Development of observing dolphin population method using Small Vertical Take-off and Landing (VTOL) Unmanned Aerial System (AUV)

B Subhan1*, D Arafat1, P Santoso1, K Pahlevi1,5, B Prabowo1, M Taufik1, B S Kusumo1, K Awak2, D Khaerudi1, H Ohoiulun4, F I Nasetion4, H Madduppa3

1Scientific Diving Laboratory, Department of Marine Science and Technology, Bogor Agricultural University
2Student of Marine Technology, Bogor Agricultural University
3Marine Biodiversity and Biosystematics Laboratory, Department of Marine Science and Technology, Bogor Agricultural University
4WWF Indonesia
5Fisheries Diving Club, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University

*E-mail: beginersubhan@apps.ipb.ac.id

Abstract. Indonesia has a very high diversity of Cetacean, observation with good accuracy and precision must be a priority in every observation. Several methods have been developed to help calculate the marine mammal population, one of them by using Vertical Take-off and Landing (VTOL) Unmanned Aerial System (UAS). VTOL UAS is flown at a certain height to capture photos that contain the number of individuals in a pod, while also mapping the movements and recording their behaviors. The aim of this study was to determine the ideal angle to capture the photos. Several observation angles, 30o, 60o, and 90o were tested Observations were conducted in three sites in Indonesia (Sepa Island, Thousand Islands, Kepulauan Seribu National Park (TNKS); Liang Beach, Maluku Island; and Nai Island Kei Archipelago). The results showed that the angles greatly affected the number of objects in the photograph. For example, on the Island of Sepa, at the angle 30o, 60o, and 90o, the number of dolphins obtained were 3, 9 and 14, respectively. This study did not find any object rejection during observation with VTOL UAS. This study suggests that higher angle of photograph from VTOL UAS increases the accuracy of the observation of marine mammals.

Keywords: AUV, Cetacean, observation, population, VTOL

1. Introduction

Indonesia is well known for coral and reef fish diversity [1], besides that Indonesia also has a high diversity of cetacean (Whales, Dolphins, and Porpoises). Among 86 species of whales and dolphins in the world, Indonesia hosts about 31 species [2], which means more than one-third of all known cetaceans can be found in the Indonesian waters.

These cetaceans and other megafauna such as whale shark are facing increasing threats and stressors; there are eight threats to marine mammals worldwide: disease, sound, contaminants, harmful algal blooms, direct fisheries impacts, indirect fisheries impacts, habitat change, and environmental change...
Humans also contribute to several marine megafauna such as whale shark and mammals’ mortality cases through killing, hunting, and accidents such as being hit by a ship; tourism also may be a threat to them [4, 5]. A better understanding will be needed to encounter the threats.

Knowledge of marine mammal populations can support conservation activities. Several methods have been developed to help calculate the marine mammal population, one of them is by using Unmanned Aerial Systems (UAS) [6]. Observation of cetaceans using UAVs is advantageous compared to standard ship-based surveys and allows collecting of very important data on spatial and temporal resolution compared to traditional methods [7, 8]. Initially, UAS was developed to cover the drawback of remote-sensing instruments mounted on spacecraft or manned aircraft [7]; also recently UAS has been used for wildlife observation [9]. The military has described the classification of UAS based on size, flight endurance, and capabilities, i.e., Micro or Nano Air Vehicles (MAV or NAV), Vertical Take-off and Landing (VTOL), Low Altitude-Short/Long Endurance (LASE or LALE), Medium Altitude-Long Endurance (MALE), and High Altitude-Long Endurance (HALE); these classifications have been used widely by Scientists all around the world [10]. Fiori et al. 2017 [9] have narrowed the classification of the UAS to the types which can be used for observations of marine mammals and similar studies, i.e., LALE, LASE and VTOL.

In this research, we used VTOL UAS to observe the marine mammal population. VTOLs UAS is an aircraft which does not require takeoff or landing runs, and this multi-rotor UAS uses electricity as a power source [10]. We can take high-quality pictures by using VTOLS UAS due to its flight stability compared to fixed-wings UAS [9]. Nowadays, VTOLs UAS have been used several times to study marine mammal’s behaviors and populations; researches which have been recorded and published are listed in table 1.

| Study Objective | Model | Sensor |
|-----------------|-------|--------|
| Photogrammetry of Humpback whales (Megaptera novaeangliae); [11] | Splashdrone | Canon PowerShot D30 |
| Photogrammetry of blue whales (Balaenoptera musculus); [12] | APH-22 | Olympus E-PM2 M.Zuiko 25 mm F1.8 lens |
| Photogrammetry and photo-identification of killer whales (Orcinus orca); [13] | APH-22 | Olympus E-PM2 M.Zuiko 25 mm F1.8 lens |
| Abundance surveys and photogrammetry of seals in Antarctica; [14,15] | APH-22 | Sony NEX-5, Canon EOS-M, Olympus E-P1; 22 mm or 45 mm lens |
| Abundance surveys, photogrammetry, and photo-identification of seals in the UK; [16] | Cinestar 6, Skijib, Vulcan 8 | Sony HDR-CX760 and PJ650 |
| Abundance surveys and photo identification of Steller sea lions (Eumetopias jubatus); [17] | APH-22 | Canon EOS M; EF-M f/2 STM 22 mm lens |

2. Materials and Methods

In this research, data was in the form of photos which was taken using VTOLs UAS. VTOLs UAS was operated at an altitude of 15 m - 40 m above sea level. The photos were taken at various angles of capture and could inform the number of individuals in the marine mammal pods. Additionally, the captured images could tell the behavior of marine mammals. With Geographic Positioning System (GPS) which is present in VTOLs UAS, we can provide movement tracking data of marine mammal’s pods. The tracking data will then be processed to acquire a map of marine mammal movement in the study location. Photos from the air are then processed using photo editor tool such as Photoshop to sharpen the image, so the dolphins will be seen more clearly and make it easy to distinguish between dolphins and water.
We used a small multi-rotor UAS because VTOL capable to be operated from boat or coast, and we required stability in flight for photographic operations. The VTOL UAS model that we choose is a DJI phantom 3 advanced with specifications in table 2.

**Table 2. VTOL UAS DJI phantom advance specifications (www.dji.com/phantom-3-adv/info).**

| Category                                         | Specification                                      |
|--------------------------------------------------|---------------------------------------------------|
| Aircraft Weight (Battery & Propellers Included)   | 1280 g                                            |
| Max Ascent Speed; Max Descent Speed; Max Speed    | 5 m/s; 3 m/s; 16 m/s (ATTI mode)                   |
| Max Tilt Angle; Max Angular Speed                 | 35°; 150°/s                                       |
| Max Service Ceiling Above Sea Level               | 19685 feet (6000 m)                               |
| Max Flight Time                                   | Approx. 23 minutes                                |
| Controller’s Max Transmission Distance            | FCC Compliant: 3.1 mi (5 km)                      |
|                                                   | CE Compliant: 2.2 mi (3.5 km) (Unobstructed, free of interference) |
| Camera Sensor                                    | 1/2.3” CMOS                                       |
| Lens                                             | Effective pixels: 12.4 M (total pixels: 12.76 M)  |
| ISO Range                                        | FOV 94° 20 mm (35 mm format equivalent) f/2.8 focus |
|                                                 | at ∞                                               |
|                                                 | 100-3200 (video)                                  |
| Electronic Shutter Speed                         | 100-1600 (photo)                                  |
| Still Photography Modes                          | 8 - 1/8000 s                                      |
|                                                   | Single Shot                                       |
|                                                   | Burst Shooting: 3/5/7 frames                      |
|                                                   | Auto Exposure Bracketing (AEB): 3/5 bracketed frames at 0.7 EV Bias |
| Video Recording Modes                            | Timelapse                                         |
|                                                   | 2.7K: 2704 x1520p 24/25/30 (29.97)                |
|                                                   | FHD: 1920x1080p 24/25/30/48/50/60                  |
|                                                   | HD: 1280x720p 24/25/30/48/50/60                    |

This research took place at 3 locations in Indonesia; Sepa Island, Thousand Islands on August 2017; Maluku Island on May 2016, and Nai Island, Kei Archipelago on October 2016 (figure 1). These locations were taken based on a report about marine mammals’ discovery. Sepa Island was taken to a sample location for this study. There are four species of dolphin that were encountered in Thousand Islands [18]. The selected location to represent Maluku was the Liang Beach waters, and to represent Kei Archipelago is Nai Island. Besides the fact that East of Indonesia (includes Maluku and Kei Archipelago) is the central of migration and distribution area of 31 cetacean species [19], additional information about the presence of dolphins on Maluku Island and Kei Archipelago is derived from local statements. This information is then supported by one of the researchers who had visited the island before, although for different research.
3. Results

3.1. Sepa Island, Thousand Islands, Kepulauan Seribu National Park, Jakarta
The previous section has mentioned that photos will be taken from various angles. In this case, the photos of dolphins on Sepa Island was taken on several angles, which are about 30°, 60° and 90° from the sea surface and the location of the dolphins (figure 2), these angles are the smallest angle between drones and objects. It is seen in the figure, that the difference in the angle of the drawing can produce different estimates of dolphins in a pod. A 30° angle of capture shows that dolphin’s amounts are only 2 or 3 individuals (figure 2a), then 60° shows nine dolphins in the pod (figure 2b). The angle of 90° shows a significant difference in numbers compared to the previous two angles with 14 individuals in a pod (figure 2c).

In addition to individual counting, in this study we also monitor the activity of dolphins, such as the direction of the move. Figure 3 shows that dolphins move back and forth around the island. The movement starts from the west side of the Sepa Island, then follows the coast to the southeast side of the island.

We identified that the species of dolphins found on this occasion were Bottlenose Dolphin (*Tursiops truncatus*). A previous study had stated that bottlenose dolphins were usually found between nearshore and offshore, also spending 92% of its time at less than 32 m depth and located at 1 km from the shore [20] sometimes it can be found distributed around 500 m from the beach [21]. This depends on many factors such as bathymetry, oceanography and *etc*. In this study, we found a dolphin pod 100 m from the beach; it’s conformity with the previous study.
Figure 2. Aerial photos of a dolphin pod in around Sepa Island captures on angles that approximately (a) 30°, (b) 60°, (c) 90°.

Figure 3. Movement pattern of the dolphins around Sepa Island.
3.2. Liang Beach, Salahatu, Maluku Island

On the Liang Beach, Salahatu, island of Maluku we also photographed with angles of captures similar with the previous case, but on this occasion we focused on the two angles of 60° and 90° (figure 4). Each angle 60° and 90° respectively gives an estimate of the number of dolphins around 29 and 44. Again we get the fact on how influent the angle of observation with the results of enumeration.

![Figure 4](image-url)

**Figure 4.** Aerial Photos of a Dolphin Pod in Liang Beach Waters, angle of captures were approximately (a) 60° and (b) 90°.

Dolphins which were encountered in Liang Beach by researchers were identified as short-beaked common dolphin (*Delphinus delphis*), the movement pattern described in figure 5. Its movement just ranging around the east side of the island, we find some schooling tunas along the movement path; so, we assume that the movement was made as feeding activity. A research mentions that *Delphinus delphis* movements geographically in Mercury Bay, New Zealand were influenced by the seasons. During summer and autumn they are more often found around the offshore area, while when spring comes, the dolphins move and are more often found around inshore areas [22].

3.3. Nai Island, Kei Archipelago

Because at that time the wind was blowing very fast, drone flight at an altitude of more than 15 meters would be very risky; so, on Nai Island, the treatment was different from when on Sepa Island and Salahatu Island. On this occasion, the drone which flies at low altitudes only took photos to be used as an image of dolphin’s behavior (figure 6).

It appears that figure 6a shows a dolphin that leaps out of the waters and the other one just dives back into the water while leaving its tail on the surface, this behavior is called as Breaching. Then figure 6b is a photo that was captured before the dolphin jump out of the water in to the air then does a spinning motion before fall back in to the water, this behavior is called as aerial. As we can see in figure 7, the nearest point to the beach of the movement pattern is 2 km and then moves away further from the beach.
Figure 5. Movement pattern of the dolphin pod along Liang Beach, Salahutu, Maluku Island.

Figure 6. Dolphin's behavior (a) breaching, (b) aerial.
4. Discussions

In this study, dolphin shooting was conducted with several different aerial photo angles. At an angle of 30 and 60 degrees, fewer dolphins were observed compared to the 90 degree angle. Based on these results, the angle of observation greatly affected the individual enumeration in the pods. If we consider the sea and the object is the x-axis, the greater the (closest) angle of x will result in a better estimation. At a higher angle, the observer or AUV could still observe the dolphin diving under the surface (figure 4a). This is in line with the previous findings [6] which state a higher angle produces a better estimate.

There are things that need to be considered as well, such as the presence of sun glint that we can see in figure (4a). If the observer uses a 90 degree shooting angle the reflection of sunlight at sea level can be caught by AUV cameras. This light covers a portion of the image so that information is inaccurate. To prevent this can be done by adjusting the time of shooting when the sun's position is still low against the horizon [8]. Observations at certain times such as morning (- before 10.00 pm or afternoon – after 4.00 pm can reduce the reflection or sun glint.

5. Conclusion

This study suggests that using high photograph angle of small vertical take-off and landing (VTOL) Unmanned Aerial System (AUS) can improve accuracy for marine mammals’ population calculation, which in turn can support the management and conservation of these important marine mammals.

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