DRONES
IN SEA TURTLE CONSERVATION
The Sky Is the Limit

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Recent advances in drone technology—also called unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UASs)—have made such devices increasingly cost-effective, easy to operate, and widely accessible. Alongside many other tools and techniques, drones are transforming sea turtle conservation and research. Yet even with drone technology advancing quickly, we have only begun to scratch the surface of its potential.

An aerial photo taken with a drone shows the tracks of leatherback turtles that emerged in Grande Riviere, Trinidad, the night before. Drones are giving field biologists new ways to collect sea turtle data. © Ben J. Hicks/benjhicks.com. **AT LEFT:** Drones can be outfitted with thermal imaging accessories to capture nighttime imagery such as this thermal image of a turtle returning to the sea after nesting. © Miguel Rodrigues Varela

CURRENT USES OF DRONES IN SEA TURTLE CONSERVATION

A number of sea turtle studies involving drones have been published in the scientific literature since 2015, and they provide a range of novel insights. Drone studies carried out on sea turtles have primarily focused on obtaining estimates of population abundance, distribution, and density by using aerial imagery to count nesting females, their tracks or nests, or turtles in the water. To date, these studies have primarily taken place in breeding areas, where sea turtles predictably gather in large numbers in accessible, nearshore waters. From the initial, more basic studies that monitored turtles in the water and recorded behavior, drone research has progressed to collect increasingly advanced data. Some examples include (1) identifying the operational sex ratios of turtles gathering at the start of a breeding season or (2) incorporating semiautomatic counts of turtles aggregating offshore at an *arribada* (mass nesting) beach using artificial intelligence.

Although drones come in many different styles, shapes, and sizes, relatively small fixed-wing and rotary-wing aircraft are the types that are most frequently used to gather video and photographic data, and they have been most commonly used for sea turtle research. Larger drones can be equipped with larger, heavier sensors such as compact thermal vision cameras, hyperspectral sensors, and laser scanning devices such as LiDAR (Light Detection and Ranging).

Beyond drones' use in studying sea turtles themselves, drones were recently used to model a sea turtle population's nesting beach using photogrammetry. *Photogrammetry* is the computationally intense process of generating detailed three-dimensional (3D) models from a series of overlapping images, whereby the relative location of different points on the various images are used to determine the shape of the photographed subject. Researchers created very accurate 3D models of sea turtle nesting beaches with less than 15 centimeters (6 inches) of elevation error. They then projected different sea-level rise scenarios resulting from climate change onto the model to estimate habitat loss caused by flooding and to assess the potential for the beach to retreat in the future. Such 3D models can also be updated yearly to detect patterns of coastal erosion, to better understand beach dynamics, and to ultimately predict how the habitat may shift over the next 50 or 100 years.

FUTURE DIRECTIONS FOR DRONES IN SEA TURTLE CONSERVATION

Drones carrying lightweight cameras and even multispectral sensors can provide professional mapping at a fraction of the cost of previous photogrammetric techniques that required piloted aircraft. Such studies can also be combined with information about sea turtle population sex ratios and remotely sensed surface temperatures to predict new suitable (and unsuitable) areas for nesting in the coming decades. By integrating research that predicts suitable nesting areas into coastal planning, we can better understand which areas should be protected from coastal development to make sure suitable sea turtle nesting habitats will be available as the impacts of climate change progress.

Other exciting innovations that have come about recently include the use of *fluid lensing*, an experimental algorithm that uses light wavelengths that transmit through water to analyze submarine structures and thereby create detailed underwater maps that are accurate to within a centimeter. The principle is the same as in the photogrammetry study mentioned earlier, but fluid lensing technology makes it possible to map underwater habitat rather than beach habitat. Such maps could be used to monitor foraging areas used by sea turtles during their nesting period or to monitor known shallow, nonbreeding areas. Thus, they could help answer a range of research questions, such as why sea turtles prefer a particular area over another or how and why different species select certain habitats. When combined with other data types, for example, information from the remote tracking of sea turtles and fishing vessels, such underwater habitat mapping could provide a new understanding of threats to turtles, such as how they interact with local small-scale fisheries. Although this technology is too costly to be used widely today, the same could have been said about the use of drones just 10 years ago!

Another new and rapidly developing technique combines off-the-shelf drones with artificial intelligence to detect animals or objects in near real time. Data are interpreted while they are gathered through synchronization with a live video stream. The system is capable of working on a wide variety of devices, from cell phones to desktop computers, because it requires an extremely low frame rate of just two frames per second to accurately detect objects. It has been tested already with rhinoceroses and cars for different conservation-related purposes, but it has not yet been used for sea turtle conservation. Although several challenges remain, it will soon be possible to process images on board the drone and transmit the results in real time or to transmit the live feed directly to a base station that processes images in real time for animal detection. Using either standard or thermal cameras, this technique could be useful for monitoring large and inaccessible areas for the presence of turtles or for antipoaching surveillance.

Hyperspectral sensors are yet another technological tool that may revolutionize sea turtle research and conservation when combined with drones. Unlike standard cameras that sense three wavelengths of visible light (red, green, and blue) and commonly use multispectral image sensors that measure visible light and reflected energy from the electromagnetic spectrum, hyperspectral sensors measure energy in narrower and more numerous bands that can yield images with as many as 200 or more contiguous spectral bands. As a result, they produce images that contain much more data, thereby making it possible to discern differences between land and water features. For example, multispectral imagery can be used to detect and map forested areas, whereas hyperspectral imagery can be used to identify and map individual tree species within the forest. For sea turtle research, hyperspectral imagery could be used to map vegetation species along the nesting beach and, when combined with data on nesting success or emergence success of hatchlings under the canopy, allow researchers to better understand the influence of vegetation on nesting. It also could be used to monitor the spread of invasive plant species in nesting areas or to map the density of vegetated habitats that can't be mapped effectively using traditional photogrammetry. A range of other applications are also possible.

Despite the growing capabilities of drones in terms of sensor quality and flight times, some big challenges must also be overcome:

- **Data processing and storage.** The geospatial, imagery, and other sensor data collected by a drone can quickly grow to very large file sizes.
- **Costs.** Licenses for specialized processing software can be expensive.
- **Legal constraints.** Restrictions on the use of drones vary from location to location and include visual line of site obligations, no-fly zones, and so on.
- **Adverse weather conditions.** Drones can't safely operate in bad weather, thus limiting their usability for certain tasks.

The combination of technological advances and the inventiveness of researchers will no doubt lead to more and more uses for drones in sea turtle conservation and research over the years ahead. When it comes to using drones in sea turtle conservation, the sky is the limit! •