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FEASIBILITY OF THERMAL IMAGING USING UNMANNED AERIAL VEHICLES TO DETECT BORNEAN ORANGUTANS

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Abstract: Conventional ground monitoring of protected areas are commonly being conducted by foot or using light aircrafts. Time, financial ability, energy, and safety are some of the main concerns during monitoring large landscapes. Monitoring of orangutans during night-time was arduous using conventional observation method. This study described the detection success of a thermal device (FLIR Vue 9Hz) attached to a Dji Phantom Pro 3 UAV to locate orang-utans at their sleeping sites in Semenggoh Nature Reserve (SNR) and Sepilok Orang Utan Rehabilitation Center (SORC) in East Malaysia. Using the thermal device, we had captured images of orangutans in six separate locations, and all the nests were then verified by ground-trothing. The white-hot mode of the FLIR VUE was feasible to detect orangutans in the forest canopy and in open areas. Open areas give the most accurate and clear thermal visual. Whereby, the thermal visuals from the inner forest is limited to the density covered by the tree canopies. Results of this study demonstrated the feasibility of the method for locating mammals under large canopy. However, there are several challenges that could be overcome and the future potentials of the method in relation to the rapid advancement of the drone and thermal imaging technology.

Keywords: Drones, Dji Phantom 3 UAV, FLIR Vue, orang-utan, thermal imaging, Semenggoh Nature Reserve, Sepilok Orang Utan Rehabilitation Center.

Introduction

The critically endangered orangutans (*Pongo* spp.) have very slow life histories (Kuze *et al.,* 2012; van Noordwijk *et al.,* 2018), and they utilise trees to build nests (Prasetyo *et al.,* 2009; Van Casteren, 2012; Van Casteren *et al.,* 2012). Orangutans are highly adaptable on tree nesting preferences, especially for tree species (Ancrenaz *et al*., 2004). As these great apes rarely move on the ground, dependency on canopy trees is viewed as a strategy for protection against predators, such as tigers and snakes (Loken *et al.,* 2013). Orangutans also utilise the surrounding canopy as food source, easy access to find fruits as they are highly frugivorous, although they are also opportunistically feed on arthropods, leaves and barks (Galdikas, 1988). As these primates are highly dependent on the forest, the recent habitat loss in their roaming areas, deforestation and habitat fragmentation has led to declining population in both Sumatra and Borneo. Currently orangutan is listed as critically endangered animals (IUCN Red List).

Challenges in studying and monitoring wildlife and their habitats, especially in larger landscapes, often arise from the insufficient manpower to survey the vast areas. It is also due to the cryptic nature of the intended study species, such as the orangutan. Conservation areas often encompass different types of ecosystem, which can be difficult to access (Nowacek *et al.,* 2001; Dunford *et al.,* 2009; Koh & Wich, 2012; Christiansen *et al.,* 2016; Rees *et al.,* 2018). The safety of the wildlife rangers or researchers could also be in jeopardy, especially during night-time, when illegal logging or poaching frequently occurs (Witter & Satterfield, 2019).

Assessment of conservation areas or species can be facilitated using technologies that reduce costs, workforce and time (Schuette *et al.,* 2018). For example, Unmanned Aerial Vehicles (UAVs) are feasible to monitor detrimental algae bloom events in coastal ecosystems (Ventura *et al.,* 2016), monitor natural or anthropogenic disasters, such as landslides and forest fires (Merino *et al.,* 2012; Rossi *et al.,* 2016; Burnett & Wing, 2018) and evaluate land use changes over time (Koh & Wich, 2012; Stark *et al.,* 2017). Since UAVs are energy-efficient, they assist in rapid and effective monitoring processes (Paneque-Gálvez *et al.,* 2014) and inform government agencies and policymakers by providing thorough environmental data (Tang & Shao, 2015). Other conservation efforts using drones include the monitoring of large-bodied animals such as rhinoceroses (Mulero-Pázmány M *et al.,* 2014), elephants (Vermeulen C *et al.,* 2013) , orangutans (Szantoi *et al*., 2017; Fadzly *et al.,* 2018) and chimpanzees (Bonnin *et al.,* 2018)

Thermal imaging is a powerful tool that detects the specific heat signature for different subjects or surroundings (Paneque-Gálvez *et al.,* 2014). Thermal imaging is commonly used for safety surveillance (Castallado *et al*., 1996), maritime monitoring (Klimkowska *et al*., 2016), Non-Destructive Testing (NDT) or materials testing (Titman, 2001), cell inspection (Quater *et al*., 2014), and others. Combining thermal imaging with conservation drones may offer a new way to monitor larger arboreal mammals, specifically orangutans in habitats that are difficult to access from the ground.

In this study, the detection ability and feasibility of thermal imaging device mounted on a UAV to detect sleeping sites of Bornean orangutans in the forest canopy and in semi-wild conditions were tested at two study sites, the Semenggoh Nature Reserve (SNR) and Sepilok Orangutan Rehabilitation Centre (SORC), respectively. These sites were opted due to its easy access and closest to natural setting of the highly dense tropical rainforest as native habitat of the Bornean orangutans in Malaysia. We expected to locate orangutans sleeping at a certain height above ground in the canopy as this integration tool was reported to be potentially capable of detecting large-bodied and warm-blooded animals (Kays *et al.*, 2018).

Materials and Methods

Study Sites

The study sites were at the Semenggoh Nature Reserve (SNR) (1.3998° N, 110.3241° E) and Sepilok Orang Utan Rehabilitation Centre (SORC) (5.8644° N, 117.9488° E). SNR in Sarawak is a 653-hectare nature reserve, home to semi-wild orangutans and located approximately 24 km from Kuching. SNR is managed by Sarawak Forestry Corporation (SFC), a government-linked corporation (GLC) authorised by the Sarawak Forestry. This nature reserve was previously an arboretum and comprise of wildlife rehabilitation center (especially orangutans and crocodile), arboretum and botanical research centers, in addition to its large part of lowland dipterocarp forest reserve (Ling & Julia, 2012). In SNR, these orangutans are independent and forage in the forest, but some occasionally visit the feeding platforms that are provisioned daily to get supplementary food from the managing staff.

SORC is an orangutan rehabilitation centre that is part of the Sepilok-Kabili Forest that comprises 4,294 ha area of virgin forest. SORC's facilities include a veterinary clinic and ward amenities, indoor and outdoor enrichment playgrounds, feeding platforms, visitor trails and monitored by veterinarians and security guards. SORC functions as a rehabilitation centers for over than 200 orphaned orangutans so far, with most of them being reintroduced to the Tabin Wildlife Centre.

Both study sites hosted free-ranging orangutans but under different conditions (Figure 1a and Figure 1b). SNR is a forest where orangutans sleep in the wild and can use the infrastructure (e.g., feeding platform, ropes) at the centre. The compound itself has only a few buildings. SORC is a rehabilitation centre with several buildings, such as a clinic, indoor and outdoor enclosures, feeding platform, galleries,

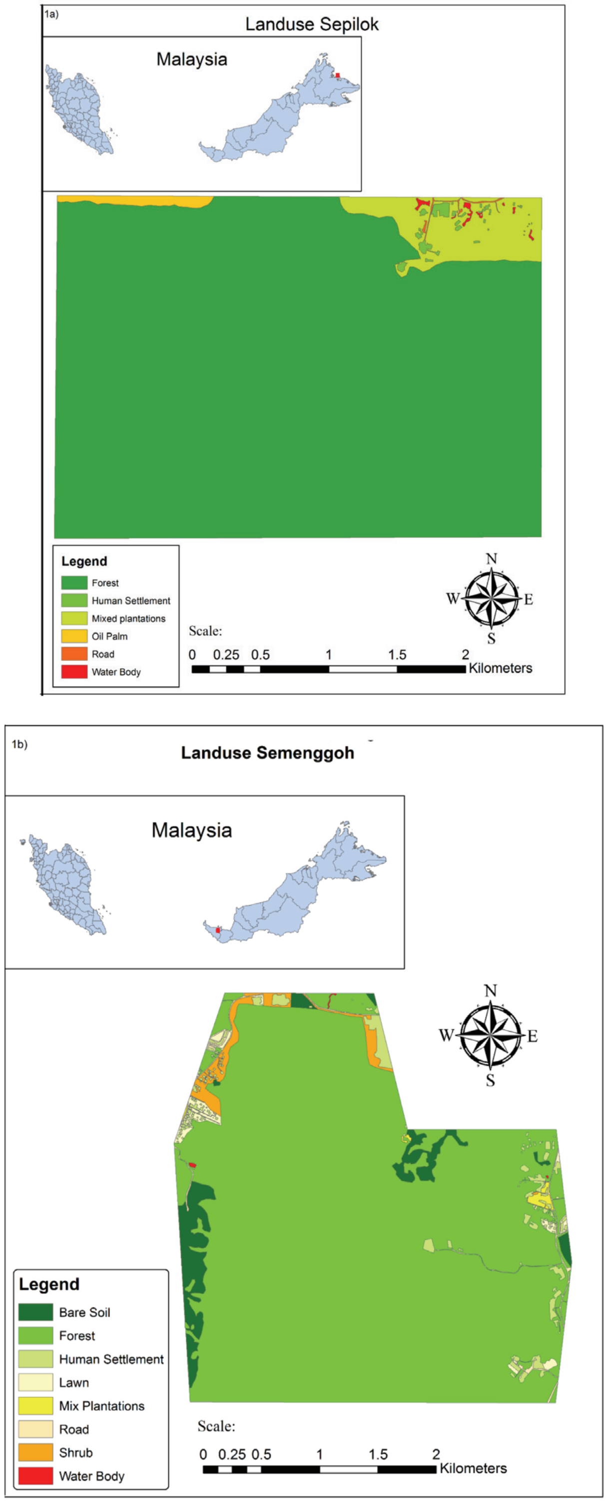

Figure 1: (a) Points map of SNR; (b) points map of SORC

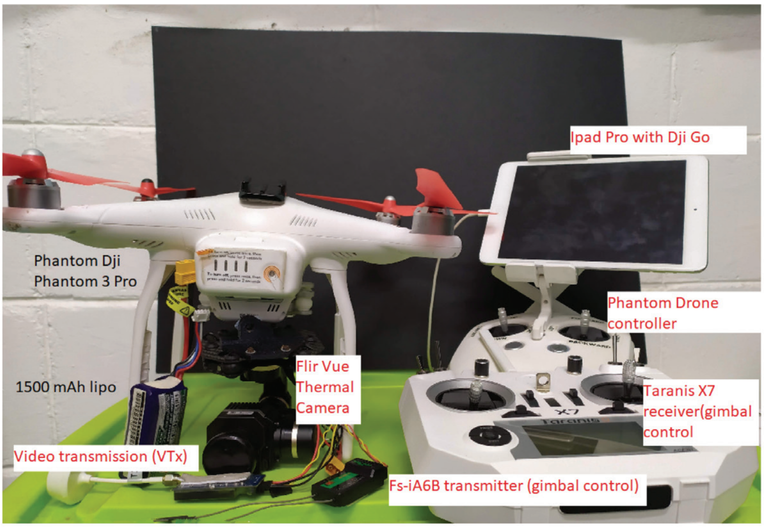

Figure 2: Setup of the thermal camera equipped drone

toilets, a café and parking lots, and other amenities.

System Setup

For this pilot project, a multirotor Dji Phantom Pro 3 with a thermal FLIR Vue (640. 13 mm, 9 Hz) camera was used. This integration required a long-range UHF 433MHz RC system, long-range 1.2 GHz video transmission system, long-range antenna system 1.2 GHz, Fs-iA6B long-range transceiver 915 MHz telemetry, Taranis X7 receiver and 3-axis camera gimbal. The FLIR Vue and gimbal are powered by 1500 mAh Lipo battery. Dji Go was used as ground control app on an Ipad console. Camera was faced straight down when we flew the drone. Figure 2 shows the setup of the drone.

Target Detection

A four point's map were sketched on Google Map to estimate the pathway of the UAV. These four points, time and dates of flight and details of the pilot were approved and established by civil authorisation bodies, which were The Department Survey and Mapping Malaysia, Chief Ministry Office and Department of Civil Aviation (DCA). Safety measures such as the welfare of the orangutan, the welfare of the public and schedule of the commercial flight were considered while choosing the sites. We flew our drones when the orangutan had left their nests as the noise generated by the drone could have disturbed the orangutan. The Dji Phantom Pro 3 attached with the FLIR VUE was flown at the nesting areas of orangutans at both centers during the night. The UAV was navigated following a set of flight path. We started each flight around 8.00 pm during dry and still wind weather conditions. We set the UAV to fly about 50-100 m above ground and within a radius of 500 m. Each flight took approximately 15- 20 minutes. Once we have detected a heat signature of interest (indicating a large animal) by using white-hot mode, we went on a pursuit to the determined spot on the next morning for ground-truthing of the orangutan's nests.

Ethical and Legal Compliance

For Sabah, this project was supported by the Sabah Wildlife Department (JHL PPOUS 600-6/4/115) and the Sabah Forestry Department (JPHTN/PPP/PR.700-4/4 (67)). The research permit was authorised by the Sabah Chief Ministry Office (JKM/HEDN&P 700-3/33 JLD.3/(33)) and the Sabah Biodiversity Center (SaBC) (JKM/MBS.1000-2/2 JLD.3 (143)). For Sarawak, this research permits were

Figure 3: (3a) Orangutan sleeping in nest (verified by ground truthing); (3b) Orangutans sleeping on the rooftop of SORC

authorised by the Sarawak Forestry Department (WL024/2016) and the Sarawak Chief Ministry Office (/JKM/UP/605/4/3/JLD.5). Final permits were issued by the Malaysian Department of Surveying and Mapping (JUPEM.BGSP.(S)20Q6.PERMIT(119)) and the Department of Civil Aviation (DCA) Malaysia ((49)DCA/PTU.1/57.3 Vol.9). Figure 2 shows the flow chart of the methodology for this study.

Results and Discussion

Data Collection, Footage Analysis and Ground

During our first flight at SORC, we detected a thermal image of an orangutan in a tree nearby to the outdoor enclosure (Figure 3a). We visited the tree on the following day and found an orangutan nest on it. During our flight operation on the next night, we flew near to the clinic enclosure area (Figure 3b). We recorded heat images of several

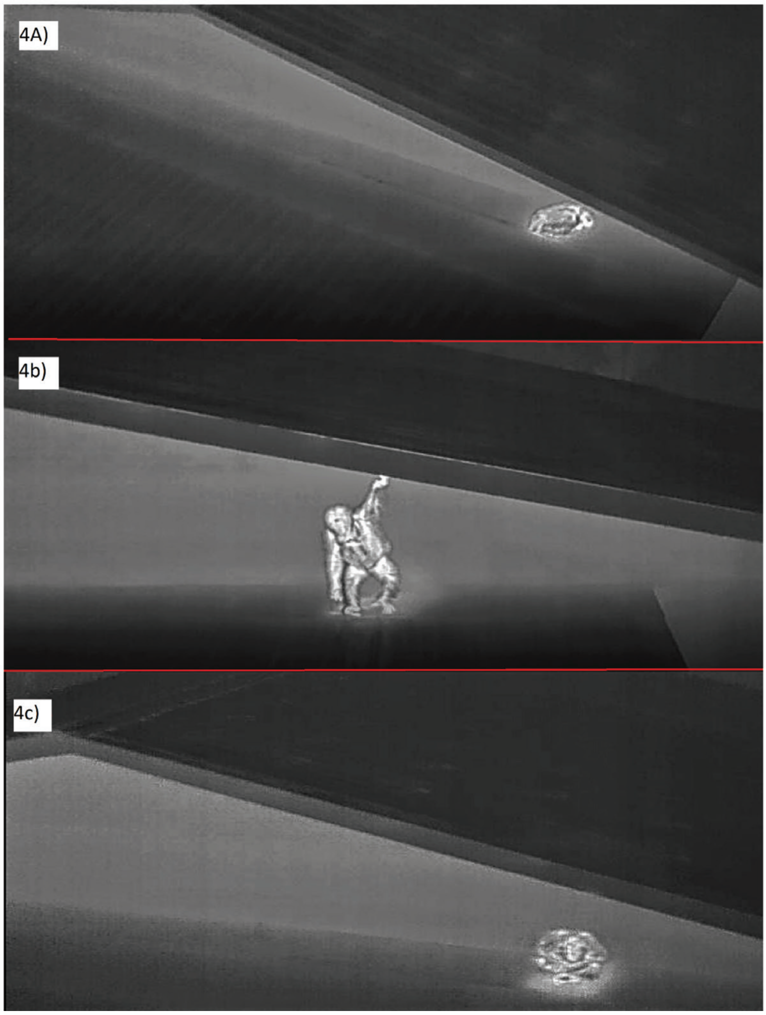

Figure 4: Male Bornean orangutan (named Kolapis) reacted when the UAV approached his sleeping site by standing up. A few minutes later he resumed his resting position.

orangutans lying on the rooftop of the clinic and indoor enclosure. We did not fly the drone closer than 50 meters, to avoid disturbing the sleeping orangutans. During the same mission that night, we also saw moving white objects in the canopy but could not verify the type of animal.

Our mission continued on the subsequent night to the approaching outdoor enclosure of SORC. On this mission, the drone had also detected the orangutans sleeping on the rooftop. The white-hot mode of the FLIR VUE proved its feasibility to detect orangutans in open areas. Even though we launched our UAV more than 100 meters away from the individuals, one of the orangutans seemed to be slightly disturbed. The ranger had identified the orangutan as a male from the rehabilitation centre, known as 'Kolapis'. At first, the orangutan was awakened and curiously observed the UAV while standing up, but later on had slowly returning to rest position on the rooftop (Figure 4). Similar to Kays *et al.* (2018) observations, the literature described that noises could be reduced when the distance between the wildlife and UAV is elongated. It was also observed that their UAV is not affecting the wildlife when the distance reaches more than 40 m. As compared to flying

Figure 5:(a) heat image of unidentified moving animal. (b) same unidentified animal after it moved to the outer branched of the tree.

during night time, there could be chances that wildlife disturbance would be proliferated if the UAV is flown in daylight (Kays *et al.,* 2018). Since our UAV was flown during nocturnal hours, observable disturbance could be minimised as only small LED navigation light is visible. We continued our mission and headed to the nearby forest where we found another heat signature. However, ground truthing yielded no evidence of an orangutan or nest at the target tree.

During the last two-night flight missions at SORC, we had also detected orangutans sleeping on the rooftop of the buildings. While flying over the forest at SORC areas, heat images of a smaller animal was also recorded, but did not show a clear silhouette. Ground-truthing on the next day showed that the target tree did not have a fresh nest. At SORC, one occurrence was recorded, where an object was moving but were unable to identify the species (Figure 5a and Figure 5b). The nocturnal UAV with the thermal camera was tested out at SNR at a distance approximately 10-50 meters from the subject. Due to time constraints, rain, and windy turbulence, only one flight managed to be carried

Figure 6: Two orangutans (mother right and son to the left) sleeping in tree at SNR.

out per night. Two orangutans were found in one spot (Figure 6). The ranger had identified these individuals as Ganya and Seduku, a family of a mother and son. We could not move the UAV any further as the forest condition was much denser at SNR area. Our work had demonstrated the feasibility of UAV and thermal devices to detect orangutan thermal signatures during night flight observations. The thermal device weighs at about 115 g and equipped with a multirotor, it provided convenient to subtle manoeuvering and proximate flying closer to the tree range (less than 100 m high). The white-hot (thermal) mode captured images of animals based on emitted body heat temperatures, so the dense tropical canopy covers could easily be differentiated from the animals. Furthermore, orangutans are of arboreal nature, and their nests were built at the top of the canopy, which allowed thermal signatures to be detected with ease by using the UAV.

Challenges and Potential of Using the Thermal Camera and UAV

Manouvering in the dense tropical rainforest with a drone-mounted thermal camera observations had provided us the prospect to reflect on some of the challenges and opportunities using this approach. We had expected to see more individuals prior to the commencement of the study. Nevertheless, our FLIR VUE are unable to completely penetrate the dense tropical forest canopy, our pilots had to acutely navigate from different angles to obtain the best shots. FLIR VUE has two different models that are available, a 9 Hz and 30 Hz model. The higher the Hz capacity, as with the 30 Hz model, the faster and offers a better thermal image. However, the 30 Hz model is only allowed for sale in the USA, and it is illegal to export them to outside countries (FLIR, 2019). Our 9 Hz model had managed to detect the orangutan subjects. However, with a better capability, using a 30 Hz model would greatly improve the detection rate (Burke *et al.,* 2018). Light-weight multirotor UAVs are also more challenging to navigate than the fixed-wings models, even with equipped GPS, our flight conditions were negatively affected by the wind turbulence and obstructed visibility. Our Dji Phantom 3 has a sonar and bottom facing camera that stabilises the aircraft. However, these sensors are useless during night time, and wherever at heights more than 9 ft (the sensor limitation effectiveness). Therefore, it is suggested that to use open-source hardware, for example using a quad or a hexacopter with Pixhawk flight controller and Ardupilot flight stack. The added weight of the gimbal and FLIR Vue had affected the Phantom's flight endurance (high battery consumption due to weight). Whereas using a Pixhawk quad with only the FLIR Vue, could provide longer battery life and better customisation (such as adding pulse width modulated controlled searchlight). A better option is by using a LIDAR sensor. Multiple beam LIDAR is rather expensive, mayhap those prices be more affordable in the future.

During the pilot survey, visibility problems encountered due to rain or wind turbulence resulted in failing to detect nests or yielding false detections. Without ground-truthing follow up, there is a possibility of false detection as the detected thermal heat signature may not be an orangutan's. This is similar to the problems reported by Bonnin *et al*., (2018) who had assessed chimpanzees using UAVs. Detection is limited by the clarity of the image from the FLIR VUE. False detections may result in overestimating or underestimating population densities of animals. Common weather factors such as rainfall, wind turbulence, and fog could affects the image quality and animal detection (Burke *et al.,* 2018). Israel and Reinhard (2017) reported that the best condition to observe bird nest when using thermal camera is during warm days with overcast sky. Moreover, ground truthing (validation of detected heat signatures by observers on the ground) could be improved (Lhoest *et al.,* 2015; Kays *et al.,* 2018). Lhoest *et al.* (2015) stated the importance of having an algorithm on automation of image detection as vital, especially when dealing with monitoring large habitats and managing high amount of data. We had validated our findings by verifying the presence of a nest at the site where the heat image was detected, however this method is impractical when dealing with larger amount of data.

Observing animals using drones can be challenging, as animals hide beneath the canopy or underneath trees, and reflection of the images would be impeded since the radiation is blocked by the vegetation (Burke *et al*., 2018). Bindeman *et al.* (2017) found that images captured by drones are rather difficult to use for person identification (e.g. sex, race, and age), but with further technological advances, future studies could be carried out for more thorough wildlife monitoring using UAVs and thermal devices at isolated areas. Kays *et al.* (2018) also suggested that future work could combine automated detection of animals from thermal infrared imagery with flash photography or IR illumination to enable species ID during nocturnal surveys.

The potential benefits of integrating thermal camera with the UAV are evident, as such, further improvements need to be made in the future. As technology related to UAV and thermal camera is evolving fast, this method should be improved to encourage monitoring of endangered mammals in their natural habitat. Conservation measures could be developed accordingly as more thorough monitoring will improve information on any specified species. In addition, more detailed behavioural related studies on wildlife, such as, their sleeping site and sleeping patterns in nocturnal conditions could be explored further. This approach shed more opportunity to build advance collaborative efforts between researchers, authorised conservation centres and local communities by training rangers or community representatives (stewards of protected areas) to benefit this surveillance method. Financial support and sufficient manpower is crucial, as this approach need a high capital investment, due to its higher operation and management expenditures. The future research and expanded studies could be legitimately carried out to advance the use of this method and contribute to the conservation of the threatened mammals in larger landscapes.

Conclusion

This study had tested the integration of the UAV technology with a thermal imaging device to assess presences of nocturnal mammals in a dense tropical forest conditions of Malaysian Borneo. Results in open areas were satisfying, however, the FLIR Vue could not penetrate the canopy and to detect heat signatures through the thick forest vegetation. Findings showed that the drone-mounted thermal camera detects images of the orangutans during nocturnal conditions. We encountered problems in validating the images from the drone-mounted thermal camera. Obstruction by vegetation and optimising the height for the drone flight is crucial for good thermal image analysis. We recommend an integration of thermal devices with UAV for open areas (e.g., riparian areas, savannah forest) for advance study on nocturnal mammals. With the tropical forests' studies, we suggest for a more thorough and prolonged data collection to more areas to have a better test on this integration method for conservation management of orangutans. It is suggested that using a handheld thermal camera during the night for ground-truthing as an additional effort to further validate and develop this method. Since the thermal device is partially capable to reflect heat differences from a dense forest, the method should be tested in a wider range of forest habitat types. In furtherance, the effort would establish methods which minimises ground-truthing validation. And thus, to only identify animal species from the air. UAVs mounted with thermal devices are capable to improve and establish long-term routine monitoring of orangutan populations in identified areas for population trend analysis. Last but not least, the most important achievement of this project was the network building between scientists, government officials, students, and UAV-operator companies. Perhaps in the future, more community members, park rangers, park officers or even local guides in Malaysia could be trained and licensed to use UAV to monitor the protected areas.

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Abbreviations: Semenggoh Nature Reserve (SNR), Sepilok Orang Utan Rehabilitation Center (SORC), Unmanned Aerial Vehicle (UAV)

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