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Unmanned Aerial Vehicles (UAVs) for Monitoring Sea Turtles in Near-Shore Waters

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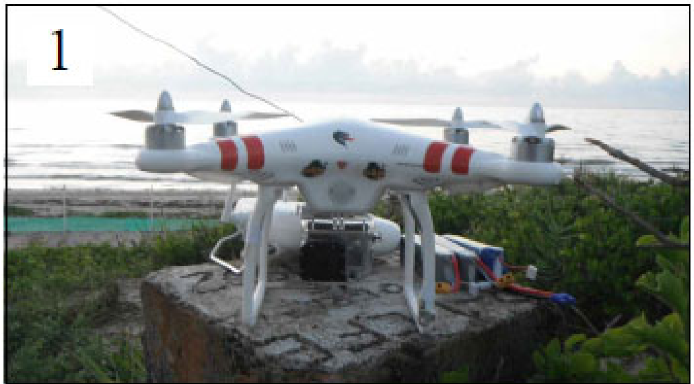
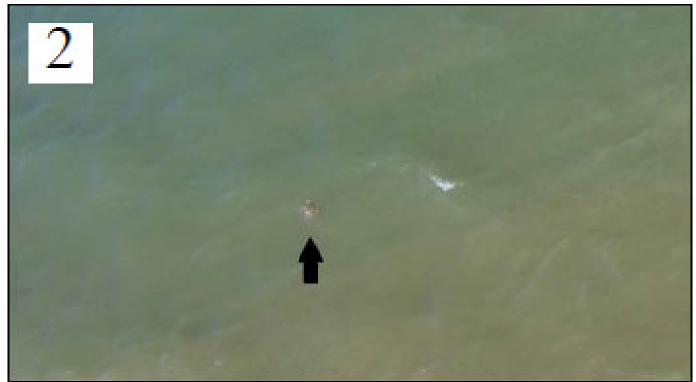
Aerial surveys have long been a standard methodology utilized in wildlife management of marine mammals and sea turtles (reviewed by Jones *et al*. 2006). More recently, the use of unmanned aerial vehicles (UAVs) for monitoring wildlife is rapidly gaining popularity (Jones *et al*. 2006; Hodgson *et al*. 2013). This technology represents a valuable tool that can potentially complement and enhance many ongoing conservation programs (Koh & Wich 2012). For example, studies have used UAVs for surveying and monitoring marine mammals (Koski *et al*. 2009; Hodgson *et al*. 2013), and the results suggest that UAVs represent an efficient and cost-effective alternative to manned aerial surveys. Additionally, the potential use of UAVs is beginning to receive some attention in sea turtle studies (Ballorain *et al*. 2014; Crawford *et al*. 2014). While many of the commercially available UAV systems are expensive and therefore not practical for lower budget sea turtle programs, there are an increasing number of low cost UAV systems becoming available. The purpose of the current study was to evaluate the effectiveness of a low-cost commercially available UAV for identifying both adult and hatchling sea turtles in near-shore waters adjacent to nesting beaches.

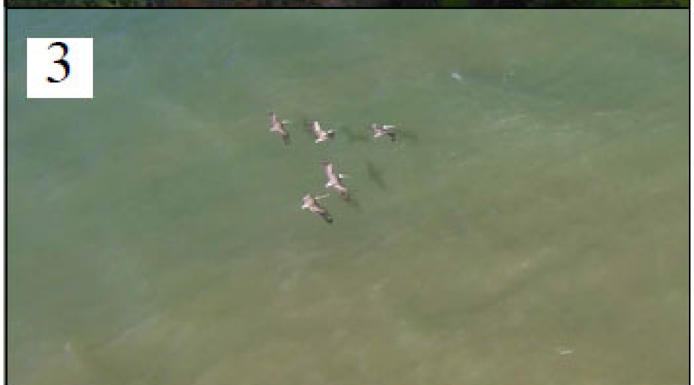
We tested a DJI Phantom 1 quadcopter UAV (DJI Innovations, Shenzhen, China), equipped with a GoPro Hero 3 Black Edition camera in near-shore waters adjacent to the primary nesting beach of the Kemp's ridley sea turtle. The Phantom UAV was remotely controlled with a handheld unit with a maximum rated communication distance of 1000 m from the operator. It has an onboard GPS-enabled Naza-M V2 flight control system which receives input from an onboard altimeter, compass, and six-axis accelerometer. This flight control system facilitates a stable and easy to control platform for aerial videography. The UAV is powered by a 2200 mAh lithium polymer battery weighing 170g with a maximum rated flight time of 15 minutes. The dimensions of the DJI Phantom quadcopters are approximately 35 x 35 x 19 cm (length, width, height) weighing 1336 g, which includes GoPro and waterproof housing. We used GoPro video settings of 1080 p at 60 frames per second and a medium angle window. The camera was enclosed in a GoPro waterproof housing and was attached to the underside of the UAV with standard attachments included with the UAV (Fig. 1). We attached a polarizing lens filter to the housing and positioned the camera at an approximate 45o angle from vertical. The GoPro camera has a built-in 2.5 GHz WiFi system that transmitted a video feed to a mini iPad running a GoPro App for receiving the video feed.

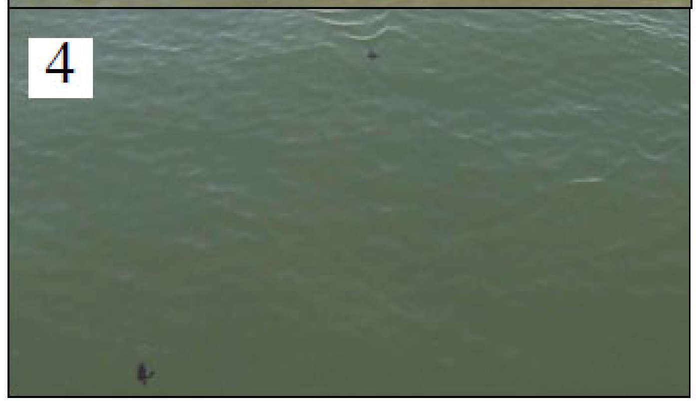
We tested the utility of this UAV system by evaluating a variety of its capabilities at the nesting beach for the Kemp's ridley sea turtle at Rancho Nuevo, Mexico, during the 2013 and 2014 nesting seasons. Specifically we tested 1) flight characteristics (e.g., stability, ease of control, etc.) and suitability for near-shore surveys, 2) video quality and ability to identify both adult and hatchling turtles from video of near-shore waters, 3) working distance of the WiFi system to provide video to the iPad, 4) time lag on the video feed, and 5) flight time duration per battery during typical surveys over near-shore waters. In addition to documenting adult females and hatchlings in near-shore waters, we evaluated the ability of this system to identify objects close to the surface in near-shore waters by suspending submersible balls, approximately 8 cm in diameter, at 30 and 60 cm from a float on the surface of the water. These objects were deployed by boat at approximately 75 m from shore. In a separate trial we flight tested a newer model of quadcopter, the DJI Phantom 2 UAV system in a terrestrial urban environment. The Phantom 1 was previously flight-tested in the same terrestrial urban environment, allowing us to compare live video feed quality and maximum flight distance between the Phantom 1 and 2. The Phantom 2 was equipped with the same camera as used in previous trials (GoPro 3), but was also equipped with a 5.2 GHz video link for first-person view (FPV), seven inch FPV monitor with built-in receiver, and iOSD module for superimposing flight data on the video monitor. Additionally, the Phantom 2 has a larger lithium polymer battery (5200 mAh) for extended flight times (flight time of 20-25 minutes) in comparison to the Phantom 1 (10-15 minutes flight time).

The UAV system proved to be a stable video platform that was easy to fly and control. The Phantom was quite responsive, nimble, agile, and predictable in flight. Most flights were conducted during clear to mostly clear days from 7 am-12 pm. However, approximately 4 flights were flown in the afternoon hours from 12-4 pm. Winds were variable, but relatively light (approximately 10 mph or less), since stronger winds tended to decrease the UAV's ability to consistently maintain the desired flight path. Their size and weight makes them easily portable, but decreases their stability in strong winds. A newer quadcopter, the DJI Inspire 1 (which we have not yet tested) is almost three times heavier than the Phantom series, weighing 2935g and is reputed to be more stable in strong winds. The Phantom was capable of maintaining a stable position in relatively calm winds when desired by the operator, due to the GPS-enabled flight control system. The Phantom's vertical takeoff made it possible to launch the aircraft from a circular area no larger than the approximate footprint of the Phantom itself, although on windy days it drifted during take-off. It proved to be an effective video platform for both dynamic transects of the near-shore waters adjacent to the nesting beach as a well as a stationary video platform. Over the two nesting seasons during which this study was conducted, we flew approximately 40 flights. The majority of these flights were coordinated with the release of hatchlings from nests that had emerged the evening prior or were conducted as adult females were leaving the beach after nesting. Thus, in all such flights, turtles were observed and recorded in the water. The purpose of this preliminary study was to evaluate the capabilities of UAVs for detecting turtles so that these methods could potentially be integrated into future standardized in-water surveys. The capabilities of the UAV system were well suited for daytime surveys of nesting Kemp's ridley turtles and would be appropriate for documenting other sea turtle species in near-shore foraging and nesting environments as well as hatchlings dispersing from the beach during early daylight hours. We underscore the applicability of the UAV platform for daytime surveys considering all tests were conducted during daylight hours. Although the GoPro 3 Black Edition camera can be used in low light levels it does not have night vision or IR capabilities. In the case of the Kemp's ridley, nesting occurs during the day and some hatchling emergence occurs during early daylight hours. We routinely flew the UAV system at 20 to 30 m in altitude and up to 100 m offshore without loss of agility or responsiveness to operator commands. Altitude in the current study using the Phantom 1 had to be estimated by the operator on the beach. In contrast, the Phantom 2 with iOSD provides continuous, on-screen flight information to the operator, including altitude, distance from the operator, and battery life remaining. These capabilities facilitate precise, standardized in-water transects. It is important to note that we did not attempt to reach 1000 m from the controller, the maximum reported distance capable for this UAV platform in any of our flights, and we flew the UAV system in failsafe mode, which would automatically return the UAV to its take-off location if it lost contact with the control unit. Two recently available upgraded UAV platform permits GPS- programmable flight plans that would allow the operator to spatially standardize survey transects.









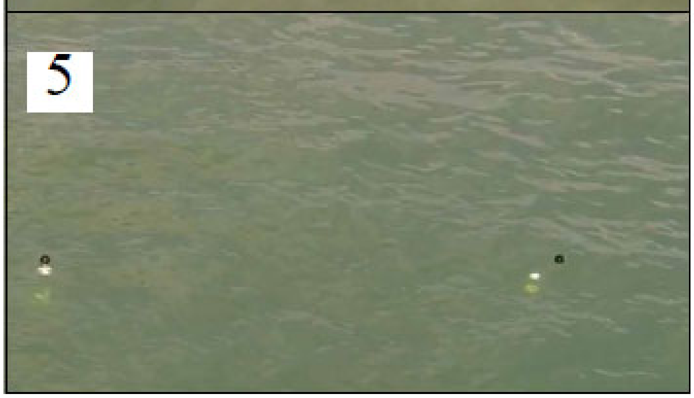


Figure 1. The DJI Phantom UAV system that was evaluated for near-shore surveys in areas adjacent to the nesting beach at Rancho Nuevo. The system is equipped with a GoPro Hero 3 Black Edition camera in a waterproof housing.
Figure 2. A female Kemp's ridley turtle surfacing for the first time after returning to the sea. The turtle is in turbid and shallow water approximately 50 m from shore. The UAV is hovering in a stable position at approximately 30 m in altitude.
Figure 3. Ten seconds after the Kemp's ridley female initially surfaced, brown pelicans flying through video area, providing a perspective of the view from UAV.
Figure 4. Examples of multiple Kemp's ridley hatchling photos taken from the UAV as hatchlings were dispersing from shore. The UAV was hovering at approximately 5 m in altitude and 50 m offshore.
Figure 5. Objects 8 cm in diameter suspended at 60 cm (yellow 12 cm weighted ball) and 30 cm (white 10 cm weighted ball) below a surface float (black 10 cm ball). These objects were deployed by boat at approximately 75 m from shore. The UAV was flying at approximately 10 m in altitude.

The GoPro Hero 3 Black edition provided smooth high resolution video. As examples, Figs. 2 and 3 show frames taken from video of a post-nesting female travelling away from the beach through turbid near-shore waters. In these figures, the UAV was maintained in a stationary position approximately 30 m in altitude and 75 m offshore, and was able to record the turtle surfacing twice over an approximate 30 second period as it was heading away from the nesting beach. In addition to documenting adult turtles, the video allowed us to visualize hatchlings dispersing from the nesting beach (Fig. 4) and predation events from birds. We were also able to identify the 8 cm-diameter submersible objects at 30 and 60 cm below the surface approximately 75 m from the beach (Fig. 5). The GoPro can be set on a variety of resolutions for video quality and offers three field of view options, wide (170° angle), medium (120° angle), and narrow (90° angle) settings. For this study, we kept the GoPro set on a 1080p medium field of view. Using the 1080 p medium field of view and flying at an altitude of 30-50 m throughout this study resulted in a survey width that was 60-100 m.

We found that the ratings for battery life for the Phantom 1 were fairly accurate and determined by flight characteristics and payload (e.g., camera and housing). The flight time per battery was approximately 10 to 12 minutes before the UAV began flashing the red "low battery" warning signal. Once the red "low battery" signal began flashing, we returned the UAV to the beach. It typically took less than two minutes to bring the UAV back to the beach, replace the battery and re-launch it for the next flight. In comparison, the Phantom 2 was equipped with a larger battery reported to allow for up to approximately 25 minutes of flight time. In our Phantom 2 trials, we did not test maximum flight times, yet we routinely flew the Phantom 2 for ca. 20 minutes before getting a low battery signal.

The video feed from the GoPro WiFi used on the Phantom 1 had limitations. First, there was an approximate three to four second lag in the video feed that was problematic when we were attempting to actively follow turtles as they travelled away from shore. Second, the WiFi had a limited range, and was useful at 50-75 m offshore, but lost functionality between 75-100 m from shore. The WiFi signal was stronger if the back of the camera was facing the operator. The functional range for video feed from the Phantom 1 in offshore flights was similar to flight tests in the terrestrial urban environment, with a range of about 50-75 m. In contrast to the GoPro WiF video feed used with the Phantom 1, in later trials with the Phantom 2, the live video feed using the 5.2 GHz link with the iOSD system was effective and useful. We tested it at up to 270 m from the operator in the terrestrial urban environment and there was no lag time in the video, and the video was constant and clear. Additionally the flight information displayed on the FPV monitor was useful. The display included real-time readings for altitude, distance from operator, horizontal velocity, vertical velocity, and UAV orientation.

Collectively, the results indicate that this UAV system provides a practical and effective method of conducting daytime surveys in near-shore waters for monitoring sea turtle abundance and movements. Even in turbid near-shore waters, we were able to monitor the surfacing of adult females as they left the nesting beach. We were also able to monitor hatchlings swimming at or near the surface as they dispersed from the nesting beach. In addition to movements, we were able to monitor hatchling predation by birds in near-shore habitat. As an example, during one flight while following the hatchlings off the beach, a group of seagulls began preying on hatchlings in near-shore waters and at least five hatchlings were depredated. It is also plausible that predation of hatchlings by fish could be monitored at or near the water's surface. We underscore the utility of this UAV video platform for environmental and conservation applications for various size classes of sea turtles. While the UAV was controlled from shore in the current study, it could also be launched and controlled from a boat for monitoring turtles in offshore areas such as foraging grounds. Additionally, the popularity of these low-priced UAV systems is resulting in a rapid increase in their capabilities. For examples, the newer Phantom 2 had significantly better live video feed and flight times in comparison to the Phantom 1. Further, recent upgrades in the NAZA M V2 flight control system for the Phantom allow it to fly fully autonomous flights, including automated takeoff and landing, with flight paths programmed via an iPad or PC laptop based on GPS waypoints. This capability would facilitate standardization of surveys.

The results of the current study exemplify the potential of UAVs to collect survey data that would normally be logistically difficult to collect. For example, UAVs can provide a cost effective and practical method for surveying the near-shore environment by providing a high resolution aerial video platform, while avoiding the logistics and costs associated with boat-based surveys and manned-aerial surveys. As capabilities and potential applications grow with increasing demand, technology, and lower costs, we anticipate the use of UAVs becoming a more mainstream method for monitoring environmental systems. It is therefore pertinent for studies such as this to identify the appropriate uses and limits of such systems to guide future development and use of the technology for ecological surveys.

One of the many benefits of using this technology for wildlife surveys is that the risk of disturbing the species being studied is far less than for traditional manned aerial surveys or even terrestrial surveys. No animals exhibited any indication of detecting the presence of the UAV, likely due to its small impact to the surrounding environment (Jones *et al*. 2006; Koski *et al*. 2009).

No permits were required to operate the Phantom UAV at Rancho Nuevo, although these surveys were reviewed by CONANP, SEDUMA, and the Kemp's Ridley Working Group. The beach and near-shore waters represent a remote area with no boat traffic and a low level of air traffic. This study is an example of how these UAV- based surveys clearly meet all FAA regulations that have recently been released in the U.S. (<http://www.faa.gov/regulations_policies/rulemaking/media/021515_sUAS_Summary.pdf>). We encourage scientists who adopt this methodology to evaluate their specific location and ensure that they comply with all regulations governing UAV activity in their study area. It is possible that UAV-based surveys may not be possible in some areas due to local regulations, etc.

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