## Title

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# Five Years of Progress: A Summary of the Current Capabilities for Drone-Based Delivery of Rodenticide for Rodent Eradication Projects

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**ABSTRACT:** Invasive rodent species represent a principal threat to global biodiversity and ecosystem integrity, particularly on islands. The development of aerial dispersal of rodenticide bait from helicopters in the 1990s was a major innovation credited with driving an increase in the scale, scope, and pace of successful eradication attempts. Helicopter-based operations can, however, be logistically complex and prohibitively costly, particularly on islands that are small and remote. Uncrewed aerial vehicles (or "drones") have been identified as a promising tool to enable bait distribution on sites for which helicopter or ground-based methods are unfeasible. We report on the early evolution of this tool, documenting six drone-assisted rodent suppression and eradication programs widely spread across the Pacific. Drones were transportable on aircraft, cars, and small vessels, offering cost savings and logistical efficiency when compared with helicopters. They also proved to be a viable means of aerial bait dispersal: broadcasting 17,400 kg over an area of 796 ha across all programs. However, we encountered limitations associated with the technology in its current form. Flight plans initially took weeks to prepare, required detailed spatial data, and were not readily altered in real time during operations. The platforms we used were constrained by their lithium power source, needing extensive and time-consuming battery charging support and limiting payload capacity and endurance. Reliability issues, overcome in later projects, led to delays and abandonment of some parts of projects and necessitated the preparation and implementation of alternative methods as back-ups. Though key advancements − such as increased payload capacity and endurance − are imminent, a broad suite of improvements are needed for this method to be widely adopted. In their current form, drones provide a niche option for bait distribution on islands too large for hand-spreading of bait and where remoteness, precision, or safety considerations may limit the use of piloted aircraft. If future strategic investments in technology and people can be properly directed, drones have the potential to make the eradication of invasive rodent populations an achievable goal for a broader set of practitioners, democratizing a critically important conservation intervention.

**KEY WORDS**: aerial application, control methods, drones, ecosystem restoration, island conservation, management, rats, *Rattus*, rodent eradication, UAV

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## INTRODUCTION

Invasive mammalian predators are major drivers of biodiversity loss globally, having been implicated in the majority of recent extinctions of mammal, bird, and reptile species (Doherty et al. 2016). Invasive rodents are principal agents of this, driving habitat degradation and extinction in sensitive systems, particularly islands (Towns et al. 2006, Harris 2009, St Clair 2011). This has stimulated the development of methods to remove invasive rodent populations from areas of conservation concern. Over the last 100 years there have been more than 900 documented rodent eradication attempts across more than 700 islands, with a success rate of 88% (Spatz et al. 2022). These have acted as foundational conservation interventions for species and ecosystem recoveries with cascading benefits to island communities, near-shore coastal ecosystems, and climate resilience (Jones et al. 2016, de Wit et al. 2020, Kappes et al. 2021, Sandin et al. 2022). Aerial broadcast of rodenticide baits using helicopters represented a major innovation accelerating eradication techniques from the 1990s, allowing treatment over challenging terrain and larger areas (Howald et al. 2007, Spatz et al. 2022). These approaches are, however, typically several times more expensive to plan and implement than ground-based methods (Holmes et al. 2015). This is particularly true for islands that are small and remote, where helicopter deployment and standby costs have a major impact on project expenditure (Donlan and Wilcox 2007, Holmes et al. 2015), likely prohibitively so in many contexts. Further, precision of aerial-based bait applications is often cited as a potential reason for eradication failure and the risk of bait entering the marine environment or other sensitive boundary areas can have significant regulatory and operational implications (Will et al. 2019, Samaniego et al. 2021). There is an urgent need for cost-effective methods that deliver the benefits of aerial bait broadcast to areas where island topography prevents access for ground-based methods, and remoteness, size, or sensitivity preclude helicopter operations.

Given their ease of transport, maneuverability, and ability to closely follow pre-programmed flight plans, uncrewed aerial vehicles (hereafter "drones") have emerged in recent years with the potential to meet this need. Drones are gradually expanding the conservation toolkit (Robinson et al. 2022), offering a growing set of applications including seed dispersal (Mohan et al. 2021), habitat assessment and mapping (Sierra-Escrigas et al. 2020), and wildlife population monitoring (Hodgson et al. 2016). Their potential as an integral technology in the next generation of rodent eradications has been heralded, but their usage for control of pest species has been limited outside of an agricultural context (Campbell et al. 2015, Morley et. al 2017). Here, we report on the earliest tests of this method, documenting the first projects to use drones to broadcast rodenticide as part of a rodent eradication attempt or predator suppression initiative. We highlight important considerations for practitioners, detailing the strengths and limitations of current drone platforms, as well as identifying key advancements currently in development.

## METHODS

### Context

We report on six operations using drone technology to broadcast rodenticide bait (see Table 1), taking place between 2019 and 2023. Five of these were eradication projects focused on islands widely spread across the pacific: on Ngerkeklau in Palau; Nukufeta'u, Nukufotu, Nukuloa, Nukuafo, Nuku'lae'lae, Luaniva, and Fugalei Islets, henceforth 'Wallis Islets', in Wallis and Futuna; Motu Oa, Takae, and Mokohe off Ua Pou in the Marquesas Islands; Kamaka in French Polynesia; and Seymour Norte in the Galápagos Islands. One mainland predator suppression operation took place in South Ōkārito, New Zealand. A further three projects (Ulong and Ngerchur in Palau, and Tetiaroa in French Polynesia) planned to use drones but ultimately switched to other methods or were delayed. An objective of all operations was the suppression or eradication of one to two species of rodent at each site. Species involved were the black rat (*Rattus rattus*), brown rat (*R. norvegicus*), Asian house rat (*R. tanezumi*), and Polynesian rat (*R. exulans*).

### Equipment, Software, and Personnel

The ENV10 drone platform (Envico Technologies, New Zealand) 1 × 1 m, weighing 12 kg was developed and refined throughout these operations (Figure 1). The first variant used on Seymour Norte was powered by two 12s LiPo 44V4 batteries, delivering a nominal endurance of 15

**Figure 1. Photo by Island Conservation of the ENV10 (Envico Technologies, New Zealand) multirotor drone during the boat-based operation on the Wallis Islets in Wallis and Futuna in 2022.**

**Table 1. Summary of rodent eradication operations using drones to broadcast bait**

| Location | Target species | Year | Area | Bait Volume | Productivity | Notes |
|---|---|---|---|---|---|---|
| Seymour Norte, Galapagos | *Rattus rattus, Rattus norvegicus.* | 2019 | 184 ha | 3,000 kg @ 6 kg/ha of brodifacoum bait | 2 days with 2 ENV10 drones<br><br>87-97 kg/hr<br><br>Flight altitude of 30m | *Due to mechanical issues with the bait buckets, only 97 ha (53%) of the island was treated using drone during the first application of bait, with the remaining 87 ha completed by hand. The second application was completed entirely using drone.* |
| South Ōkārito, New Zealand | *Rattus rattus, Trichosurus vulpecula* | 2021 | 360 ha | 870 kg @ 2 kg/ha of 1080 bait | 14 kg/hr with ENV10 drone<br><br>Flight altitude of 60m | *Used to achieve precision deployment of 1080 to sensitive areas. Complementing helicopter and hand broadcast techniques as part of broader mainland predator elimination project.* |
| Ngerkeklau, Palau | *Rattus tanezumi, Rattus exulans* | 2022 | 8 ha | 700 kg @ 40 kg/ha of brodifacoum bait | 1 day with 1 ENV50 drone: 200 kg/hr<br><br>1 day with 1 ENV10 drone: 96 kg/hr<br><br>Flight altitude of 30m | *First attempt at using heavy lift ENV50 (50 kg payload) drone. Multiple mechanical failures led to the abandonment of attempts to apply bait to two further islands and the completion of the second bait application on Ngerkeklau using the smaller ENV10 (10 kg payload) drone.* |
| Kamaka, French Polynesia | *Rattus exulans* | 2022 | 50 ha | 6,210 kg @30 kg/ha of brodifacoum bait | 10 days with 1 ENV10 drone 80kg/hr<br><br>Flight altitude of 260m with coastal baiting at 80m | *Challenging terrain and weather resulted in a prolonged − though successful - baiting operation.* |
| Wallis Islets (9), Wallis and Futuna | *Rattus exulans* | 2022 | 148 ha | 5,450 kg @20 kg/ha of brodifacoum bait | 9 Days with 1 ENV10 drone<br><br>70 kg/hr<br><br>Flight altitude between 90 and 120 m depending on topography | *Successful deployment from barge across nine islands.* |
| Motu Takae, Motu Oa, and Motu Mokohe, Ua Pou, Marquesas | *Rattus exulans* | 2023 | 46 ha | 1,170 kg @ 25 kg/ha of brodifacoum bait | 6 days with 1 ENV10 drone<br><br>10 kg/hr | *Boat-based operation. Strong winds and swells lead to considerable delays and resulted in just two of three islands being adequately treated. Motu Mokohe received a single uncomplete application.* |

minutes with a payload of 20 kg. A specialized bait spreader bucket with 10 kg bait capacity was mounted directly to the airframe. Bait was fed through a T-bar spinner whose speed could be varied alongside flight speed to modulate bait application rates. Bait dispersion was configurable to a 360° swath (up to 70 m), 180° directional swath (up to 25 m), or narrow swath (18 m) as required. Further, the ENV50 (Envico Technologies, New Zealand), a prototype all-electric heavy lift drone 2.7 × 2.7 m, weighing 80 kg with a payload of 50 kg, was developed based on the ENV10 platform and bait spreader, and used for part of the operation on Ngerkeklau, Palau.

Custom flight planner and management software were built to establish flight patterns, flight altitudes, coastal perimeter flights, bait exclusion zones, and automatically generate flight and bait density maps. High resolution (<10 cm) drone-derived orthomosaic and digital surface models were collected prior to each project to develop flight plans. In general, baiting strategies followed conventional helicopter bait application strategies with parallel straight lines using the 360° configuration with 50% overlap in the interior and coastal perimeter flights above the high tide water line using the 180° directional swath or narrow swath as needed. A downward-facing camera was mounted to monitor bait flow in real time, linked to a flight management system to deliver semi-autonomous distribution according to pre-programmed flight plans. Drones maintained constant communication and video transmission using 900 MHz telemetry systems. The bait spreader could be turned on and off autonomously based on pre-programmed bait start/stop points or remotely via the flight controller. The spreader's on/off state was recorded by the flight management system for export and further interpretation.

Treatment areas could be broken up into different blocks based on the optimal flight line orientation, elevation, or distance from a load site. Flight altitudes typically targeted 20-30 meters above ground level. However, the drones were not capable of autonomous terrain-following while baiting, and a fixed flight altitude was determined for each treatment block based on the highest elevation point or anticipated maximum vegetation height. Where the island had significant terrain (>30m), sites generally used two flight altitudes one for the interior of the island based on the highest elevation point and one for the coastal treatment zones.

Drone operational teams consisted of at least two flight personnel but generally three to four personnel: one acting as pilot in command, and the others logging flight data, monitoring bait flow, managing the flight management system, and generating bait density maps. In all cases at least two drones were on site to facilitate continuous operation and operational redundancy, with a single drone flown at a time.

## RESULTS AND DISCUSSION

17,400 kg of brodifacoum bait was successfully deployed on a combined area of 796 ha across six projects, with supplementary hand broadcasting in some instances (see Table 1). The mainland South Ōkārito operations were part of a larger project combining helicopter, hand, and drone broadcast to suppress predators within a 100,000-ha area. Five of five island eradications (Seymour Norte, Ngerkeklau, Kamaka, Wallis Islets, and Ua Pou islets) have been confirmed as successful. While demonstrating the potential for drones to successfully implement rodent eradication in a variety of real-world operational settings and defining their unique value proposition and capabilities, these operations also highlighted considerable limitations and challenges associated with the technology in its current state.

### Regulatory Restrictions

Regulatory regimes varied across the operations. The drone platforms were first tested, registered and approved for the aerially dispersal of rodenticides by the New Zealand Civil Aviation Authority, providing a basis for regulatory permission with the aviation authorities in other jurisdictions. In all cases, special use permits were required to aerially disperse rodenticides and required that operations maintained visual line-of-sight using an observer in direct communication with the pilot.

### Logistical Considerations

Transport of aviation equipment to field sites can be prohibitively complex and costly. This is especially true for deployment of helicopters for extended periods to remote islands, which require chartering of large, specialist vessels. By contrast, both the ENV10 and ENV50 were designed so that the arm mounts could be disconnected from the main body and frame, making it possible to break the drone down into multiple, smaller cases meeting the maximum dimension of commercial flight luggage. Thus, they were straightforward to transport, and were carried as accompanied luggage on international and domestic commercial flights, transported in the back of a small car, and ferried on small vessels (<20 m). This ease of transport was particularly advantageous on Kamaka and Ua Pou where transport options were limited, eliminating extended charter times and associated costs compared to helicopters.

Lithium-ion polymer batteries could not be flown commercially, however, and required freight over land and sea. Lead times of 3-4 months were required to ensure that batteries arrived in time, particularly given COVID-19 related global shipping delays at the time of these operations. Batteries were generally disposed of after the project or retained in-country in long-term storage with the potential to support future eradication attempts. To maintain continuous operations, batteries were changed after each flight and recharged on one of two or more multi-port charging stations. Batteries were charged in natural or constructed shade via portable or boat-based generators (6.5 kW or greater) with a charge time of approximately 10 minutes per battery. Seymour Norte, Wallis, and Ua Pou were all boat or barge-based operations due to the need for multiple load sites, lack of coastal access, and desire to minimize bait handling and damage. Kamaka, elevation of 160 m, was a land-based operation which required the establishment of a radio communications antenna and 500 m of fiber optic cable to maintain communication with the drone on the other side of the island. This cable was chewed by rats on the first day of the operation, resulting in a delay until a protected replacement could be obtained.

### Pre-flight Planning Requirements

A key asset of drone-based platforms was their ability to follow pre-programed plans defining flight paths, altitude, and treatment and exclusion areas. However, these required very high resolution (<10 cm) imagery and digital surface models covering the areas concerned, necessitating specific scoping trips to map the sites in advance often at a substantial additional cost. During the initial operations these flight plans took several weeks to months to prepare, but that time was greatly reduced with pre-operational mapping flights and flight plan development completed within a matter of days on later projects. In contrast to helicopter-based operations, real time alteration of flight plans was challenging, leading to a degree of inflexibility if conditions in the field or accuracy of bait deployment did not conform to expectations. For example, a spiral flight plan used in South Ōkārito left unexpected gaps in bait coverage, which required flying additional lines to address. Manual alterations were also necessary to account for inaccuracies in the drone-derived digital surface models and vegetation blocking planned flight lines during this operation. On Kamaka, most of the island was treated at a high altitude (260 m) with coastal baiting done at much lower altitude (80 m) due to programming and communication limitations, where ideally it would have been treated at an altitudinal gradient maintaining a consistent height above ground level.

### Capacity for Precise and Consistent Baiting

Consistent flight speeds, precise GPS controlled adherence to pre-programmed flight plans, and the ability to modulate bait flow via small incremental changes in flight speed (e.g., 0.1 m/s) meant that drones were capable of a level of precision control not achievable with helicopters.

This allowed for the targeting of smaller treatment areas, as well as stricter adherence to defined boundaries. For the large-scale mainland project in South Ōkārito, drones complemented hand- and helicopter-based methods, delivering precise baiting of remote sensitive boundary areas.

**Lift Capacity, Endurance, and Sensitivity to Wind and Sea Conditions**

The low endurance of the lithium battery power source imposed considerable limitations on the baiting productivity of current drone platforms. Batteries drained rapidly and charged slowly, creating a time limiting step within the workflow, even when multiple batteries and generators were used. Consequently, although the lift capacity of the ENV10 was up to 20 kg depending on configuration, the actual payload used was optimized to 10 kg to extend range and reduce delays in charging batteries. A helicopter, by contrast, can carry payloads up to 1,300 kg (Broome 2009, Garden et al. 2017). Drones carrying 10 kg were able to fly for about 10-15 minutes before needing to return to swap batteries and refill bait. This placed a constraint on the area that could realistically be covered and created the need for multiple loading sites in some instances. The productivity realized for these drones across a variety of contexts ranged from 13 to 97 kg of bait deployed per hour (see Table 1).

The ENV50, a heavy lift drone capable of carrying 45 kg, was used for one application of bait to the 8-ha island of Ngerkeklau, Palau, achieving a productivity of 200 kg of bait deployed per hour. This demonstration of the increased potential productivity of drones was cut short by mechanical failure in both ENV50 models used for the operation (see *Reliability*, below).

Endurance, application rate, and application accuracy were further impacted by wind, with a limited capacity to operate effectively in winds exceeding 15 knots. This is a lower tolerance than that of helicopters, which can apply bait in winds up to 20 knots (notwithstanding higher bait drift in these conditions). Bait drift from target lines due to wind was a problem during the Kamaka operation, requiring additional flights along reprogrammed paths to resolve. During the Ua Pou operation, persistent southeast trade winds were often above the drone operational wind tolerance, limiting treatment days. Moreover, constant wind meant a low swell was always present, even in the lee of the three target islands. This made take-offs and landings problematic from the shallow-draft ship being used to operate from, and one island was not completed as its orientation did not provide shelter from the prevailing swell direction. Using a ship with a deeper displacement and hard chine would have reduced the rolling motion and reduced drone launching and recovery duration and risk.

**Reliability**

Reliability remains a consideration in planning drone operations. During the first project − on Seymour Norte, Galápagos Islands − mechanical issues with both spreader buckets stopped drone flights and forced 47% of the island (87 ha) to be completed by hand broadcast. This problem was resolved in time to complete the second application of bait entirely by drone. During the Palau project, two units of the heavy lift ENV50 model were grounded due to multiple mechanical failures after a single application of bait had been completed on 8 ha Ngerkeklau.

Adoption of a novel technology during the early stages of its development inevitably incurs an elevated risk of failure. But as the sources of problems are identified and equipment and procedures refined, this risk is reduced. It is notable that the most significant reliability issues occurred during the earliest deployments of the respective drone models. All ENV10 operations subsequent to Seymour Norte were successfully implemented with no major mechanical issues, demonstrating marked improvements in reliability and efficiency through time.

**Cost**

Aerial broadcast of bait is a powerful tool for rodent eradication, but the cost of helicopter operations can be a major obstacle to its adoption. This is especially the case for islands that are small and remote, and in places where helicopter infrastructure and pilot experience is limited. The comparative ease and affordability of transporting drones to project sites (see *Logistical considerations* above) provides a promising cost-effective alternative, especially in contexts where terrain or target area size impair the viability of hand broadcast options.

Eventual project costs will be impacted by several additional factors, which impinge on the different broadcast methods in varying ways depending on context. Bait application by hand generally requires more personnel than aerial applications (for example, completing the first application of bait on Seymour Norte (87 ha) by hand required more than 30 people, compared with the 6 people required for drone operations), while drone applications have a greater requirement for specialist personnel (2-3 skilled pilots for each of the projects described here). Aerial broadcasts also require investment in obtaining regulatory approval and licensing for pilots and operations as appropriate to the jurisdiction.

Prolonging project duration can have a multiplicative effect on various costs, such as those associated with personnel and vessel charter. While the time required for hand- and drone-based methods to cover equivalent areas will vary depending on the number of personnel and drones committed, in practice both take considerably longer than helicopters. A single application of bait on Kamaka took 5 days using a drone, whereas this took less than 6 hours during the helicopter-based attempt in 2015. Reliability issues and limited wind tolerance caused delays to planned activities and necessitated investment in planning ground-based methods as contingencies in the event of equipment failure.

The most cost-effective bait broadcast method is therefore highly dependent on project context. Bait application by drones on Seymour Norte in the Galapagos was estimated at half the cost of using helicopters, delivering an approximately 15% saving on overall project costs. The early stages of development of a technology might be expected to be associated with elevated costs, and so it is encouraging that drones have already proven to be the most cost-effective option for multiple projects. The proportion of projects for which this is true should increase as technology becomes more powerful, refined, and widespread.

**Priority Advancements to Improve Utility for Baiting Applications**

Drone technology for island eradication has evolved significantly over the course of the five years and six operations reported here, yet major barriers remain to wide scale use and adoption. Based on our experiences, the following priority advancements are needed to increase the usability and performance of drones for rodent eradications: 1) improved flight endurance capabilities carrying payloads 25 kg or greater for 45 minutes or longer 2) alternative power sources which would simplify logistics by avoiding the constraints of lithium power units 3) improved mission planning software to adjust flight parameters such as orientation, altitude, and exclusion zones during an operation 4) improved communication capabilities, operating procedures, and regulatory approval to enable Beyond Visual Line of Sight operations 5) simplified flight management systems and operating procedures to reduce personnel requirements and expertise 6) physical mechanisms on the bait spreader that can modulate bait flow so that application rates are not solely reliant on flight speed 7) capability, procedures, and approval to fly more than one drone with a single pilot 8) autonomous terrain following and dynamic flow rate control so that drones can maintain a desired application rate as terrain, speed, and other parameters change and, 9) proven reliability in a variety of diverse, harsh coastal environments.

As of the 2024, there are multiple new platforms under development, from electric multi-rotor models with increased payload capacities of 25-50 kg to uncrewed diesel- or petrol-powered helicopters with payload capacities up to 200 kg, and hybrid power units offering intermediate capacities (e.g., SA-200 Syos Aerospace, New Zealand; ENV50 Envico Technologies, New Zealand, and Firefly, Parallel Flight Technologies, United States). However, investments in flight management systems, hardware, and operational know-how are equally as important as developing the platforms themselves. Building long-term relationships with vendors that understand the whole context of rodent eradications and can build end-to-end solutions will be the key to success. Based on our experience, future developments should not underestimate the costs, timelines, and risks of building reliable drone solutions for rodent eradications and, despite the temptation, approach the development of bespoke one-off solutions with a high degree of caution.

## CONCLUSIONS

The progression of projects implemented via drones over the last five years demonstrates both the ability to implement increasingly complex projects and current limitations compared to conventional tools. Drones have now been implemented in a variety of international operational contexts including sites with steep terrain, open-ocean conditions, and spanning multi-island complexes with application rates up to 40 kg/ha. From an end-user perspective the operational parameters and limitations for small all-electric drones are now well defined and near a level of maturity that they could be transitioned to other entities and increasingly replicated over the next 5 years. Currently available all-electric drones like the ENV10 are a reliable and proven system for treating islands up to 200 ha depending on operational requirements, logistics, and expertise. Further, by testing the limits of current drone capabilities these projects have defined the requirements for the next generation of drone developments that will enable landscape scale aerial broadcasts on sites 1,000 ha or greater.

Cost is a frequently cited reason for pursuing alternatives to helicopter-based aerial eradication. While drones are now a reliable alternative option for some islands, cost is only one of several factors that should be considered when selecting an eradication method. We highlighted several logistical, planning, and operational constraints and their cost implications to inform decision making for future projects considering drone based aerial broadcast - several of which can only be addressed by larger drones with larger payloads and longer flight duration.

As with any new tool, innovation requires calculated risk-taking and baiting drones were no exception. As early adopters we needed a higher risk tolerance, diligent risk management, and an ability to work within new and unknown operational constraints. Three of the eight total island projects planning to use drones (Ulong, Ngechur, Tetiaroa) were delayed, abandoned, or later implemented via alternative methods because of unforeseen setbacks. We have subsequently built drone baiting specific checklists and an assessment framework to apply to future developments and mitigate risk. That being said, three of the five island sites (Kamaka, Wallis Islets, and Ua Pou) would not have been attempted in the last five years without the availability of drone technology.

In our experience, projects should remain open to all baiting options and are only limiting themselves if they consider one method (e.g., drones or helicopters) as the only viable option. Drones are now one of several tools in the eradication toolbox, and ideally suited for specific settings. Further developments in flight time, payload capacity, power source, and flight management are needed to make them more directly competitive with helicopters at large landscape scales. However, the strategies deployed by drones to date have largely mirrored those of helicopter operations and have not yet been designed to maximize the unique capabilities of drones. Night-time operations, operations in fog or low visibility, multi-drone swarms, remotely stationed and activated "drone-in-a-box", or automated-precision applications along sensitive boundaries are all unique use cases that could offer complementary or novel operational capabilities improving future eradication efficiency or enabling eradications on projects otherwise currently not feasible.

The next five years of technological development offer much excitement and hope for an improved eradication toolkit and the democratization of aerial rodent eradications on sites that are currently beyond the reach of conventional helicopter and ground-based methods. Given their niche capabilities, numerous island sites and organizations with limited helicopter availability would benefit from access to drone technology. Coordinated and significant investments in technology and people are needed to make drones an equitably and readily available global method and would benefit from communities of practice and public-private partnerships. Given the current biodiversity and climate crises facing islands, tools that improve the scale, scope, and pace of island restoration are urgently needed − and drones are undoubtedly poised to play a major role.

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