Unmanned Aerial Vehicle (UAV) Use as a Tool to Assess Crawling and Swimming Speeds in Hatchling Sea Turtles

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The use of low-cost, unmanned aerial vehicles (UAVs) for ecological and biological studies has increased significantly in recent years (Rees et al. 2018). These UAVs provide a relatively low-cost video platform for documenting animals and animal behavior in their natural environment. For example, various models of UAVs have been utilized for a wide variety of biological and ecological surveys and studies (Hodgson et al. 2013; Bevan et al. 2015, 2016; Christiansen et al. 2016; Rummler et al. 2016; Sykora-Bodie et al. 2017; Rees et al. 2018). These studies are demonstrating the increasing utility of UAVs for studying the biology of animals in their natural habitat.

The potential impact of UAVs on animal behavior appears variable depending on the species and experimental protocol. For example, in the case of penguins (Rummler et al. 2016) and waterfowl (McEvoy et al. 2016), the presence of the UAV impacted the animals' behavior, whereas in marine mammals (Christiansen et al. 2016), the results were more variable, with little to no apparent impact in some cases. Focusing on sea turtles specifically, Bevan et al. (2018) investigated UAV flight height and effects on sea turtles and noted that sea turtles on nesting beaches did not alter behavior in response to a UAV at heights of 10–40 m. However, these were adult sea turtles, and studies focusing on the behavior of juvenile and hatchling sea turtles are currently lacking.

UAVs could potentially represent an avenue for monitoring hatchlings during their sea-finding behavior and during their initial movements through the surf-zone and near-shore waters. Hatchling sea-finding behavior represents a critical period in the early life history of sea turtles. The amount of time hatchlings spend on the beach exposed to predators and potentially lethal hot beach temperatures is determined by the amount of time it takes hatchlings to crawl from their nest and down the beach to the surf (Ischer et al. 2009; Wood et al. 2014). Additionally, effective swimming behavior of hatchlings through the surf zone and away from the beach is also critical to their survival since it has the potential to quickly move hatchlings through near-shore waters, which are often areas of high predation (Gyuris 1994; Pilcher et al. 2000).

Previous studies have shown that hatchling fitness can affect crawl speeds and swim speeds in reptiles and thus hatchling survival (Janzen 1993; Elphick and Shine 1998). Additionally, hatchling crawl speed has previously been used as a potential metric of hatchling fitness in studies (Ischer et al. 2009; Mickelson and Downie 2010; Fisher et al. 2014; Sim et al. 2014; Wood et al. 2014). For example, in leatherback sea turtles, it has been reported that nest incubation temperature can affect hatchling crawl speed and thus can potentially affect hatchling survival and fitness (Mickelson and Downie 2010). Therefore, it would be advantageous to have standardized methods for assessing the crawl speed of hatchlings produced in sea turtle conservation programs. The current study evaluates a UAV-based method for assessing hatchling crawl speed and swim speed as potential metrics for hatchling fitness. The study focuses on hatchlings produced in a conservation program on the most important nesting beaches for the critically endangered western Pacific leatherback (Tiwari et al. 2013, Tapilatu et al. 2014), located along the north coast of the Bird's Head Peninsula, Papua Barat, Indonesia (Dutton et al. 2007; Hitipeuw et al. 2007; Tapilatu et al. 2013, Tapilatu 2014). A small (< 2 kg) UAV was evaluated as a video platform for documenting and determining hatchling crawling and swimming speeds as potential metrics of hatchling fitness.

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Methods

A DJI Phantom 3 Pro was utilized during this study. This UAV has a maximal flight time of approximately 20 minutes and is equipped with a gimble-stabilized camera. During this study videos were captured at a resolution of 1080 p at 30 frames per second and stored in an on-board microSD card. The UAV was flown using the DJI Go app and a Nvidia Shield tablet provided a live HD video feed to permit first person view (FPV) control of the flight.

The hatchlings used in this study were from nests that were monitored during the on-going leatherback conservation program at the Jamursba Medi and Wermon nesting beaches. Both of these beaches are located on the north side of Bird's Head Peninsula and have relatively clear waters depending on weather and tides, which can facilitate the monitoring of hatchlings during their initial movements away from shore. Hatchlings observed in this study came from recently emerged nests and were monitored during their sea-finding behavior and swimming behavior. Observations were recorded for hatchlings that were undergoing these behaviors around dusk (1600–1900 h)

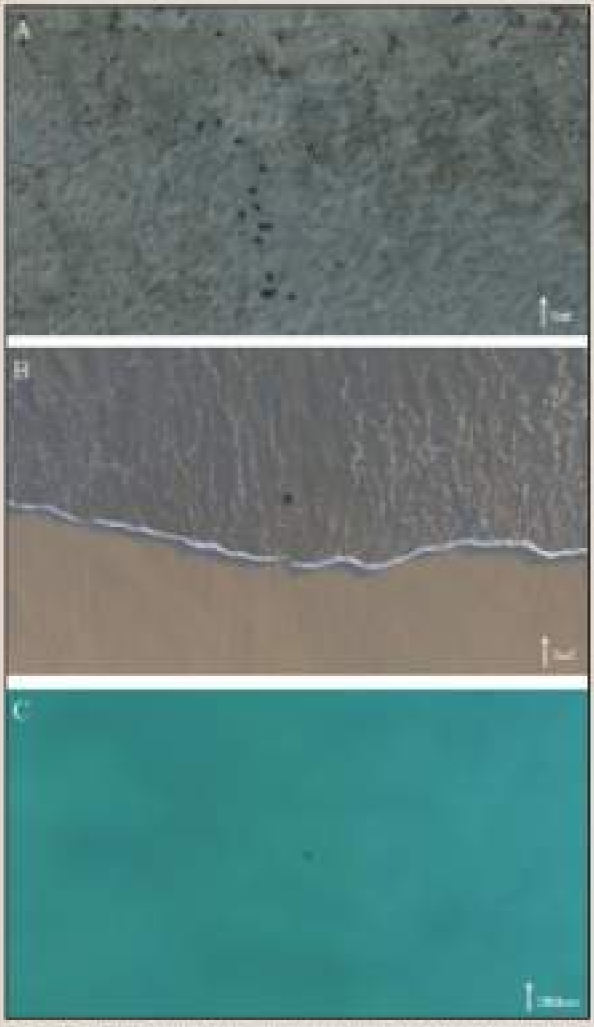

Fig. 1. The UAV was used to monitor sea-finding behavior and initial movements away from shore in leatherback sea turtle hatchlings, Bird's Head Peninsula, Papua Barat, Indonesia. (A) Example of sea-finding and crawling behavior as hatchlings orient and move in the direction of the surf. (B) Example of hatchling transitioning from sea-finding behavior to swimming behavior as they enter the surf. (C) Typical behavior of hatchling in the near-shore water, swimming approximately perpendicular to shore. Hatchlings were monitored for a maximum of 300 m away from shore (distance limited by battery life). The video data allowed us to calculate crawl speeds and swimming speeds as proxies of fitness.

Fig. 2. Example of a change in hatchling swimming direction as it encounters a needlefish in near-shore waters. The needlefish is indicated by a dashed arrow and the hatchling is indicated by a solid arrow. (A) Pre-encounter, needlefish and hatchling both swimming approximately perpendicular to shore towards one another. (B) As hatchling approaches needlefish, both turn approximately 90° to the right (i.e. parallel to shore). (C) Hatchling re-oriented approximately perpendicular to shore. This demonstrates the ability of the UAV to monitor behavior as well as swimming speed and direction.

or dawn (0500–0700 h) between July 2015 and February 2016. These observation time periods are within the normal range of times when hatchlings emerge from nests on these beaches. At Jamursba Medi, a total of 54 hatchlings were monitored for crawl speed and six of these hatchlings were followed for swimming speed once they entered the water. At Wermon, a total of 24 hatchlings were monitored for crawl speed, but due to logistical and weather limitations, no hatchling swimming speeds were recorded. During their movements down the beach, hatchlings were observed in groups ranging from 1–18 individuals.

To optimize quantification of results the following methods were implemented. Naturally occurring driftwood sticks were utilized to mark the beach at 0.5 m intervals for the 10–20 m area extending from the nesting zone to the surf zone. The UAV was flown at an altitude of 5 m directly above the area of beach traversed by the hatchlings and was slowly advanced towards the surf as the hatchlings progressed down the beach. Care was taken to minimize UAV movements. The movements of hatchlings were monitored remotely via the HD video feed, with the operator located outside the study area, above the high-tide line near the vegetation zone bordering the beach. Hatchlings were allowed to crawl down the beach, enter the surf, and swim offshore uninterrupted. Due to logistical constraints, if a group of hatchlings was monitored during sea-finding behavior, once they begun dispersing through the surf a single hatchling was monitored with the UAV. Hatchlings would occasionally pause during their crawl to the surf before continuing and this time was included in crawl speed calculations. Additionally, if hatchlings encountered any raised or lowered portions of the sand, sticks, etc. which slowed or hindered their crawl, this time was included in the crawl speed calculations. Crawl speed was based on the amount of time a hatchling took to traverse an approximate 10–20 m linear distance on the beach.

The distance that an individual hatchling was monitored was dependent upon battery life versus the speed of movement during sea-finding and swimming. The average distance a hatchling was followed was 133.8 ± 98.3 m, and ranged from 30–300 m. Individual turtles were monitored on the HD video feed and distance from shore was recorded at 10-m intervals based on the UAV's internal GPS system which was relayed to the operator's remote control unit. Hatchling swim speed was based on the time required for the total distance monitored for each hatchling (30–300 m).

Results

Fig. 1 demonstrates the ability of the UAV system to document the movement of hatchlings down the beach (Fig. 1A), through the surf (Fig. 1B), and in near-shore waters (Fig. 1C). The results provided the first documentation of crawl speeds and swim speeds of hatchling western Pacific leatherbacks from Jamursba Medi and Wermon beaches. Hatchlings at Jamursba Medi had a mean crawl speed of 0.04 ± 0.01 m/s (N = 54). Hatchlings at Wermon had a mean crawl speed of 0.06 ± 0.01 m/s (N = 8). These crawl speeds were not significantly different (t_s = -4.74, $p > 0.05$). Hatchlings at Jamursba Medi had a mean swimming speed of 0.55 ± 0.13 m/s (N = 6).

The ability to utilize the UAV for monitoring sea-finding and initial offshore movements was limited by several factors, including weather, UAV battery life (approximately 20 minutes per flight), ambient light levels, and hatchling visibility in the surf zone. For example, wind and rough surf conditions at Wermon were too turbulent to consistently find and follow hatchlings in the water.

One instance of a hatchling altering swimming direction in response to a fish (Fig. 2) was recorded. As the hatchling approached a fish, both hatchling and fish turned approximately 90° to the shore (i.e. parallel to shore). Following this interaction, the hatchling re-oriented to an off-shore swimming direction (i.e., perpendicular to shore). One instance of avian predation on a hatchling at Jamursba Medi (Fig. 3) was also recorded. During the predation event, the UAV was positioned 5 m above two hatchlings that were swimming within the frame of view when a White-bellied Sea Eagle (*Haliaeetus leucogaster*) entered the frame, caught, and flew off with one of the hatchlings. The other hatchling, unaffected, continued to swim offshore on the same heading.

Discussion and Conclusions

The results of the current study indicate that consumer-level UAVs (e.g., DJI Phantom 3 Pro, etc.) can provide a cost-effective method of documenting hatchling movements during sea-finding behavior and initial swimming behavior in near-shore waters. The advantage of using a UAV system for documenting these behaviors is that it provides a video platform from directly above the hatchlings and thus optimizes the ability to accurately quantify hatchling behavior (e.g., crawling and swimming speeds) during these early life-history events.

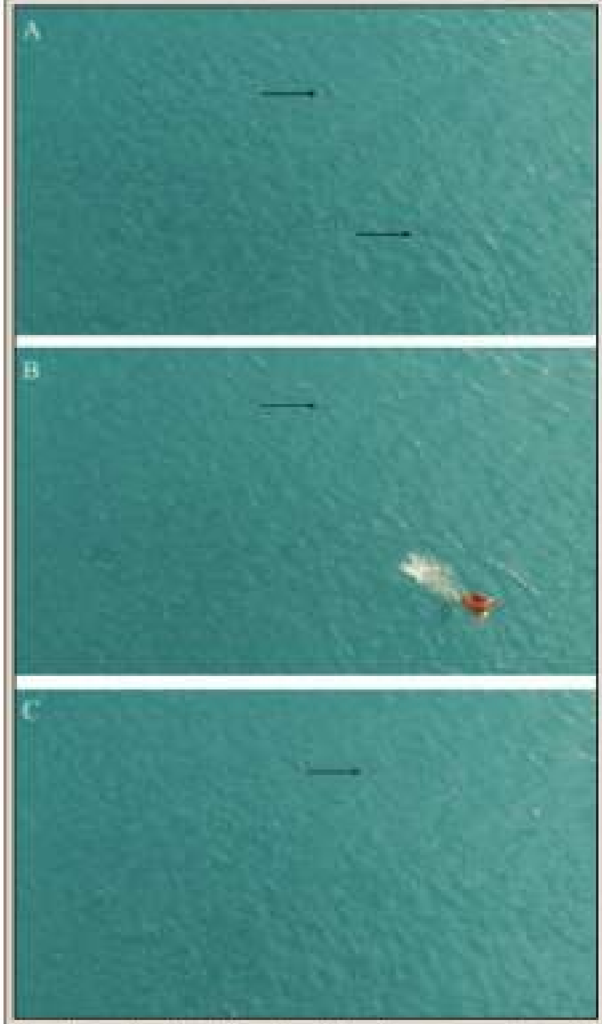

Fig. 3. Example of hatchling depredation by an avian predator. (A) Two hatchlings (indicated by arrows) swimming in near-shore waters. (B) Avian predator (White-bellied Sea Eagle, *Haliaeetus leucogaster*) catching one hatchling while second hatchling (indicated by arrow) continued to swim in an offshore direction. (C) Single hatchling swimming. This hatchling did not make any obvious changes to its swimming behavior.

Hatchlings were allowed to crawl down the beach and swim through the surf in a natural fashion. Therefore, hatchling crawling and swimming behaviors were monitored continuously without recovering the UAV and changing the battery. Although it was possible to quickly recover the UAV and change batteries, when we attempted to deploy the UAV post battery change it was difficult to relocate the swimming hatchlings. In the current study, the swimming of hatchlings was monitored for up to 300 m from shore, and this distance was typically limited by battery life rather than loss of visual contact with the hatchling. Therefore, a significant portion of the battery life was consumed during the sea-finding movements prior to monitoring swimming behavior. In contrast to the current study, if a battery was dedicated specifically for monitoring swimming behavior, it may be possible to follow hatchlings in near-shore waters for up to 20 minutes. Following the hatchling for longer periods of swimming would enhance the accuracy of predicting swimming speeds and would take into account potential variations in swimming speed as well as decrease error associated with GPS-based distance of the hatchling movements.

This study also revealed several environmental factors that limit the use of a UAV system for documenting these behaviors. UAV flights and video recordings were limited to daylight hours. As tested, the UAV could record videos only under ambient daylight conditions, as the unmodified UAV lacks lights for illuminating areas during flights in dark conditions. Additionally, weather conditions such as strong winds and rains can prevent flights. Surf conditions can also limit flights. For example, at Wermon, the surf conditions were too turbulent to consistently find and follow hatchlings.

The movements of hatchlings appeared to be both directed and continuous during both sea-finding and swimming behaviors. Thus, there were no obvious indications that the UAV was significantly altering hatchling behavior. For example, hatchlings swimming through near-shore waters primarily remained near the surface of the water and maintained a course that was roughly perpendicular to the shoreline. Further, hatchlings did not undergo any diving or other obvious changes in behavior that would suggest the UAV had affected their behavior. The results indicated one instance of predation on a hatchling (Fig. 3), during which the predator was not deterred by the presence of the UAV. It is plausible that controls could be run to evaluate the potential impact of UAVs on hatchling crawl and swim speeds. For example, ground-based wildlife cameras positioned on the beach could be used to record hatchling crawl speeds for a comparison to UAV results. Evaluating the impact of UAVs on swimming hatchlings is more challenging. However, it is feasible that this topic could be addressed by comparing results from UAVs flown at different altitudes as well as comparisons to alternative methods for evaluating swimming speed, such as radio-transmitter tagged hatchlings.

Although the primary goal of the current study was to evaluate the utility of a UAV-based method for assessing hatchling crawl speed and swim speed as potential metrics for hatchling fitness, the results also provided base-line data on crawling and swimming speeds in western Pacific leatherback hatchlings. Additionally, based on the results of the current study, hatchlings should be filmed while traversing a cleaned and smooth beach, in order to standardize movements and minimize variation associated with obstacles and beach surface topography. The ability to accurately quantify these behaviors could provide a new avenue for evaluating hatchling fitness on a large scale. For example, these behaviors could be monitored to evaluate the fitness of hatchlings from different nesting beaches (within a population or between populations), different times of the nesting season, etc. Such information could indicate the impact of specific factors (e.g., beach temperature, rainfall, etc.) on travel speeds and potentially hatchling fitness and provide insight on the impact of the nesting environment on the ecology and conservation of sea turtles.

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