IOP Conf. Series: Earth and Environmental Science **54** (2017) 012066 doi:10.1088/1755-1315/54/1/012066

# Quadcopter applications for wildlife monitoring

**S Radiansyah*, M D Kusrini and L B Prasetyo**

Tropical Biodiversity Conservation Studies Program, Graduate School of IPB, Darmaga, Bogor, Indonesia

E-mail: rade03499007@gmail.com

**Abstract**. Recently, Unmanned Aerial Vehicle (UAV) had been use as an instrument for wildlife research. Most of that, using an airplane type which need space for runaway. Copter is UAV type that can fly at canopy space and do not need runaway. The research aims are to examine quadcopter application for wildlife monitoring, measure the accuracy of data generated and determine effective, efficient and appropriate technical recommendation in accordance with the ethics of wildlife photography. Flight trials with a camera 12 - 24 MP at altitude ranges from 50-200 m above ground level (agl), producing aerial photographs with spatial resolution of 0.85 – 4.79 cm/pixel. Aerial photos quality depends on the type and setting of camera, vibration damper system, flight altitude and punctuality of the shooting. For wildlife monitoring the copter is recommended to take off at least 300 m from the target, and flies at 50 - 100 m agl with flight speed of 5 - 7 m/sec on fine weather. Quadcopter presence with a distance more than 30 m from White-bellied Sea Eagles (*Haliaeetus leucogaster*) nest and Proboscis Monkey (*Nasalis larvatus*) did not cause negative response. Quadcopter application should pay attention to the behaviour and characteristic of wildlife.

## 1. Introduction

Unmanned Aerial Vehicles (UAV), often called the drone, is a flying robot with a remote control which is capable of carrying payloads in accordance with the purpose and designation. Some wildlife studies used airplane/fixed wing type of drone [1][2][3][4][6][9] and multirotor [1] [5]. Small UAVs to be useful as management or research tools, they should be durable, modular, electric powered, launchable and recoverable in rugged terrain, autonomously controllable, operable with minimal training, and collect georeferenced imagery [2]. Multirotor drone such as quadcopter is a drone type which is appropriate for research in the forest with large canopy space and unavailable of runway [5]. Quadcopter can be operated manually and automatically with a programming of flight path using open-source software.

Drone applications for wildlife data collection depends on the purpose and environmental parameters which will be taken at each site. This requires UAV system settings that vary according to the capacity of UAV, the camera and the distance or scope of the study area [1][2][3][4][6][9]. Photographing using quadcopter in wildlife monitoring is part of the wildlife photography. Principle ethic of wildlife photography is doing a photo shoot by minimizing the impact / disturbance to wildlife and the environment. Information required in the application of this principle is about the wildlife objectives, locations, regulations and expertise photographer [7].

The fundamental questions about the use quadcopter as wildlife monitoring instrument that is how are the technical applications, how well the accuracy of the data generated and how is the response of wildlife to the application. To answer these questions then conducted research with the aim to examine quadcopter application and measuring accuracy of the data generated and the factors that influence it. From the results and based on wildlife target responses to the presence of quadcopter, then determined technical recommendation of quadcopter application which is effective, efficient and appropriate with the ethics of wildlife photography.

## 2. Method

The study was conducted over 15 months. Preparation and quadcopter development conducted in March-May 2015 (3 months). While field data collection held in June 2015 - May 2016 (12 months).

Quadcopter (multirotor drone with 4 arms, 4 rotors and 4 propellers) used in this research is a type of assembly results from multi-branded component. Dimensions of quadcopter are: width 700 mm, height 415 mm (landing skids installed), and 80 mm ground clearance. Empty weight without batteries and camera is 1800 g. Quadcopter equipped with a battery checker (10 g), LiPo iP3 8000 mAh main battery (850 g), or 6200 mAh (600 g) as reserve battery. Quadcopter flight endurance ± 25 minutes and capability of carrying payloads up to 1200 g.

The camera is mounted on the front and facing downward (camera angle is 90$^{o}$ to the quadcopter/flight direction). Quadcopter can be flown manually using a radio controller or automatically flight using autonomous mode. Quadcopter called "Aerialview-650", since assembled using Tarot 650 frame Sport with semi automatic landing skids (
Figure **1**).

### *2.1. Quadcopter Applications Trial*

The quadcopter application trial conducted in Dramaga Campus, Bogor Regency, West Java Province, at 3 locations, namely:

1. LSI Lake - Rektorat IPB (S 6$^{o}$33’35.98” – E 106$^{o}$43’34.25”);
2. Soccer field at Soka street (S 6$^{o}$33’12.92” – E 106$^{o}$43’22.34”);
3. Horse ranch at Cendana street (S 6$^{o}$33’14.45” – E 106$^{o}$43’04.93”).

Flight endurance test based on payload is done by a flight without a load (without camera mounting and cameras) and flight with load, with the addition of camera mounting and 5 types of camera (Table 1). Flight mode used is:

1. Hovering, done manually or semi-manual on flying altitude 2-30 meters above the ground level at the take off (m agl) within ± 1 ha area (visually controlled).
2. Flight path, flown automatically in accordance with flight path which has been set previously using mission planner program (open-source software).

Data analysis quality which generated from quadcopter application has been conducted through automatic flight path by 3 altitude levels (200, 100 and 50 m agl). Flight altitude of 200 m agl using action cam w9 sport, flight altitude of 50 and 100 m agl using sony α5100 single lens 16-50 mm mirrorles camera. While shooting a flight speed of 5 m/s, is set regardless height level. Photo shooting is done at various intervals, adjusting to the flight altitude and type of camera used. The flight time is done at various times, from 07:00 am to 18:00 pm, not in rainy day (quadcopter designed for non waterproof condition). One flight takes an average time of one hour.

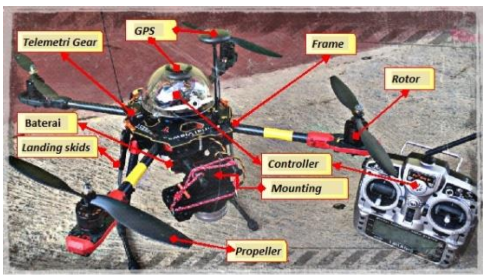


***Figure 1**. Aerialview-650*

**Table 1**. Camera used for Quadcopter Applications Trial

| No | Camera type | Brand | Resolution (Pixel) | Lens/ Focal length (mm) | Aperture | Weight (g) | Production year |
|---|---|---|---|---|---|---|---|
| 1 | Action cam | W9 Sports Camera | 12 MP HD 1080P | Fisheye | f/2.8 | 150 | 2015 |
| 2 | Action cam | GoPro HERO4 Silver | 12 MP HD 1080P | Fisheye 17-34 | f/2.8 | 150 | 2015 |
| 3 | Digital compact | Canon power-shoot A1400 | 16 MP | 28-140 | f/2.8-6.9 | 300 | 2015 |
| 4 | Mirrorles | Sony α5100 | 24.3 MP APS-CMOS | Pancake 16 | f/2.8 | 370 | 2015 |
| 5 | Mirrorles | Sony α5100 | 24.3 MP APS-CMOS | Single lens 16-50 | f/3.5-5.6 | 400 | 2015 |

Noise level analys based on the sound of quadcopter that flown in hover. The shortest distance between quadcopter and recorder is 5 m (vertical and horizontal). The recordings were analyzed using praat sound analysis program to get the value of the noise intensity.

### *2.2. Quadcopter Application for Wildlife Monitoring*

#### *2.2.1. White-bellied Sea Eagles (Haliaeetus leucogaster)*

White-bellied Sea Eagles nest monitoring carried out on the tower of 500 kV high-voltage wires in PT PJB UP Paiton, Probolinggo, East Java (S 7°42'55.96" - E 113°34'44.76"). Quadcopter flown across the eagle's nest tower with flying height 100, 80 and 70 m agl with 5 m/s flight speed when recording. Interlude between flight altitude level around 15-30 minutes (Figure 2a). Flights performed at 7:15 to 9:00 am. The timing was based on the eagle's daily behaviour which has been observed previously by researcher. At that time male eagle leaving the nest to the sea for foraging, while the female perched in another tower (adjacent tower to the nest). The female always keep an eye on the nest and territory while sunbathing. Eagle nest is empty, there are no eggs and chicks. The camera used in the first repeat is action cam GoPro HERO4 silver, while in the second repetition using the mirrorles camera sony α5100, pancake lens 16 mm. The image is taken automatically.

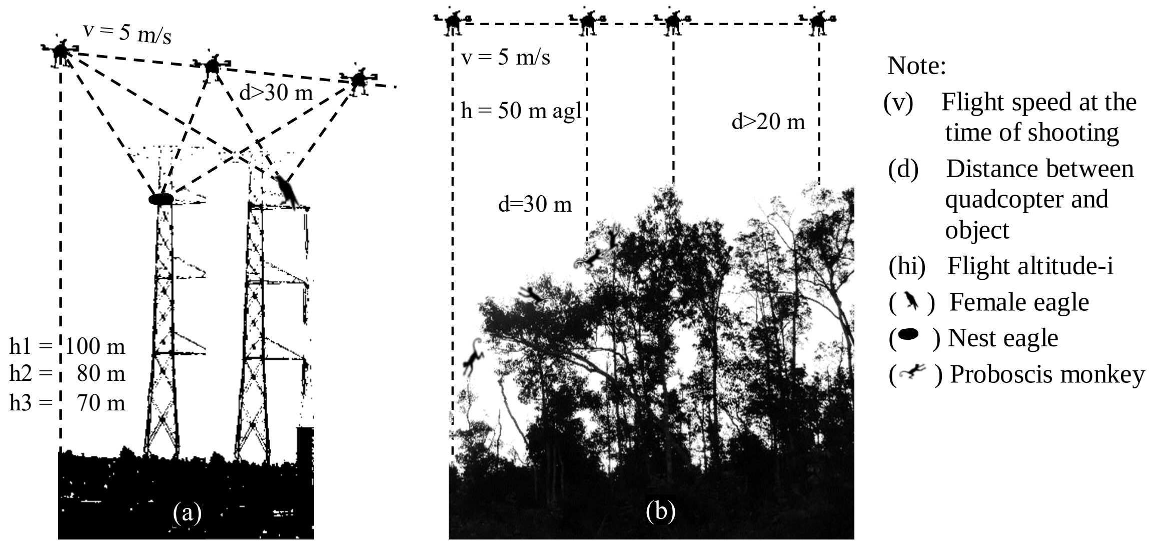


**Figure 2**. Design of Data Collection: Quadcopter Application for Wildlife Monitoring
(a) White-bellied Sea Eagles (*Haliaeetus leucogaster*) nest
(b) Proboscis Monkey (*Nasalis larvatus*)

#### *2.2.2. Proboscis Monkey (Nasalis larvatus)*
Quadcopter application for Proboscis monkey in riparian zone at High Conservation Value Areas (HCVA) of Palm Oil Plantations PT AMR, Kota Waringin Barat Regency, Central Kalimantan Province (S 2°19'14.88" – E 111°46'0.58") performed in the morning (7:00 to 08:00 am) and in the afternoon (15:00 to 16:00 pm). The timing is based on daily behaviour information of wildlife in HCVA by PT AMR. Flights carried out on flight path with altitude 50 m agl, and 5 m/s flight speed at the time of shooting (Figure 2b). Photo shoots using sony α5100 mirrorles camera, 16 mm pancake lens, shutter speed of 1/2000 second, 16 mm focal length, f/2.8 for aperture and 320 for ISO, is set manually.

### *2.3. Data Analysis*
1. Spatial analysis for object identification on aerial photographs and orthophoto mosaic establishment (using agisoft photoscan software).
2. Descriptive statistical analysis to provide weights and flight duration relationship, and the parameters that affect the accuracy of aerial photographs.
3. Effectiveness and efficiency analysis for quadcopter technical applications and disturbance to the wildlife target using criteria and indicators in Table 2.

## 3. Result and Disscusion

### *3.1. Aerialview-650 Development and Application*
Aerialview-650 is quadcopter assembly, which is developed as wildlife monitoring instrument. Considerations for the use of quadcopter assemblies are:
1. Designed for mapping and monitoring wildlife.
2. Quadcopter can load different types of cameras as needed.
3. Flight endurance can be adjusted with the weight of battery and type of camera system (payload).
4. Application software used open-source (free of charge).
5. Quadcopter can be partially repaired if damaged.
6. Easiness of obtaining replacement component.

Overall quadcopter application trial (28 flights) indicate an inreament both in the aviation system and aerial photographs produced. Extra vibrator damper and enhancement in the type of camera (camera resolution 12 to 24 MP) results in quality improvement of aerial photographs. Constraints experienced in the application of Aerialview-650 include:
1. Maneuver spontaneously due to the displacement of two GPS navigation systems.
2. Take off and landing on narrow areas manually.
3. Missing propeller can result quadcopter crash.
4. Running out of battery during the flight resulting in hard landing.
5. Bad heading estimate (navigation disturbance) resulting in quadcopter uncontrolled.

**Table 2**. Criteria and Indicators of Effectiveness and Efficiency Quadcopter Applications and Disturbance to Wildlife

| | Criteria | Indicators |
|---|---|---|
| Effectiveness | The data generated can be used for wildlife identification (large mammals and birds) | Objects can be differentiated well<br>Objects colors properly translated<br>Wildlife identification to the species level<br>Accuracy photo reaches 10 cm/pixel |
| Efficiency | Quadcopter applications with a combination of flight altitude and time to generated the most optimal data | The shortest flight time<br>Fewest number of aerial photos<br>Wide range of aerial photographs greatest |
| Disturbance | Quadcopter noise level | Noise intensity > 60 dB |
| | Wildlife response to the presence of quadcopter | View, voice, panic, avoidance and attack |

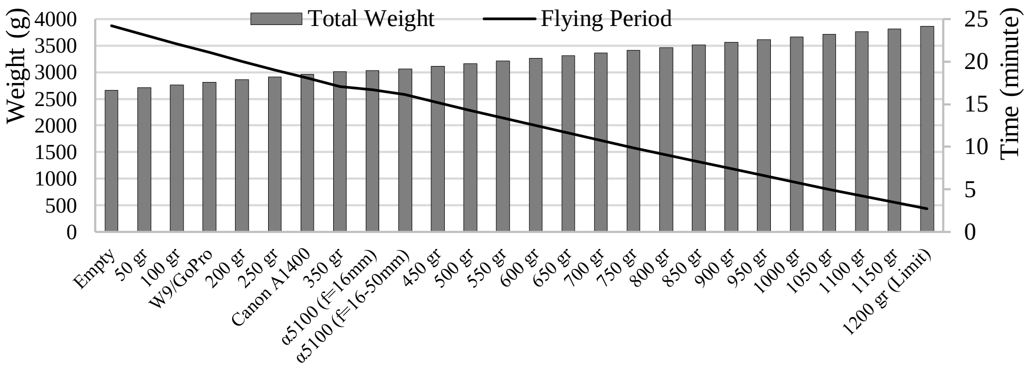


**Figure 3**. Relationship between Weight (Quadcopter and Camera) and Flight time

In broad outline, quadcopter development parameters are similar to the type of airplane/fixed wing. The addition of damping system, an increase in the type/quality of cameras used and the settings for the shooting is done to improve the performance and quality UAV aerial photographs produced [2][3]. The time limit quadcopter for safe flight is 15 minutes. To get these flight time, weight of camera that can loaded Aerialview-650 below than 500 g (Figure 3). Type of camera with weight less than 500 g has become alternate in quadcopter application.

### *3.2. Data Quality Generated*

Spatial resolution of orthophoto mosaic generated from flight at altitude of 50-200 m agl is 0.85 to 4.79 cm/pixel (Table 3). Flight at altitude of 50 m agl generates fivefold greater detail image compared to 200 m agl. The quality of orthophoto mosaic between flights at an altitude of 50 and 100 m agl did not show significant difference. Both analysis in the difference of flight altitude emphasis on identification of objects from aerial images produced. Aerial photo at an altitude of 50-200 m agl can be used for identification of large wildlife (with a size more than 1 m). The results of aerial photography at flight altitude of 200 m agl using action cam w9 sports produce greater detail images than conservation drone (airplane type). Conservation drones using Canon or Pentax camera with a focal length of 5.7, 200 m agl altitude, produce 5.3 cm/pixel aerial photo resolution [3].

Application quadcopter on the flight 100 m agl produce aerial photographs that can be used to detect the presence of wildlife to the species level. This is similar to aerial images produced by FolBat (airplane UAV) an altitude of 100-150 m, which is able to distinguish some seabirds (*Egretta* sp. & *Mycteria americana*) as well as medium-sized vertebrates [2]. The resulting aerial photographs on a flying height of 50 m agl can be used for identification of wildlife species measuring up to 30 cm. The quality of the data generated proving that quadcopter applications is effective for medium-sized wildlife monitoring.

Trials with nearly the same flight time indicate the flight at an altitude of 200 m agl produce coverage area of twenty-five-fold compared to low flight of 50 m agl. Flight at 100 m agl require shorter shooting time by half compared to low flight of 50 m agl. The number of images produced on the flight of 100 m agl is 30% of the total number of photos on the flight of 50 m agl.

**Table 3**. Data Quality Based on Flight Altitude and Photo Shoot Parameter

| No | Camera type/ brand | Flight altitude (m agl) | Shutter speed (s) | Focal length (mm); Aperture; ISO | Photo Overlap/ Sidelap (%) | Dimensional aerial images (pixel) | Orthophoto mosaic resolution (cm/pixel) |
|---|---|---|---|---|---|---|---|
| 1 | Action cam/ W9 Sports | 200 | 1/30-1/60 | - ; f/2.8; 200-400 | 80/60 | 4000 x 3000 | 4.79 |
| 2 | Mirrorles/ Sony α5100 | 100 | 1/1250 | 16; f/5.6; 320-640 | 80/60 | 6000 x 4000 | 0.94 |
| 3 | Mirrorles/ Sony α5100 | 50 | 1/2000 | 17-21; f/4-f/5; 320 | 60/40 | 6000 x 4000 | 0.85 |

Aerial photo which generated in sunny weather, whether it is taken in the morning or in the afternoon produce good quality. So did the shooting in the morning until noon on cloudy days. However, the shooting on the afternoon at 17:24 pm with cloudy weather, produced dark images. This indicates the quality of images strongly influenced by the lighting which has received by the camera lens. Despite the cloudy weather, when the lighting of camera is adequate, could produce good quality image. Dark aerial photos can not be combined into orthophoto mosaic.

The main factors affecting thoroughness of mosaic orthophoto are the quantity and quality of aerial photographs which has been combined. In the early stages of trials, there is an imperfect fusion in orthophoto mosaic. This is due to less good quality images which became constituent for mosaic (the image is blur). The high frequency of quadcopter vibration is the main factor. To overcome this requires appropriate camera and shooting settings. The next trial used a camera with better specifications and equipped with a vibrator damper as well as a mounting and vibration dampers. Vibrator dampers can minimize the vibration frequency at the same speed shooting, so that the camera sensor can capture images in a good and clear condition. Automatically camera settings to the lighting and focal length is recommended. To reduce blur, the shooting speed is set at 1/320 - 1/1000 and added damping system made from low density foam packaging [3].

The number of photos produced is not necessarily all of them can be used to build the mosaic. The more aerial photos that can be combined from the total of aerial photographs produced, the more perfect orthophoto mosaics that can be created. However, in case coordinate of aerial photographs produced has too large deviation, the result of orthophoto mosaics will be imperfect. (Table 4). This condition is a result of constantly changing from focal length determination. To overcome the changing, focal length is locked by fixed setting as well as can be done by replacing the lens using pancake lens [4][9].

Relationship among camera weight, quadcopter, flight time, camera type, flight altitude and accuracy of the data generated, can be used to formulate compatible quadcopter application with appropriate output data as needed. For example, wildlife monitoring that requires output spatial resolution of 2-5 cm/pixel, can be done at flight altitude of 100-200 m agl and using 12-16 MP camera (camera's weight less than 300 g). Whereas to generate aerial photos with a spatial resolution of 0.85 to 1 cm/pixel, the flight can be done at altitudes of 50-100 m agl using 24 MP camera with a weight of 350-500 g.

### *3.3. Effectiveness and Efficiency of Quadcopter*

Based on effectiveness criteria which has been established, the result of aerial photographs from entire flight has met all indicators. Criteria and indicators of efficiency that has been set by the quadcopter application is fulfilled by the flight altitude of 100 m agl. Despite the quality of images is good enough, the identification of wildlife to the species level with a size range of 30-100 m still have to use images from flight altitude of 50 m agl.

Technical recommendations for wildlife monitoring which effective and efficient are:

1. Flight altitudes of 50-100 m agl. The distance between wildlife and the highest object with the quadcopter is as far as 20-30 m. Flight will adjust to the size and characteristics of the wildlife.
2. The use of light-weight type of camera (< 500 g) with high resolution (≥ 20 MP), vibration damper system, fixed or pancake lens, shutter speed between 1/1250 - 1/2000 and flight speed 5 m/s.
3. Images are taken in the morning until afternoon (7:00 am to 17:00 pm) in sunny weather so the lighting needed by the camera is fulfilled.

**Table 4**. Estimation of Camera Position Error Based on the Precision of Aerial Photos

| No | Flight altitude (m agl) | Σ Total aerial photo (N) | Σ Appropriate aerial photo (n) | Proportion n/N (%) | X *error* (m) | Y *error* (m) | Z *error* (m) |
|---|---|---|---|---|---|---|---|
| 1 | 200 | 53 | 53 | 100.00 | 57.48 | 12.93 | 1.42 |
| 2 | 100 | 23 | 23 | 100.00 | 28.46 | 13.27 | 0.22 |
| 3 | 50 | 72 | 61 | 84.72 | 40.67 | 29.07 | 10.54 |

### *3.4. Wildlife Response to the Quadcopter Application*

#### *3.4.1. Noise Level*
Rotation of the rotor and propeller provide noise pollution. Results of identification issued quadcopter sound intensity at a distance of 5 m reach 26.5 dB. This value is relatively low and below the threshold of disturbance for wildlife in the vicinity. Noise levels ≤ 60 dB of quadcopter at a distance of 2 m is considered leave no impact for shorebirds [8][9][10].

#### *3.4.2. Monitoring of White-bellied Sea Eagles (Haliaeetus leucogaster) nest*
Quadcopter flown across the nest of White-bellied Sea Eagles near the breeding season. The identification of the eagle nests indicate that nest each empty, no eggs and chicks. Even the nest looks clean, no visible remains of food such as fish bones, skull of fish or small mammals and litter, just visible twigs with leaves that are still green (new branches). The dimensions of the nest by measurements on aerial photographs show nests longest diameter of 201 cm and 159 cm shortest (Figure 4a).

Overall, there was no negative response shown by the presence of quadcopter that flew over the eagle nest. This is consistent with the results of research on bird behavior to the presence of quadcopter with the closest distance of 4 m from the bird [8]. Quadcopter application for eagle nest monitoring should be performed once without a repetition in adjacent time. Repetion of data retrieval can be done with different intervals and taking into account the characteristics and daily behavior of the eagles.

#### *3.4.3. Monitoring of Proboscis Monkey* (*Nasalis larvatus*)
The result of aerial photographs taken in the morning at HCVA of PT AMR, has been identified some Proboscis Monkey above trees canopy on riparian. Overall, quadcopter application does not have any impact on the foraging activity of Proboscis Monkey at their habitat. Proboscis Monkey remain active as usual at the time of quadcopter passed over the trees. These suggest that the Proboscis Monkey is not responsive to the presence of quadcopter.

Proboscis Monkeys in this area has been accustomed with the presence of wildlife that pass in the air, since this area is also the habitat of Hornbill. Several Hornbills, alone in a group (with a number of 2-5 individu) often flew over the trees where Proboscis Monkeys foraging. The size of hornbill is larger than the dimensions of quadcopter and has a sound of wing stroke noisier than the sound of quadcopter. Morphometry of Proboscis Monkeys were captured based on spatial resolution aerial photo shows a body length is 31.4 cm and 35.2 cm, which is juvenile category (Figure 4b; Figure 4c).


**Figure 4**. Identification Result of Wildlife from Aerial Photo
(a) White-bellied Sea Eagles nest, aerial photo size of 768 x 768 pixels, photo insert of 200 x 200 pixels with a magnification of four-fold, spatial resolution of 1 cm/pixel, L1 (longest diameter), L2 (shortest diameter)
(b) (c) Proboscis Monkey, aerial photo size of 2000 x 2000 pixels, photo insert of 200 x 200 pixels with a magnification of twenty five-fold, spatial resolution of 1 cm/pixel, L (body length)

### *3.5. Quadcopter Application which in Accordance with the Wildlife Photography Ethics*

Technical recommendations in accordance with the ethics of wildlife photography are:

1. Before flight, the daily behavior of wildlife target should be known in advance.
2. Take off at least 300 m of wildlife to avoid being detected.
3. Minimum distance between quadcopter and wildlife target or highest object is 30 m.
4. Flight speed at 5-7 m/s in accordance with quadcopter and camera capabilities.
5. Flight repetitions require interval (pending bit longer or different days)

## 4. Conclusion

Aerial photographs which generated from the application of quadcopter can be used to identify wildlife species up to 30 cm of size. Flight altitude at 50-100 m agl with a flight speed while shooting or recording 5 m/sec and using a camera weighing <500 g, is the technical recommendation which is effective and efficient of quadcopter application for wildlife monitoring. Flights abiding the ethics of wildlife photography do not cause negative response from wildlife target.

## Acknowledgements

This project is partially supported by PT Meganesia Tirta Foresta (MeTTa), PT PJB UP Paiton & Astra Group. We are grateful to PT Riap Indonesia & MeTTa for master schollarship programme; Malang Regency Goverment for study permit; Bogor Agricultural University, PT PJB UP Paiton, PT AMR for research location and amenities. In particular we also would like to thank AN Putra, E Juarsa, LM Laban, A Suprabhana, IS Sugato for their material support; RW Subekti “Nano” as UAV coach, WN Akbar “Waladi” as Aerialvew-650 maker; Zulham, BA Yulianto, H Farmen, R Hardansyah, A Kurniawan, Rismunandar, FI Mansyur, A Chandra, A Herdiyanto for their comments on this manuscript; MeTTa Institute, Paiton Eagle Team, Kumaigreen HCV Team for their technical assistance.

## References

[1] Hodgson J C, Baylis S, Mott R, Herrod A and Clarke R 2016 Precision wildlife monitoring using unmanned aerial vehicles *Scientific Report* **6** 22574
[2] Jones G P, Pearlstine L G and Percival H F 2006 An assessment of small unmanned aerial vehicles for wildlife research *Wildlife Society Bulletin* **34** 750-758
[3] Koh L P and Wich S A 2012 Dawn of drone ecology: low-cost autonomous aerial vehicles for conservation *Tropical Conservation Science* **5** 121-132
[4] Martin J, Edwards H H, Burgess M A, Percival H F, Fagan D E, Gardner B E, Ortega-Ortiz JG, Ifju P G, Evers B S and Rambo T J 2012 Estimating distribution of hidden objects with drone: from tennis balls to manatees *PLoS ONE* **7** e38882
[5] Paneque-Galvez J, McCall M K, Napoletano B M, Wich S A and Koh L P 2014 Small drone for community-based forest monitoring: an assessment of their feasibility and potential in tropical areas *Forests* **5** 1481-1507
[6] Pazmany M M, Stolper R, van Essen L D, Negro J J and Sassen T 2014 Remotely piloted aircraft systems as a rhinoceros anti-poaching tool in Africa *PLoS ONE* **9** e83873
[7] Podduwage D R 2016 An ethical model for the wildlife photography of Sri Lanka *Journal of Aesthetic and Fine Arts* **1** 98-129
[8] Vas E, Lescroel A, Duriez O, Boguszewski G and Gremillet D 2015 Approaching birds with drones: first experiments and ethical guidelines *Biology Letters* **11** 20140754
[9] Watts A C, Perry J H, Smith S E, Burgess M A, Wilkinson B E, Szantoi Z, Ifju P G and Percival H F 2010 Small unmanned aircraft systems for low-altitude aerial surveys *Journal of Wildlife Management* **74** 1614–1619
[10] Wright M D, Goodman P and Cameron T C 2010 exploring behavioural responses of shorebirds to impulsive noise *Wildfowl* **60** 150-167