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The potential of using Unmanned Aerial Vehicles (UAVs) for precision pest control of possums (*Trichosurus vulpecula*)

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Abstract

Unmanned Aerial Vehicles (UAVs) and remote image sensing cameras have considerable potential for use in pest control operations. UAVs equipped with remote sensing cameras could be flown over forests and remnant bush sites, particularly those not currently receiving any pest control, to record the unique spectral signature of the vegetation and to detect the presence of possums (*Trichosurus vulpecula*) and the damage they cause. UAVs could then be deployed to precisely distribute either toxins or kill traps to these identified locations. Predator-free 2050 is an ambitious policy announced by the New Zealand Government where several pests, including possums, are to be eradicated by the year 2050. In order to achieve this goal, pests must be identified, targeted and controlled, requiring creative and novel ideas. UAVs provide flexibility, can fly in remote and difficult terrain, and are considerably cheaper to purchase and operate than the planes and helicopters currently used in conventional aerial pest control operations. Current challenges associated with UAVs include payload capacity, battery limitations, weather, and flying restrictions. However, these issues are rapidly being resolved with sophisticated technological advances and improved regulations. A directed and targeted approach using UAVs is an additional and novel tool in the pest management toolbox that could significantly reduce pest control costs, cover inaccessible areas not receiving any pest management, and will help New Zealand advance towards its predator-free aspiration by 2050.

Keywords

New Zealand, pest control, forest, Predator-free 2050

INTRODUCTION

Remotely Piloted Aerial Systems (RPAS) or Unmanned Aerial Vehicles (UAVs) are affordable, have miniaturised GPS receivers with sophisticated navigational capability, and are able to provide accurate high-tech remote sensing imagery (Bagheri 2017). Their use in the applied sciences has developed rapidly due to their operational flexibility and ability to capture high-resolution geospatial information (Shahbazi et al., 2014). Multispectral and hyperspectral sensors attached to UAVs can be flown over most terrain to assess the health of the vegetation below (Shang et al. 2015; Pullanagari et al. 2016). Hyperspectral sensors are able to detect plant stress through colour changes, enabling detection of leaf disease and tree damage (Ehsani and Maja 2013; Honkavaara et al. 2016). Intelligent flight management systems and Geographical Information System (GIS) analysis platforms can now generate repeatable and accurate surveys providing characterisation of many biological variables, including vegetation (Eisenbeiss 2009; Strecha et al. 2012; Heaphy et al. 2017; Huang et al. 2017).

UAVs are routinely being used to: estimate tree crown diameters, tree fall and canopy openness (Inoue et al. 2014; Panagiotidis et al. 2017; Perroy et al. 2017); detect and map invasive species (Gonzalez et al. 2016; Müllerová et al. 2017); detect nutrient and water deficiencies in agricultural crops (Gago et al. 2014; Salamí et al. 2014; Martínez et al. 2017); and assist in the management of insect pests (Faiçal et al. 2014; Näsi et al. 2015; Severtson et al. 2016). UAVs are also being trialled to deliver merchandise from retailers, such as Amazon's "Prime Air" service (Amazon 2017). Operational regulations are rapidly advancing, especially in New Zealand (CAA; Price, *personal communication*), allowing UAVs to be deployed for an even wider range of activities (Perroy et al. 2017; Torresan et al. 2017). Here, we propose another use for UAVs.

New Zealand's landscape (26.8 million ha) is diverse, with glaciers, fiords, rugged mountains, vast rolling alluvial plains, volcanic plateaus, geothermal zones and over 15,000 kms of coastline. Viewed aerially, New Zealand is a mosaic of natural forest managed mainly by the Department of Conservation (DOC), commercial plantation forests, agricultural land (with numerous small shelterbelts and bush remnants predominantly in steep gullies), lakes, rivers, small reserves, and urban areas. Ownership and administration of this fragmented landscape is equally fragmented, involving numerous landowners and councils, multiple land management practices, and a wide range of views about the need for and value of pest management.

CURRENT STATUS OF PEST CONTROL IN NEW ZEALAND

About 10 million ha of land in New Zealand is already under active pest management for a variety of conservation, agricultural and economic reasons (Russell et al. 2015; Byrom et al. 2016; Parkes et al. 2017). Currently, two thirds of this pest management work is done by 380 pest-control groups or entities, many of which are voluntary and work relatively close to urban centres (Department of Conservation 2016a; Peters et al. 2016; LINZ 2017). Most of this is ground-control work is time-consuming and costly. For example, investment by a significant funding agency, the Natural Heritage Fund, only controlled pests over 1.3 percent of New Zealand's land over the last 25 years (Department of Conservation, 2016a).

Most of the more difficult and remote terrain is managed aerially by broadcasting 1080 (sodium fluoroacetate) to control pests (Goldson et al. 2015; Byrom et al. 2016). In 2014, 1080 was applied to over 694,000 ha during a mast seeding year to protect native birds (Elliot and Kemp 2016), with 845,839 ha planned for an expected mast seeding event in 2017 (Department of Conservation, 2016b). Mast seeding years are now known to create massive predatory pressures on native wildlife (King and Moller 1997). In 2015/16, TBfree NZ controlled brushtail possums (*Trichosurus vulpecula*) over 5,883,107 ha using both aerial and ground procedures, freeing 1.5 million ha from the threat of bovine tuberculosis (TB: *Mycobacterium bovis*). An additional 1 million ha is planned to be TBfree by 2026 (OSPRI 2016).

Many current pest control methodologies are limited in scope. For example, the control methods used on islands or isolated locations cannot be deployed on many parts of the mainland for social and ecological reasons (Parliamentary Commissioner for the Environment 2011; Niemiec et al. 2017), ground-control operators cannot work in hazardous terrain, and for financial reasons, helicopters or fixed-wing aircraft are not used to control pests over small areas. Not surprisingly, areas with low pest numbers are quickly excluded when budgets tighten. Possums and some other pest mammals carry TB, and are therefore a threat to farm animals. Thus, a significant portion of the funding for pest management in agricultural areas is due to management of TB in pest populations. If TB disappears, so does the funding.

The Department of Conservation manages about 8.6 million hectares for the Crown (Department of Conservation 2016a). However, financial constraints mean that some areas are ignored. For example, the Waima and Mataraua Forests in Northland (c. 4000 ha) are called 'ghost forests' by the local communities because they receive no sustained pest control (Baigent-Mercer 2015). Tongariro Forest Park (15,000 ha) is an important stewardship area that received aerial pest control in 2001 and again in 2014 (OSPRI 2016). Such sporadic control likely means multiple source opportunities for pest reinvasion. Thus, the status quo delivers regular and large-scale compromises on the overall viability of pest control and New Zealand cannot become predator-free using current approaches. At best, current methods deliver short-term biodiversity protection and a requirement for further investment (Griffiths and Barron 2016).

Other issues affecting sustainability of pest management include a requirement to obtain consents to undertake poisoning operations in some areas and cultural issues in relation to resource ownership by indigenous Māori (Jacobson and Stephens 2009). Further, a lack of coordination of pest control efforts by different management entities can result in a lack of synchrony between adjacent pest control operations.

Despite the enormous investment and ongoing pest control work, many parts of New Zealand still receive little or no pest control including many commercial and private forests, agricultural land with patches of bush/forest, localised reserves, and alpine areas.

These areas may be geographically inaccessible, have low pest numbers, or have restricted access, and can support reservoir pest populations when pest control is undertaken nearby. Unfortunately, the large-scale pest management programmes run by organisations such as DOC or TBfree NZ (Department of Conservation, 2016a; OSPRI, 2016) are potentially compromised because adjacent areas may receive no pest control.

PREDATOR FREE 2050

New Zealand is an acknowledged leader in the development and application of pest management methods, for example, to protect biodiversity or eliminate TB (Gormley et al. 2015; Holmes et al. 2015; Jones et al. 2016). Recently, the New Zealand government announced an ambitious policy to be "Predator-free New Zealand" by 2050. This ambitious concept targets eradication of introduced mammalian pests, including possums and an array of rodents and mustelids (Russell et al. 2015). The policy will require innovative ideas and technologies and a holistic synchronised effort by all landowners across New Zealand (Niemiec et al. 2017).

Realistically, the reliance on thousands of trap-lines and aerially bombarding some large remote areas with 1080 every few years (Byrom et al. 2016) is ultimately unsustainable. Consequently, in order to be predator-free by 2050, there needs to be a quantum shift in current thinking and practice. UAVs offer one such opportunity. We therefore propose deploying UAVs, first, as a monitoring tool to detect possums and the damage they cause (Dandois and Ellis 2013; Lisein et al. 2013; Zahawi et al. 2015), and second, to deliver a precise load of toxin (or kill-traps) to populations not currently under any control programme. This approach would reduce a reliance on labour-intensive and often imprecise monitoring systems such as the foliar browse index (Payton et al. 1999).

WHAT UAVS CAN BRING TO THE PICTURE?

Detection of foliage damage using hyperspectral signatures is now achievable and could be used to enable rapid detection of pest activity (Lehmann et al. 2015; Windley et al, 2016), or even of the pests themselves (Chrétien et al. 2016; Gonzalez et al. 2016). Possums are known to selectively defoliate tree species including kamahi (*Weinmannia racemosa*), northern rātā (*Metrosideros robusta*), kohekohe (*Dysoxylum spectabile*), tree fuchsia (*Fuchsia excorticata*), and other plant species (Pekelharing et al. 1998; Sweetapple and Nugent 1999; Gormley et al. 2012; Holland et al. 2013). Pests also target young pine (*Pinus radiata*) trees in commercial plantations (Clout 1977; Keber 1983). Identifying that damage using remote sensing cameras on UAVs (Dandois and Ellis 2013; Shang et al. 2015; Torresan et al. 2017) is a new tool that could enable managers to precisely target pest management activities. Once possums or browse damage are identified, UAVs could deliver baits or self-setting kill traps to precise locations (Carter et al. 2016). UAVs could also be used to transport kill-traps and baits to specified locations in advance of the arrival of a ground-based field team. Although UAV technology is still in its infancy, precision deployment of UAVs has already been used to spray pesticides on crops (Faiçal et al. 2014), control invasive weeds (Huang et al. 2009; Rasmussen et al. 2013), manage wildfires (Christensen 2015), initiate back-burning fires by dropping balls filled with potassium permanganate powder (Reed 2015), and deliver biological control agents over soya bean crops (Rangel 2016).

Currently, 1080 is the only toxin registered for aerial application. Because of the controversy surrounding 1080 (Parliamentary Commissioner for the Environment 2011; Goldson et al. 2015), researchers are exploring a range of new baits and delivery mechanisms (Eason and Ogilvie 2009; Blackie et al. 2014, 2016; Shapiro et al. 2016). A new delivery method currently under development is woven flax packets/balls (flax bombs) containing toxin and coated in a thin layer of wax. Toxins currently undergoing registration include diphacinone/cholecalciferol mix for possums and norbormide for rats (Eason et al. 2015; Choi et al. 2016). Delivery of these toxins could be tested using flax bombs, and UAVs should provide a suitable delivery mechanism. A pilot study conducted near Rotorua showed both possums and rats consuming non-toxic flax bombs (*personal observations*).

While toxins are not always welcome, targeted methodologies could allay fears by enabling precision delivery of baits or kill traps. Morgan et al. (2006) suggested that controlling possums around the 'perimeter' of an area (a novel approach) is just as cost-effective as broadcast control of the entire site (the traditional approach). Nugent et al. (2012) achieved >90% kill rates for possums using cluster-sowing of baits in forests, whilst reducing toxin use by up to 80%. Nugent and Morriss (2013) recommended delivering small clusters of bait (0.17 kg ha-1) every 150 m in remote high country areas, rather than conventional aerial broadcasting. They achieved significant operational cost savings and considerably reduced the amount of toxin used. The reductions in volume demonstrated in these studies combined with targeted use of UAVs might be more acceptable to communities that oppose the broadcast distribution of toxins.

After large-scale aerial operations, small remnant populations can be extremely costly to mop up using ground-based methods (Sweetapple and Nugent 2011; Gormley et al. 2015; Holmes et al. 2015). UAVs dropping toxin on remnant nearby populations soon after these large–scale aerial operations could also be used to maintain suppression and minimise reinvasion by possums and rats, which will inevitably appear in the overall control area (Armstrong et al. 2014: Innes et al. 2015; Cowan 2016; Griffiths and Barron 2016; Sweetapple et al. 2016).

CHALLENGES TO USING UAV FOR PRECISION PEST CONTROL

Although a myriad of applications have been suggested for UAVs, several challenges remain. Limitations to operational use include payload capacity, flight-time restrictions, weather, civil aviation authority (CAA) regulations, and legal constraints. Nevertheless, emerging solutions include user-friendly aerial platforms, larger machines enabling larger payloads, longer flight times, and built-in transponders meaning that pilots no longer need line of sight (Salamí et al. 2014; Gago et al. 2015). In fact, the technology is evolving so quickly that some of the latest off-the-shelf solutions now offer features that address these issues, such as 'intelligent' flight batteries, obstacle avoidance sensors, and increased operational safety (Knight 2016; Hartley 2017; Mogg 2017).

The requirement for line of sight flying is still one of the biggest barriers, especially for flight operations over forests where maintaining visual contact can be difficult. In order to carry out operations beyond visual line of sight (BVLOS), the more advanced 102 certification can be granted by New Zealand's CAA if an operator can manage the high level of safety and risk (Perlman, 2017). New technology such as UTMs (UAV Traffic Management Systems) and the ADS-B (Automatic Dependent Surveillance Broadcast) systems are being developed to provide pilots with information on the altitude, velocity and position of any manned aircraft in the area (Kopardekar 2014; Knight 2016; Patterson 2017). New Zealand has perhaps the most progressive CAA in the world, so it will be just a matter of time before the regulations catch up with the advances in UAV technology.

We suggest that UAVs could genuinely revolutionise pest management. Integrated technologies have recently been applied with great effect in New Zealand, such as use of UAVs mounted with thermal cameras to detect hot spots on the Port Hills in Christchurch during a serious fire event (Hartley 2017). The UAV images provided better detail than satellite maps, helicopter-based thermography, or traditional "cold-trailing" ground methods. The images were used to detect hot-spots that were then ground-truthed and dealt with by fire-fighters (Christensen et al. 2017).

CONCLUSION

If New Zealand is to become predator–free, then all of New Zealand requires pest control, including gullies, steep slopes, commercial forests, small parks and reserves (both private and public). To achieve this predator-free aspiration, pest control cannot be based on affordability, biodiversity protection and TB control. Operationally, UAVs provide substantial cost and time-saving advantages over larger conventional aircraft and ground-control methods. They can fly to designated sites using pre-programmed GIS coordinates in a fraction of the time it would take a person placing traps or bait stations on the ground. Delivering baits in precise loads to specific sites using small versatile UAVs could transform pest control. Further, UAVs are easily transportable, especially to remote locations such as small offshore islands or steep gullies in broken terrain. We believe a directed and targeted approach using UAVs has the potential to significantly reduce pest control costs while improving effectiveness. Without such genuinely novel approaches, predator-free New Zealand will remain an unachievable dream.

AUTHOR CONTRIBUTION

Author contribution: CGM, developed the concept and designed the manuscript: 65%; JB, RH and IM provided key information and helped revise the manuscript, 10% each; and DH and DM provided key intellectual support 2.5% each.

Authors	Contribution	ACI
CGM	0.65	9.286
JB	0.1	0.556
RH	0.1	0.556
IM	0.1	0.556
DH	0.025	0.128
DM	0.025	0.128

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