Institution: Liverpool John Moores University (LJMU)		
Unit of Assessment: UOA7		
Title of case study: Drones to improve conservation		
Period when the underpinning research was undertaken: 2014-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Prof Serge Wich Prof Steve Longmore	Professor in Primate Biology Professor of Astrophysics	01/08/2012 to date 01/03/2013 to date
Period when the claimed impact occurred: 2014-2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

The research on the usage of drones for detection of animal and habitat monitoring has led to successful collaborations with Governments (e.g. Madagascar) and Non-Governmental organizations (e.g. Durrell Wildlife Conservation Trust, Orangutan Information Centre, WWF, Endangered Wildlife Trust, Borneo Nature Foundation). These organizations have indicated that drones and the analytical methods we have developed are facilitating their conservation efforts through more cost-effective animal surveys, being able to obtain higher-resolution data of land-cover that allows for classification of vegetation types and changes over time, and being more efficient in detecting and extinguishing peat fires.

2. Underpinning research

Ecosystem services (carbon sequestration, pollination, flood buffering, and so forth) are estimated to have a value of 125 trillion USD per year. This value is being eroded at a rate of 4-5 trillion USD per year through the negative impact of human activities on these ecosystem services. An important component aspect of ecosystem services is biodiversity. Conservation efforts are attempting to counter biodiversity loss rely on accurate data on animal abundance, data on land cover and change therein, methods to reduce poaching, and methods to reduce other threats such as fires.

Since 2011 I have been using drones as a data collection platform to replace or complement existing methodologies as these can be inefficient in terms of time, too costly, or do not provide the data that are needed to support conservation efforts. The drone research described here (UR 1-6) has been conducted since 2014 and was funded with a total of £1.42M from various funding bodies. The focus of the research was to assess the usefulness of drones to obtain data on animal distribution and density, land-cover, and threats (poaching and fires).

UR 1 showed that drones equipped with standard visual spectrum cameras can be used to detect and count orangutan nests. These data can then subsequently be used to determine orangutan distribution and relative abundance. The aerial drone counts correlated with orangutan nest counts conducted with standard line transects on the ground indicating that counting orangutan nests with drones can be an alternative for ground counts. Because visual spectrum sensors do not allow for detecting animals at night and because they only allow for a small part of the spectrum to be sampled which hampers animal detection of animals that do not stand out from the background in the visual spectrum Prof. Longmore (an astrophysicist) and I started a collaboration to explore the potential of using thermal sensors to detect animals and automate this process (UR2). This seed funding led to two STFC and one EPSRC grants to explore this further. One of the studies conducted was on spider monkeys in Mexico in which we successfully showed that counting spider monkeys with thermal sensors is possible and is comparable and overall more accurate than humans counting the spider monkeys from the ground (UR3). We used similar methods to conduct a study in Tanzania during which we flew a drone equipped with a thermal and visual spectrum camera over people and showed that poachers could be detected with a higher probability on images obtained with the thermal sensor than those obtained with a standard visual spectrum camera (UR4). Another major threat to biodiversity is fires. In Indonesia these occur regularly at a large scale. We conducted an experimental study to determine whether drones with visual spectrum and thermal cameras could be used to detect above and below ground peat fires (UR5). In that study we showed the feasibility of such detection which led to another STFC grant. The combination of both STFC grants led to an EPSRC grant in which we combine research on animals, poachers, and fires, as well as land cover mapping (UR6). Because land cover change has a large influence on biodiversity and satellite images have limited resolution we also studies whether we can improve upon the classification of land cover types by satellites using drones and whether the images from drones can be classified into land cover types relevant for orangutans (e.g. UR6). In UR 6 we show that using images acquired by a drone equipped with a visual spectrum camera can be used as training data for algorithms that used satellite images for land-cover classification and increase the accuracy of these land-cover classifications as well as the number of land-cover classes. In addition, we have been using drones with visual spectrum cameras as a mapping tool with the data being processed into land cover types using several machine learning algorithms.

3. References to the research

All papers have been through a rigorous peer-review process prior to publication.

UR1. Wich, S.A., Dellatore, D., Hughton, M., Ardi, R. and Koh, L.P. (2016) A preliminary assessment of using conservation drones for Sumatran orang-utan (Pongo abelii) distribution and density. 4: 45-52.

UR2. Longmore, S.N., Collins, R.P., Pfeifer, S., Fox, S.E., Mulero-Pazmany, M., Bezombes, F., Goodwin, A., Ovelar, M., Knapen, J.H., Wich, S.A. (2017) Adapting astronomical source detection software to help detect animals in thermal images obtained by unmanned aerial systems. International Journal of Remote Sensing. 38: 2623-2638

UR3. Spaan, D., Burke, C., McAree, O., Aureli, F., Rangel-Rivera, C., Hutschenreiter, A., Longmore, S.N., McWhirter, P.R. and Wich, S.A. (2019) Thermal Infrared Imaging from Drones Offers a Major Advance for Spider Monkey Surveys. Drones, 3, Article number 34.

UR4. Hambrecht, L., Brown, R.P., Piel, A.K. and Wich, S.A. (2019) Detecting 'poachers' with drones: Factors influencing the probability of detection with TIR and RGB imaging in miombo woodlands, Tanzania. Biological Conservation 233: 109-117.

UR5. Burke C., Wich S., Kusin K., McAree O., Harrison M., Ripoll B., Ermiasi Y., Mulero Pazmany M., Longmore S. (2019). Thermal-Drones as a Safe and Reliable Method for Detecting Subterranean Peat Fires. Drones 3, Article number 23.

UR6. Szantoi, Z., Smith, S.E., Strona, G., Koh, L.P., and Wich, S.A. (2017) Mapping orangutan habitat and agricultural areas using landsat oli imagery with unmanned autonomous system aerial photography. International Journal of Remote Sensing. 38: 2231-2245.

Key Grants:

Total funding received for this research was **£1.42M** between 2014-2020, as follows:

1. USFWS (US Fishing and Wildlife Services), $25,536 (2014) [£19,152]
2. USFWS $36,461 (2014) [£27,345]
3. Chester Zoo $27,232 (2014) [£20,424]
4. NGS (National Geographic Society) $16,792 (2015) [£12,594]
5. ISTAT (International Society of Transport Aircraft Trading) Foundation, $4,000 (2016) [£3000]
6. STFC (Science and Technology Facilities Council) ST/P003273/1 £50,405 (May - Jan 2018)
7. STFC ST/R002673/1, £411,988, Jan 2018-Dec 2019
8. Leverhulme VP1-2017-031. £18,420 July 2018-July 2019

9. STFC, ODA Institutional Award, £70k (2018-19)
10. STFC ST/S00288X/1 Developing automated detection and monitoring of peat fires in Indonesia with thermal infrared sensors under drones", £422,696 (£357,262), (April 2019-March 2021)
11. UKRI EP/T015403/1 “Using drones to protect biodiversity and spur economic growth in Madagascar” £574,039, Oct 2019- Mar 2021

4. Details of the impact

In UR 1 we showed that drones can be used to count orangutan nests and determine orangutan distribution and relative density using standard visual spectrum cameras. The aerial counts can therefore be an alternative to ground counts of orangutan nests and reduce the time to collect data by at least a factor two.

This led a number of Non-Governmental Organisations (NGOs) in Indonesia (from 2016 onwards) to count orangutan nests for surveys on orangutan distribution and density in the areas that they work (Sumatran Orangutan Conservation Program [S1], Orangutan Information Centre [S2]) and an NGO in Tanzania (Greater Malale Ecosystem Research and Conservation) to use drones to count chimpanzee nests [S3].

Mr. Hadisiswoyo, Founder of the Orangutan Information Centre: *“In terms of orangutan survey work I estimate that the drone usage has cut the time needed for surveys and analyses in half which is a huge time and cost saving.”* [S2].

This research has also influenced research centres and NGOs (such as WWF) to start using drones for monitoring of animal species.

Dr. Goossens, Danau Girang Field Centre lead researcher: *“Drones are a key emerging technology that we are keeping a keen eye on and the research by Prof. Serge Wich has influenced our thinking about usage of drones for our conservation efforts. Serge has visited our site several years ago to demonstrate the usage of drones and provide advice on their usage for conservation projects.”* [S4].

Dr. van der Hoeven, WWF Netherlands: *“The conservation research using drones that has been conducted by Prof. Serge Wich has been very influential on getting us started with drones for various of our projects. As a result of his papers and further discussions with him we are ow using drones in several of our conservation projects and are planning to extend this. Drones have in several cases facilitated our conservation efforts….”* [S5].

The studies that used drones equipped with a thermal infrared sensor to detect and classify animals and poachers through manual and automated methods (funded by STFC for £411,988) with a thermal sensor (UR 2 and 4) led to a number of collaborations with conservation NGOs (GMERC, WWF UK/Sabah, Durrell Wildlife Conservation Trust, Endangered Wildlife Trust, ConMonoMaya), universities (e.g. University of Vera Cruz),). During those collaborations drones with thermal cameras were used to successfully detect species such as orangutans, spider monkeys, poachers and riverine rabbits.

Our collaboration with GMERC in Tanzania has shown that through using drones with a thermal camera and machine learning we can detect poachers 17x faster in images than through a manual method.

Dr Piel, Lead researcher of the Greater Mahale Ecosystem Research and Conservation Project: *“… drones coupled with machine learning can detect poachers 17x faster than when images are examined manually.”* [S3].

One of these collaborations led to a paper itself (UR 3) that indicated that drone surveys result in better counts of large spider monkey sub-groups and faster surveys (S5). As a result drones are now being used to count spider monkeys in Mexico.

Dr Spaan, Population Monitoring Coordinator of the Mexican Conservation NGO 'ConMonoMaya': *"… the drone allows for much faster coverage of an area than the [traditional] ground method does."* [S6]

The work drones and machine learning with EWT in South Africa has led to 10-15x faster sorting of images than through manual methods which saves time and money.

Dr Theron, Head of Drylands Conservation Program at the Endangered Wildlife Trust: *"The research with drones and camera traps coupled with machine learning has shown that we can now detect Riverine Rabbits much faster in images than through our default method which would require human analysts going through tens of thousands of images. We have seen by way of example that manually sorting images will take 10 to 15 times the amount of time required to simply upload the images to the machine learning pipeline. This represents a significant amount of skilled resources that can be redirected to more productive conservation activities. The direct cost saving amounts to approximately £ 1500 per large camera trap survey (80 or more cameras) or more than 20 working days in one team members time."* [S7].

This drone work has also led WWF to implement drones in various of their conservation programs in Malaysia, Nepal, and Brazil [S5 & S8].

The fire detection study that was funded by GCRF and led to UR5 indicated that peat fires above and below ground could be detected with thermal sensors. On the basis of this started a collaboration with the Borneo Nature Foundation and the University of Palangkaraya to use drones for fire detection and monitoring and directly have impact. In 2019 the LJMU team went to Borneo to test the drone equipment during the 2019 fire season and train the local counterparts on the usage of the equipment. This has led to drones with thermal and visual spectrum sensors being used by the Borneo Nature Foundation to increase the efficiency of the fire fighting teams during the fires of 2019 [S9].

In his letter, Bernat Capilla, Director of Programs at BNF, states, *"… the overwhelmingly positive feedback from fire-fighting teams and their desire for thermal drones to attend all possible fire events, attests to this positive impact. This derives from an increased ability and speed of detecting fires (compared to checking on foot, which is dangerous and may take many hours for a large fire, we estimate that use of a thermal drone allows fire hotspot location mapping to be completed around at least 10x quicker and with almost no safety risk), which in turn improves the ability of teams to monitor the current fire situation and deploy team members as necessary to prevent fire spread and extinguish hotspots. … The technology is also particularly useful in surveying fire sites post-initial fire-fighting, to confirm that all hotspots are extinguished and it is safe to leave the site, again increasing the speed of this by at least 10x. This is vitally important, as peat fires can smoulder beneath the surface, where they are difficult to detect without the aid of thermal imaging technology, and then re-emerge after fire-fighters have gone home, causing more damage."* This can be further summarized in two impacts. 1) Increased efficiency in finding/extinguishing fires: The fire-fighters estimate that compared to traditional methods, our drone system accurately identifies the location of the fires over 10x quicker, helps extinguish them 50% quicker and makes it over 10x quicker to confirm fires are extinguished. 2) Improved health of firefighters and surrounding population: the increased efficiency in finding/extinguishing the fires led to (i) virtually zero exposure to the previous safety risks finding fires; (ii) 200 days less smoke inhalation for the fire fighters, the effects of which are known to be extremely harmful; (iii) a corresponding drop in the concentration of toxic haze which had to be endured by the ~15 million

Kalimantan province residents. In 2020 we intended to bring additional drone systems with new automated fire-detection capability to additional fire teams in Indonesia. We believe this would have significantly increased the above impacts. However, COVID-19 travel restrictions meant it was not possible to deliver the systems.

The research conducted in UR2-5 led to a grant from UKRI to directly impact conservation and economic growth in Madagascar in which LJMU, the Durrell Wildlife Conservation Trust, and Government of Madagascar are collaborating to use drones to protect biodiversity but also to stimulate economic growth through drone technology in other sectors of the economy in Madagascar. An initial survey in Madagascar has indicated that Bandro lemurs can be detected 100x faster with drones equipped with a thermal imaging camera compared to the traditional surveys by canoe and saves in operating costs [S10]. Dr Hudson, Head of Research, Durrell Wildlife Conservation Trust: *"… the team then flew the system over key areas of marsh that have been inaccessible to previous surveys. In 3 x 20-minute flights, the drone system reproduced lemur densities estimated from previous surveys requiring 24 person-weeks of effort. Scaling-up this programme to cover the entire lake represents an approximately 100 times increase in survey efficiency. … The adoption of this research technology will revolutionise the scale and frequency with which DWCT and our partners in Madagascar, including the Madagascar National Parks Service, can conduct surveys."*

Dr Hudson: our drone system represents *"…a saving of £8,000, annually. In the field of conservation where funding for 'routine' actions such as monitoring is hard won, this saving is a fantastic achievement and will help to guarantee the sustainability of our field programmes, long-term."* [CS3]

The research on habitat mapping in UR 6 has also allowed for much faster mapping of orangutan habitat.

Mr. Hadisiswoyo, Founder of the Orangutan Information Centre: *"The drones have also allowed us to do habitat mapping much faster than if we were to do this on foot. I estimate that data collection is approximately 9 times faster and yields data that we would not be able to collect from the ground."* [S2]

5. Sources to corroborate the impact

S1: Letter from Dr. Singleton (OBE), Director Sumatran Orangutan Conservation Program in Indonesia.
S2: Letter from Mr. Hadisiswoyo, Founding Director of the Orangutan Information Centre in Indonesia.
S3: Letter from Dr. Piel, Lead Researcher of the Greater Mahale Ecosystem Research and Conservation Project in Tanzania.
S4: Letter from Dr. Goossens, lead research at the Danau Girang Field Centre in Sabah.
S5: Letter from Dr. van der Hoeven, Advisor Ecological Networks & Species Conservation at World Wildlife Fund for Nature (The Netherlands).
S6: Letter from Dr Spaan, Population Monitoring Coordinator of the Mexican Conservation NGO, 'ConMonoMaya'.
S7: Letter from Dr. Theron, Head of Drylands Conservation Program at the Endangered Wildlife Trust in South Africa.
S8: Letter from Ms. Loweth, Regional Manager, World Wildlife Fund for Nature (UK).
S9: Joint letter of support from Indonesian collaborators written by Bernat Ripoli Capilla, Director of Programmes at the Borneo Nature Foundation.
S10: Letter from Dr. Hudson, Head of Research, Durrell Wildlife Conservation Trust.