken much longer with less complete results.

Drones for inventory - Pritchardia flynnii *(Ben Nyberg)*