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Drones in the Coastal Zone: Report from a Regional Workshop for the US Southeast and Caribbean

October 14–29, 2020

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IOOS Integrated Ocean Observing System
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DISCLAIMER

Drones in the Coastal Zone: Report From a Regional Workshop for the US Southeast and Caribbean

Prepared by

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and

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United States Department of Commerce

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National Oceanic and Atmospheric Administration

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Photo: Duke Marine Robotics and Remote Sensing

Executive Summary

Coastal managers require tools that provide rapid, repeatable, high-resolution imagery, derived data, and visualizations to assess environmental and habitat condition, detect impacts from coastal hazards, and document and monitor wildlife populations and biological communities. Uncrewed aircraft systems (UAS), or drones, are becoming increasingly affordable tools for research and assessments of the coastal zone. UAS technology is rapidly evolving, including software for mission planning and piloting, improvements in battery life and endurance, expanded payload options, and development of automated tools for generating high-resolution maps or enumerating animals or objects. However, cost still remains one of the most significant hurdles to adopting UAS more broadly. Rapidly advancing technologies create hurdles for learning and gaining proficiency in drone operations. Furthermore, complex laws and regulations at local, state, and national levels constrain the use of drones in the coastal zone, creating additional challenges to expanding their use.

This report summarizes outcomes from a series of virtual workshops for researchers and managers in the southeast US and US Caribbean entitled Drones in the Coastal Zone. The objectives for the workshop were to:

- Identify information gaps in coastal ecosystem management
- Assess UAS expertise and experiences across the region
- Discuss regulatory, policy and ethical concerns in drone applications
- Demonstrate emerging techniques and technologies in UAS
- Share best practices for drone operations
- Establish a community of practitioners, data users and stakeholders
- Understand need for regional drone community of practice

Participants identified key coastal ecosystem needs that could benefit from UAS applications, organizers highlighted the following:

- Environmental and habitat condition
- Wildlife assessments
- Damage assessment

The workshop agenda with supplemental information is available at: http://secoora.org/wp-content/uploads/2020/08/Drone-Participant-Agenda-.pdf.

The workshop format changed from in-person sessions to virtual due to the COVID-19 pandemic. The virtual format enhanced participation throughout the region, especially by including research partners and managers in the US Caribbean. Recordings, background papers and other materials from the workshop were also made available for either synchronous or asynchronous participation and will be maintained on the Southeast Coastal Ocean Observation Regional Association (SECOORA) host website.

Participants requested further development of a community of practice in drone operations and applications. A workgroup was formed to develop a scope of activities for a regional drone network in the Southeast and Caribbean. Initial objectives included continued sharing best practices, identifying opportunities for collaboration and sharing expertise, providing training opportunities for drone operations and resource management applications, and improving data sharing across agencies and organizations.

Photo: Brandon Puckett

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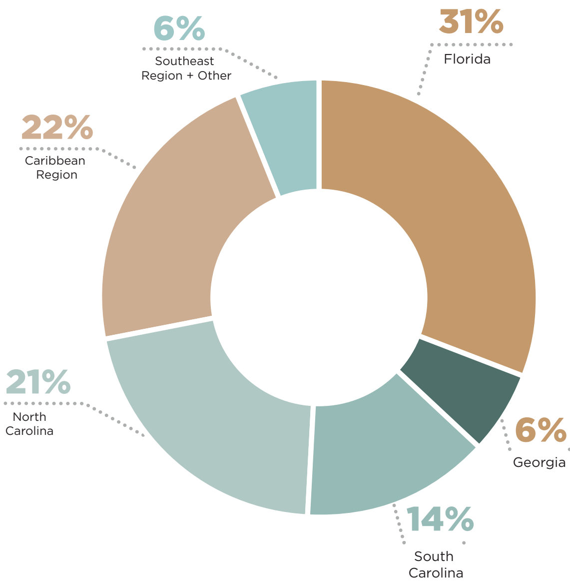
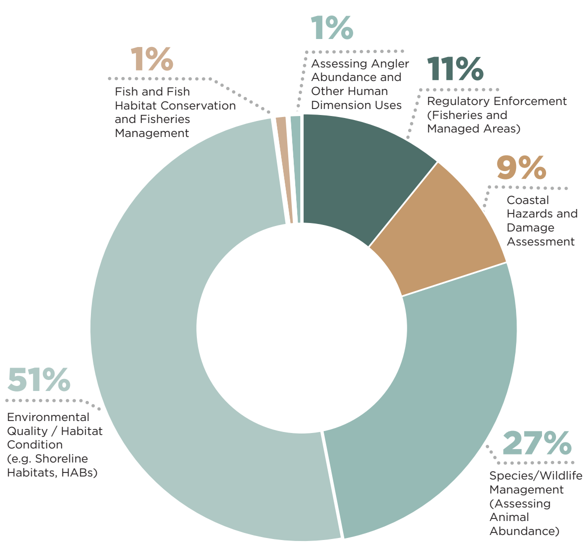
Persons Registered

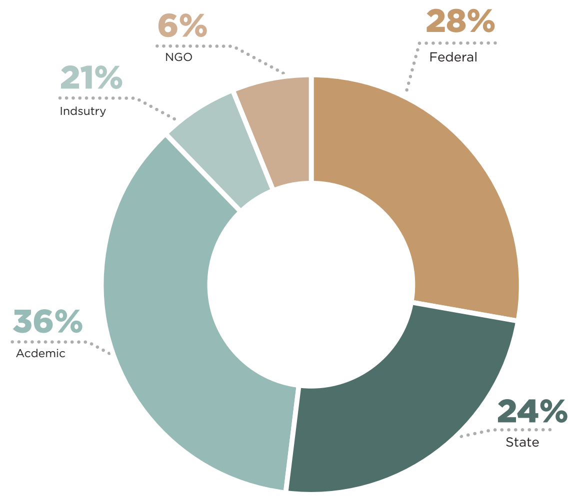
Location of Participants



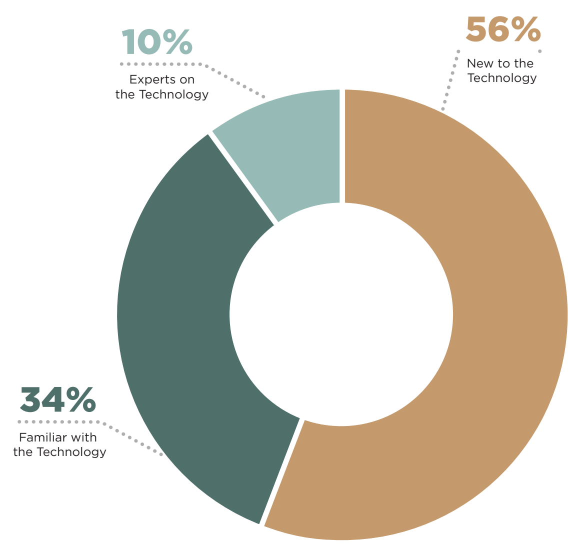
Coastal Management Needs Using Drones



Sectors of Participants



Technology Level of Participants



Drones in the Coastal Zone

By the Numbers

Chapter 1: Introduction

Rapid population growth within coastal watersheds over the past several decades has increased the use of the coastal and estuarine ecosystems, but also increased stressors on these natural resources. Coastal managers require information on the condition of coastal resources and must be able to detect and monitor impacts to establish strategies for response and restoration. Uncrewed Aircraft Systems (UAS), also referred to as Unoccupied Aircraft Systems, Unmanned Aircraft Systems, Remotely Piloted Aircraft Systems (RPAS), or simply drones, are becoming increasingly available, with sensors and payloads capable of acquiring high-resolution videos as well as still imagery in color, thermal or multispectral bands. Computing power and open-source image processing tools are evolving in step, allowing for automated detection of features of interest, or to produce maps or models with unprecedented extent, detail, and positional accuracy. As with any emerging technology, the number of published scientific papers focused on applying drones to theoretical and applied science problems is growing rapidly. Indeed, several specialized journals have sprung up to support scholarly publication of studies focused on the use of drones in science and conservation (e.g., Journal of Unmanned Vehicle Systems and Drones).

While advances in microelectronics, batteries, and communication systems have facilitated the accessibility of consumer drones, the observed rise of drone use in science and conservation stems largely from a combination of key qualities associated with the operation and application of this technology. These qualities combine to make drones an appealing choice for an increasing range of science applications. These qualities align with five general themes that warrant consideration when drones are an option in research applications:

- **Affordability:** Inexpensive; reasonably priced
- **Immediacy:** Bringing one into direct and instant involvement
- **Efficiency:** Achieving maximum productivity with minimum wasted effort or expense
- **Quality:** The standard of project deliverables relative to other methods; the degree of excellence
- **Safety:** Being protected from or unlikely to cause danger, risk, or injury to researchers as well as their study subjects and operating environments

In spite of the advantages UAS can provide, there are still barriers to adopting them more broadly in support of coastal ecosystem management. Commercial off-the-shelf drone systems are affordable and readily available, but may lack the durability or functionality to be used in scientific or survey applications. Survey-quality drones with advanced sensors and payloads can be quite costly and software tools for image interpretation and processing can also be expensive. Regulations and laws also constrain the use of drones in the coastal zone, with layers of local, state and federal laws creating a complicated landscape for conducting drone operations. Furthermore, training and proficiency is necessary to remain familiar with the regulatory landscape, but also keep up to date with the current state of technology. Finally, there is a lack of focused interoperability effort amongst researchers and managers using drones in coastal systems. It is essential that best practices and standardized approaches to the use of drones in coastal research and management are established and disseminated so that comparisons across regions and study sites will be viable.

In an attempt to address challenges to expanding the use of UAS, federal and state agencies have adopted strategies for advancing UAS applications in order to ensure their applications are within regulatory and policy guidelines while achieving mission goals. The National Oceanic and Atmospheric Administration (NOAA) established an Uncrewed Systems Strategy in 2020 with the primary goal to "sustain research and accelerate transition of research to operations, expand partnerships, and increase workforce proficiency in UxS [uncrewed air and maritime systems] use and operations" (NOAA 2020). Academic institutions are establishing robotics and remote sensing laboratories to advance the technologies and provide training for students and researchers. Private industry is often at the forefront of both research and development and field applications of drones in regulatory planning, asset surveys, and damage assessments or risk evaluations.

This report summarizes outcomes from a series of six virtual workshops entitled Drones in the Coastal Zone: A Regional Workshop in the Southeast and US Caribbean. The objectives for the workshop were to:

- Identify information gaps in coastal ecosystem management
- Assess UAS expertise and experiences across the region
- Discuss regulatory, policy and ethical concerns in drone applications
- Demonstrate emerging techniques and technologies in UAS
- Share best practices for drone operations
- Establish a community of practitioners, data users and stakeholders
- Understand need for regional drone community of practice

The workshop agenda with supplemental information is available at: http://secoora.org/wp-content/uploads/2020/08/Drone-Participant-Agenda-.pdf.

The workshop was originally developed as an in-person event, with plenary presentations, expert panel discussions, breakout sessions and hands-on demonstrations and training. Due to COVID-19, the workshop was reformatted into a series of virtual sessions. While the new format did not allow for in-person engagement and the opportunity for hands-on activities involving drones, the change in format increased overall attendance and broadened participation by individuals who may not have been able to travel to the original venue in Beaufort, North Carolina. The virtual format also allowed the organizers to develop more online materials and recordings of presentations and discussions, creating a lasting collection of references that the community could use well past the timeframe for the workshop.

Photo: Charlie Deaton

Chapter 2: Drone Technology Overview

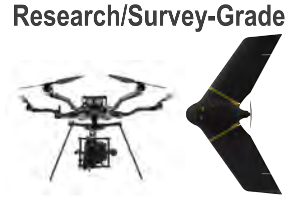
2.1 Platforms

A variety of UAS platforms are used in marine science and conservation missions (Table 1). These platforms can be categorized into three main types of aircraft—multirotor, fixed-wing, and transitional—according to their airframe configuration, propulsion method, and flight characteristics. These categories are described briefly below.

Multirotor UAS use multiple engines and/or propellers to provide lift and propulsion and to maneuver while flying (e.g., controlling pitch, roll, and yaw). Fixed-wing UAS have one or more large wings that provide lift and maneuverability and they are usually driven by one or two motors and propellers in a push or pull configuration. Several wing configurations of fixed-wing UAS are available. A growing number of aircraft combine aspects of multirotor and fixed-wing UAS to provide greater operational flexibility. These transitional aircraft take off and land vertically (VTOL) then transition to and from horizontal flight supported by a large wing and attitude control is provided by control surfaces on these wings.

Small UAS can also be categorized by their build quality and level of embedded precision instrumentation (Table 1). Consumer drones tend to have lower durability, limited options for swappable payloads and low accuracy positioning systems. Prosumer (a portmanteau of professional and consumer) systems have upgraded durability and sensor capabilities, but still lack the abilities for customization of sensors deployed. Research/survey-grade systems have high accuracy positioning systems (e.g., Real Time Kinematic, or RTK, correction) and the ability to fly multiple research-grade sensors.

Table 1. Tiers of unmanned aerial system (UAS), or drone, aircraft and general information about their specifications and capabilities.

	Consumer	Prosumer	Research/Survey-Grade
			
Capabilities	One sensor option and low customization capabilities	May have several sensor options and more flexible with customization and flight planning	Several sensor options (more high end) with better integration of custom payloads Transitional or hybrid airframes combine rotary and fixed-wing mechanics
Weight	Lightweight (<1 kg)	Lightweight (1–2 kg)	Rotary: Moderate to Heavy (5–20 kg) Fixed: Lightweight (<3 kg)
Flight time	Approximately 20 minutes	25–30 minutes	Rotary: 10–30 minutes Fixed-wing: 45–90 minutes
Cost	Low cost (<$2k)	Can be more costly with extra options (RTK, multispectral sensor) $2–7k	Higher cost $10–20k with standard sensors
Pilot skill	Beginner	Beginner to Intermediate	Intermediate to Advanced
Optimal data type	Video	Photos	Video and Photos
Optimal application	Inspection/surveillance and basic mapping	Precision mapping	Rotary: High end cinematography, multisensory rigs and specialized payloads (lidar, hyperspectral) Fixed-wing: Precision mapping

Note: Images obtained from the manufacturers website: https://www.dji.com/; https://freeflysystems.com/; https://www.sensefly.com/

Drone sensor payloads have undergone some notable advancements recently, and several types of sensors are available for use with drones either built-in or as customized attachments or modifications (Table 2). The basic sensor payload is an RGB (red, green, blue) optical camera that captures standard images or videos. Most standard RGB sensors, even built-in ones, are now high resolution and can be used to help generate stitched orthomosaics and 3D surface models when collected through appropriate flight plans (Figure 1). Multispectral sensors include RGB within their collection but offer additional bands like near-infrared (NIR) or red edge (RE) that can be useful for assessing vegetation health. Many of these cameras also include a daylight sensor and a radiometric calibration option that helps to normalize data collection regardless of lighting conditions. Thermal cameras (mid- and longwave infrared) are being paired with an RGB sensor, allowing for the concurrent capturing of both image sets. Likewise, small multirotor aircraft with the dual sensor payload can provide live video feed with high resolution black and white video overlaid with thermal signatures. Compact hyperspectral sensors are now available that can be attached to larger multirotor aircraft (because of payload weight limitations), which allow users to collect hundreds to thousands of spectral bands.

Table 2. Types of drone sensors and benefits they provide to the data captured.

	RGB	Multispectral	Dual RGB/IR	Hyperspectral
	 Sony alpha7R IV  senseFly Aeria X	 Micasense RedEdge-MX	 senseFly Duet T  FLIR Duo Pro	 Senop HSC-2
Major benefits	High resolution (24–60 mega pixels) Larger sensor sizes for more lighting versatility High precision geolocation integration	Radiometrically calibrated Global shutter reduces motion blur High precision geolocation integration	Simultaneous capture RGB and thermal Some of the highest resolution thermal imagery Duet T also allows for high precision geolocation	400–1000 nm range with a 0.1 nm spectral step Up to 1000 bands can be selected for capturing Moderate geolocation precision
Cost	$3–5k	$5–10k	$5–10k	$30–50k

Note: Images obtained from the manufacturers website: https://www.sensefly.com/; https://senop.fi/; https://www.flir.com/; https://micasense.com/; https://alphauniverse.com/

Figure 1. From mission to point cloud. Left Panel: Image locations (red dots) over Bird Shoal (Rachel Carson Reserve, North Carolina National Estuarine Research Reserve) flown with a senseFly™ eBee Plus equipped with senseFly™ S.O.D.A. camera. Center Panel: Image taken over the remote pilot crew with close up in the inset. Right Panel: Resulting point cloud from the image dataset processed through Pix4D Structure from Motion software with the same reference boxed at an oblique view. Photos: Duke Marine Robotics and Remote Sensing (MaRRS) Laboratory

Chapter 3: Coastal Management Challenges

A large proportion of the US population resides in the coastal zone, resulting in an increasing need to understand its natural systems and conserve them so that they can continue to provide the many intrinsic, economic, ecosystem, and recreational services that make these areas so valuable and attractive. These coastal zones are constantly changing due to wave energy, storm events, sea level rise, climate change, and land development. Workshop organizers gathered information on coastal ecosystem management issues and data gaps that might benefit from broader application of drones and UAS technology. Over half of the participants identified Environmental Quality and Habitat Condition as the top priority, followed by Species and Wildlife Management. Coastal Hazards and Damage Assessments and Regulatory Enforcement were nearly equivalent as third tier (Figure 2). The organizers selected three topics, with each topic hightlighted by **Lightning Talks** and breakout sessions and forum discussions. These three topics are: *Environmental Quality and Habitat Condition*, *Coastal Hazards and Damage Assessments*, and *Species and Wildlife Management*.

Coastal Management Needs Using Drones

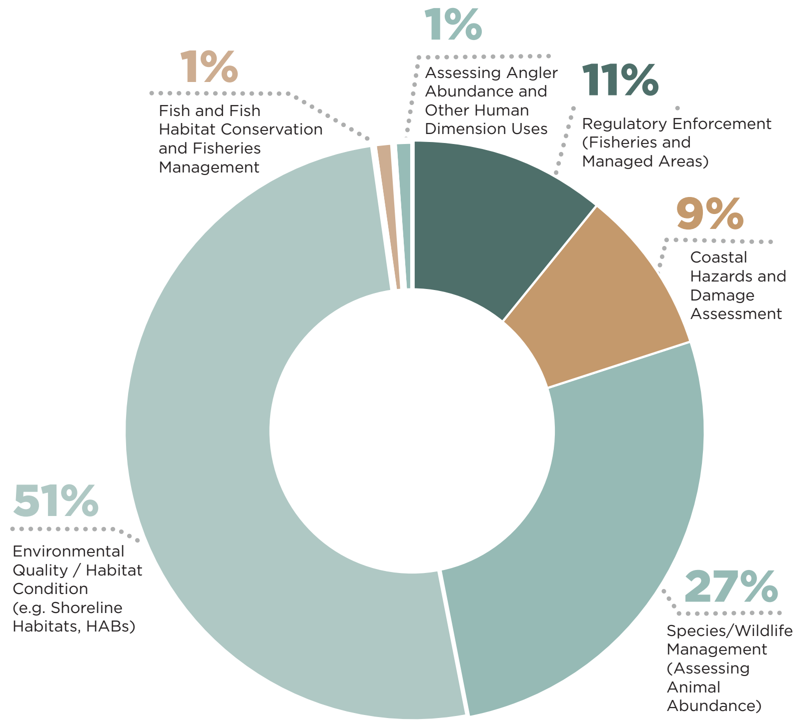


Figure 2. Ranking of coastal management needs and data gaps that could benefit from increased unmanned aerial system (UAS) applications.

3.1. Environmental Quality and Habitat Condition

Traditionally, the monitoring of coastal habitats has utilized aerial imagery, acquired either by helicopters or other occupied aircraft, satellite imagery, or with a field team on a boat or on the ground. Aerial monitoring utilizes resources at a capacity that typically does not allow for frequent monitoring efforts. On-the-ground monitoring could negatively impact sensitive habitats such as dunes, salt marshes, and oyster reefs.

When asked how UAS technology can be used for monitoring environmental quality and habitat conditions, participants overwhelmingly agreed that drones are, or could be, useful for monitoring marshes, oyster reefs, and mangroves as well as environmental quality of shorelines. Aerial observation is used to monitor environmental quality and habitat conditions within the coastal zone because UAS can capture comprehensive imagery of sites over large areas (e.g., several square kilometers).

Advantages of UAS

- *Quick to mobilize and deploy*
- *Precise in positioning*
- *Repeatable for monitoring*
- *Provide permanent image records*

Lightning Talk Summaries

Nearshore quadcopter research: surface ocean currents and high frequency radar calibration

Douglas Cahl and George Vouglaris, School of the Earth, Ocean and Environment, University of South Carolina

Cahl and Vouglaris presented an evaluation using UAS to track movement of ocean surface features and waves as indicators of surface currents in the nearshore coastal ocean. When selecting a quadcopter for measuring surface ocean currents, the authors encouraged attendees to take into consideration the resolution of the video, battery life, and the stability of the camera. It was important to also turn off safety features that would not function over water. The open-sourced software used for slicing frames into squares and processing was CopterCurrents. Through a dispersion relationship analysis, global position system (GPS), and a compass, surface ocean current direction and speed are able to be measured. These measurements were calibrated with a high frequency radar and found to be in good concordance.

Tracking Coastal Change with Quadcopters to Support Beneficial Use of Dredge Material

Clark Alexander, University of Georgia Skidaway Institute of Oceanography

Alexander presented research using UAS to document the fate of dredge disposal when used to augment marsh habitats. While our dynamic coastlines often have the opportunity to "heal themselves", there are times when they will benefit from the use of dredge materials for beach renourishment and berm/ dune building. For monitoring, the presenter shared the methods and platforms used including Pix4Dcapture, Pix4Dmapper, RTK-GPS, and ArcMap10. Several case studies were shared including a project at Tybee Island, Georgia where dunes were built in March 2020 in association with a beach renourishment project. Using drones and analysis of the imagery, analysts can identify elevation changes including natural dunes, artificial dunes, and the dune walkovers. The level of accuracy allows for car tracks to be identified within 25-cm of accuracy. This technique is used to monitor the loss of sand berms over time which can help estimate the life expectancy of the berm and continued level of protection.

Mapping *Spartina* biomass at Georgia Coastal Ecosystem LTER with Altum and Matrice 210

John Schalles, Creighton University and University of Georgia

Schalles presented research on the incorporation of UAS in the monitoring of *Spartina* marsh grass, and advances the technology provides in estimating vegetation biomass metrics. Since 2002 the Georgia Coastal Ecosystem Long Term Ecological Research (LTER) site has used geospatial analyses research projects on temporal and spatial productivity patterns in coastal wetlands, estuaries, and coastal waters using drone, airborne hyperspectral, and Landsat and Sentinel 2 imagery. Using a DJI Matrice 210 with a 6-band Micasense Altum camera, researchers have been able to map *Spartina alterniflora* biomass in coastal Georgia. Since 1984, data indicated a steady decline in growth of *Spartina* which has not recovered, especially after a four-year drought in the early 2000s. The goal of this project was to investigate the cause of the decline which could potentially be caused by wrack lines from storm surge, creek head erosion due to a below-ground mud crab which disturbs root growth, marsh die-back from an above-ground snail that eats the *Spartina* to bare mud, and sea level rise. Drones are able to provide a high-resolution view of marsh biomass. The regression model developed from the flights can be applied to adjacent marshes for monitoring and quick response to marsh decline.

Vegetation cover regeneration of a coastal urban wetland after Hurricane Maria

Elix Hernández, University of Puerto Rico

Hernández presented on the advances made possible using drones to detect changes and recovery in vegetation in remote areas of Puerto Rico following hurricanes. Hurricane Maria impacted Ciénaga Las Cucharillas, Cataño, Puerto Rico (an urban wetland surrounded by an industrial environment) with freshwater flooding, salt water storm surges, tree defoliation and fall, and negative mangrove impacts. Using UAS photogrammetry with DJI Phantoms II and III equipped with a RGB camera, Hernández and partners were able to monitor land cover changes and post-hurricane plant composition for 12 months. Since RGB cameras do not have an infrared band, Hernández used a Visible Atmospherically Resistant Index (VARI) to emphasize vegetation in the visible portion of the spectrum.

Key Points from Habitat and Environmental Condition Break-out Discussions

Using drones for monitoring environmental and habitat conditions is an established practice throughout the region including:

- Using hyperspectral data to identify toxic algae
- Using multispectral data to evaluate marsh vegetation conditions seasonally and post-storm events
- Monitoring remote and hard to access shorebird nesting habitats
- Monitoring remote and hard to access intertidal oyster reefs
- Assessing counts and distribution of wildlife, including manatees

Drones provide the ability to create repeatable and frequent monitoring efforts, which allows changes to be identified and assessed within shorter time periods

- The timing of monitoring events could potentially lead to more immediate deployment and response strategies (e.g., fishkills).
- Drones provide the opportunity to monitor sensitive habitats and sites with limited accessibility.

Key remaining gaps

- Further understanding of Federal Aviation Administration (FAA) regulatory guidelines and requirements
- Lack of clarity in agency permitting timelines
- Flight endurance and battery life of drones
- Challenges related to image quality from sunlight glare off of water

3.2 Coastal Hazard and Damage assessment

Impacts from hurricanes and other major storms are causing increased loss of property and damage to natural resources from strong winds, flooding and erosion. Chemical spills or incidental disposal from industry or recreational activities in the coastal watershed are also impacting natural areas. State and federal emergency management agencies conduct post-hazard damage assessments to develop strategies for response and recovery for private and public properties. UAS provides a platform that is safer and allows for access to remote areas to assess damage. The Federal Emergency Management Agency (FEMA) has identified requirements and training standards for UAS observations for assessing post-hazard damage. Through these programs state agencies have access to public and commercial UAS operators to establish damage assessments and formulate response activities (DHS/FEMA 2020). Federal weather offices are also employing UAS for calibrating flood and inundation models to improve forecasting of future storms (Walker et al. 2017). Debris from storm damage as well as depositions from ocean dumping wash up on shorelines, damaging coastal habitats and risking injury to animals. In this topic area, discussion focused on coastal hazards and damage assessments specifically related to threats to coastal ecosystems and natural resources. Presentations updated participants on use of UAS in monitoring and managing fires, observing shoreline erosion, and assessing impacts of boat groundings and marine debris on natural areas. The focus of UAS surveys were in estuarine reserves, military installations and public spaces such as beaches and coastlines. Previously these surveys were conducted by airplanes, boats or on foot to capture video or photographs. UAS is providing improved methods for rapid and repeatable assessments reducing costs of staffing field surveys. Georeferenced imaging is available for cataloging and archiving.

Lightning Talk Summaries

Marine Debris and UAS: Goals, Efforts and Opportunities

Peter Murphy, NOAA Marine Debris Program – Alaska

Marine debris in coastal ocean environments has a negative impact on natural resources. Debris types range from abandoned or derelict vessels to derelict fishing gear, consumer plastics, or even microplastics. Limited budgets require increased efficiency in mapping, detection and characterization. Debris detection and characterization, and association with sensitive habitats or areas is the first step in order to assess impacts and prioritize removal efforts. Marine debris detection and characterization efforts include a variety of tools from satellite to airplane assets, with the ultimate goal of guiding observations and actions on the ground or water (Figure 3). Murphy presented on current research that is evaluating UAS

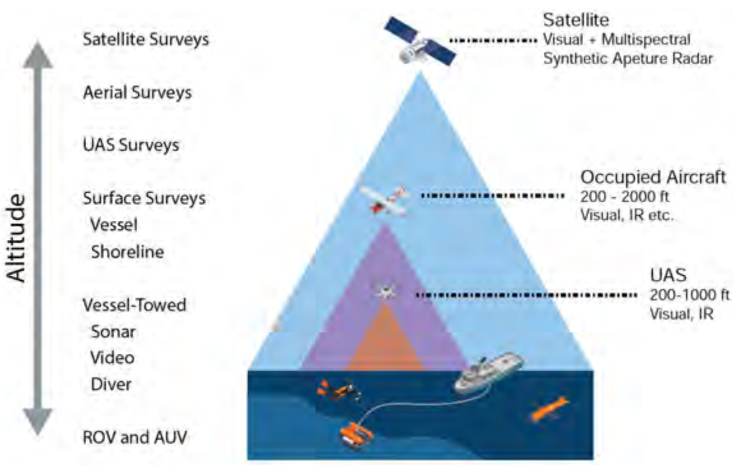


Figure 3. Schematic of relative scale of observations from UAS compared to other methods to detect marine debris.

to increase efficiency, especially in remote areas and with minimal impacts when detecting debris in sensitive habitats. Improvements in imaging sensors include polarimetric analysis that helps differentiate debris types. A key area of ongoing research is the use of artificial intelligence and machine learning to automate detection, identification, and estimate composition and quantity. NOAA is currently working on a cooperative project with Oregon State University to evaluate platform-agnostic approaches to improve this automated detection approach to debris detection and identification.

Remote Sensing with UAS for Erosion and Fire Management

Troy Walton, Attollo LLC

Walton presented on a Regional Drone Demonstration for Marine Corps Installations East (REDDIE) that identified requirements for military bases in areas of resource management, shoreline erosion and fire management that could benefit from UAS applications. The Coastal Erosion and Fire Management (CONFIRM) demonstration evaluated improvements in efficiency for UAS surveys for mapping erosion post storms, fire monitoring and wildlife tracking. The demonstrations resulted in three outcomes: (1) standard mission kits with key performance parameters in aircraft and sensors to meet installation requirements; (2) training for Basic Unmanned Qualifications and FAA Part 107; and (3) development of protocols meeting military installation airspace restrictions. Challenges to conducting work in military installations with UAS include restrictions to foreign-made commercial off-the-shelf UAS platforms. A few common aircraft considered in UAS mission kits include a SenseFly eBee fixed-wing and Parrot Anafi Thermal quadcopter; both can be outfitted with thermal and RBG or multispectral cameras.

Key Points from Coastal Hazard Breakout Discussion

Where are UAS helping?

- Assess damage and recovery, especially post hurricane
- Detecting marine debris in remote areas
- Assessing damage from marine debris
- Mapping inundation and flood risks
- UAS provided reconnaissance on dangerous shorelines before surveys on boat

Are drones always the right tool?

- Regulatory issues may restrict access by UAS to damage assessments
- Conducting assessments over private property

Key gaps and remaining challenges?

- Can UAS be intermediate between satellite and direct observations, for things like coastal water quality and harmful algal blooms?
- Mapping impact of sargassum on tropical beaches, or impacts of wrack on coastal marshes
- More rapid damage identification for strategic response
- Conducting survey limited by over the horizon restrictions
- Existing challenges in debris detection include: unpredictable encounter rates over expansive areas; variation in detection due to debris size shape and contrast with background; and details on debris identification and composition

3.3 Species and Wildlife Management

One of the most frequent uses of UAS in marine science and conservation is for assessing the abundance and density of marine and coastal organisms. At present these systems have been used to count seabirds at breeding colonies, pinnipeds at rookeries, sea turtles on land and at sea, and several species of coastal sharks. They have also been applied to successfully count dugongs, intertidal invertebrates and even some species of jellyfish.

In many cases, these assessments are done using fixed-wing UAS, although multirotor UAS are also employed for these purposes. A variety of sensors are applied to these tasks to help identify organisms. For example, for mammals and birds, thermal cameras can be helpful. Drones have also been applied to the study of individual animals. The size and morphology of an animal is a key constraint to its habitat use and foraging capabilities, and can reflect its current health and overall fitness. Researchers now use drone-based photogrammetry to study the size, body condition, and morphology of marine animals, using both manual and automated approaches. Furthermore, video captured from drones during photogrammetric work provides details on the near surface behavior of marine animals, providing insights into their individual and social behaviors. Examples of some of these applications are provided below.


Photo: Duke MaRRS Lab

Lightning Talk Summaries

The range of studies presented in this session provided a solid basis for breakout groups discussions on how UAS can be applied to study populations (e.g., abundance and density estimation), individual animals (e.g., behavioral ecology and mass estimation) and some of the possible drawbacks associated with using this technology with species that are sensitive to the acoustic or visual stimuli presented during operations. Breakout groups identified a series of opportunities and complexities regarding wildlife studies and management via drones.

Monitoring and Ecological Aspects of the Antillean Manatee (*Trichechus manatus*) in Jobos Bay NERR, Puerto Rico

Milton Muñoz, Bahía de Jobos National Estuary Research Reserve

Muñoz presented research focused on determining the presence of manatees in the inner part of Jobos Bay with aims to recognize the main habitat range use of the animals, identify or recognize individuals in the area and collect information about behavior. Muñoz described the results of 48 days of drone sampling with a DJI Mavic UAS. This effort resulted in the detection of 136 manatees, including the ability to detect calves and animals with boat scars. Respiration behaviors were also monitored. Muñoz concluded that UASs are a very useful tool for the monitoring of manatees in the waters of Jobos Bay with relatively low cost/high benefits. He identified the inner part of Jobos Bay as an important area for manatees feeding and resting, and potential areas of freshwater outcrop from the aquifer. Muñoz also concluded that the waters of Jobos Bays represent an important reproduction site for this endangered species and that manatees from the wild can be photo-identified and records can be used to identify individuals.

UAS Working Towards 'Weighing' Populations: A Case Study Across Grey Seal Lactation.

Michelle Shero, Woods Hole Oceanographic Institution

Shero presented research on the application of UAS, and Structure from Motion photogrammetric analysis for the assessment of body condition in grey seals (*Halichoerus grypus*) in Eastern Canada. As top predators, seals can serve as environmental sentinels, and because they remain hauled out on-land and there is dramatic female-to-pup energy transfer over a short lactation period they provide a particularly tractable system for testing the applicability of UAS photogrammetry. Traditional approaches to collecting body mass and condition measures on more than just a few individuals become unwieldy, as animals must be captured and often sedated. A remotely sensed approach using UAS may represent a rapid and non-invasive way to make such assessments. Shero presented the results of two field seasons of data collection in Eastern Canada where animals were assessed using both traditional (weighing and measuring animals on the ground) and UAS-based methods. Shero concluded that the application of UAS to estimate grey seal body condition is a non-invasive means of acquiring volume/mass estimates of these animals and that flight plans and efficient processing workflows allow for body size measurements to be collected from groups of animals at once–providing a larger sample size than would ever be possible using traditional methods. This approach is likely to be widely applicable across species and habitats and could be adopted to more sensitive species with changes in lenses.

Deep Learning and Drones to Automate Seabird Population Counts

Maddie Hayes, Duke Marine Robotics and Remote Sensing Lab, Duke University Marine Laboratory

Hayes provided details on an ongoing project that is applying deep learning techniques to estimate the density and abundance of Black-browed Albatross (*Thalassarche melanophris*) and Rockhopper Penguins (*Eudyptes* [*chrysocome*]) in the Falkland Islands. Using drone imagery from both fixed-wing and multicopter platforms, Hays has applied convolutional neural networks (CNN) to identify individual birds and estimate the density and abundance across several colonies. Hayes research indicated that deep learning techniques have great potential for seabird monitoring at significant and spatially complex colonies, producing accuracies of correctly detecting and counting birds at 97.66% and 87.16%, with 90% of automated counts being within 5% of manual counts from imagery. The results of this study imply CNN methods are a viable population assessment tool, providing opportunities to reduce manual labor, cost, and human error.

Wild Horses Respond to Drone Surveys: Towards Overflights That Minimize Disturbance

Anne Harshbarger, Duke University Marine Laboratory; and Paula Gillikin, North Carolina National Estuarine Research Reserve

As researchers begin to apply UAS for population monitoring, care must be taken to minimize disturbance on both target and non-target species. Harshbarger and Gillikin presented research focused on the potential of drones to disturb feral horses in the Rachel Carson Reserve. Managers had witnessed recreational drones getting very close and causing horses to run. However, no research has addressed the effects of drones being flown over horses at higher altitudes for management work, and there is a need to test for impacts to horse behavior. Harshbarger and Gillikin recorded behaviors of herd and focal individuals before, during, and after eight flights with a fixed-wing drone flown at 63.5 and 90 m altitude. Their results indicated that grazing and resting by horses decreased during fixed-wing UAS flights, whereas more vigilant behaviors such as standing alert and walking increased. They concluded that while there is good potential for using drones for monitoring and management of feral horses, additional research is needed on what is causing disturbance (e.g., sight vs sound of the drone).

Key Points from Species and Wildlife Management Breakout Discussion

Where are UAS helping?

- Surveying for protected species in areas of human activity
- Observing invasive species in remote areas
- Simultaneous surveys of animals while mapping coastal habitats
- Counting nesting seabirds with minimal disturbance
- Observing large mammal behavior in managed areas

What are the primary concerns using UAS in wildlife management applications?

- Potential disturbance of behavior of some animals being observed
- UAS activity in proximity to protected marine mammals
- Surveys that may transit private property or public spaces and interfere with human activities or privacy concerns

What are the remaining research gaps and technology needs for UAS in wildlife applications?

- Artificial intelligence or automation in detecting animals in imagery
- Waterproofing for conducting surveys over water
- Improvements in imaging sensors such as near-infrared and multi-spectral cameras
- Improvements in approaches for over-the-horizon surveys

Chapter 4: Best Practices for Droning

Incorporating UAS into research, management and conservation bring numerous considerations for best practices, understanding rules and regulations both specific to the research focus but also geographic area, and other policy, privacy and ethical considerations with using UAS in public spaces. In this chapter, we cover topics to consider as best practices in developing a drone program in an organization. First, Rett Newton provided an overview of the safety and logistical considerations for being successful at conducting drone operations to support management. Participants then learned about NOAA policies and regulations as an example of how the federal government manages UAS programs. The participants also heard from representative drone operators in state and territories that may have additional policies and regulations for UAS operations. Participants heard from a legal scholar on potential privacy and ethical considerations when conducting UAS operations in public spaces. An open forum and discussion allowed participants to ask additional questions to better understand the field. References in the following section are provided as examples. Considering rapid advances in UAS technology as well as ever changing state and federal regulations, the reader should check with authorities before engaging in UAS operations. Experts then shared best practices in planning and conducting UAS missions from operational readiness, survey design and data management. Lastly, examples of UAS training programs and professional opportunities are provided.

Best Practices for Droning

Rett Newton, Marine Robotics and Remote Sensing Laboratory, Duke University Marine Laboratory

Newton kicked off the discussion regarding best practices in drone operations with an overview of guiding principles that include multiple steps and feedback loops to continue to improve the safety, efficiency and utility of drone surveys. To build an environmental robotics program to support conservation or commercial applications, the following best practices can be helpful to ensure safe, responsible, and sustainable operations. If drones are already a prominent component of the research program, these considerations may also help expand to newer technologies and scientific environments (Figure 4).

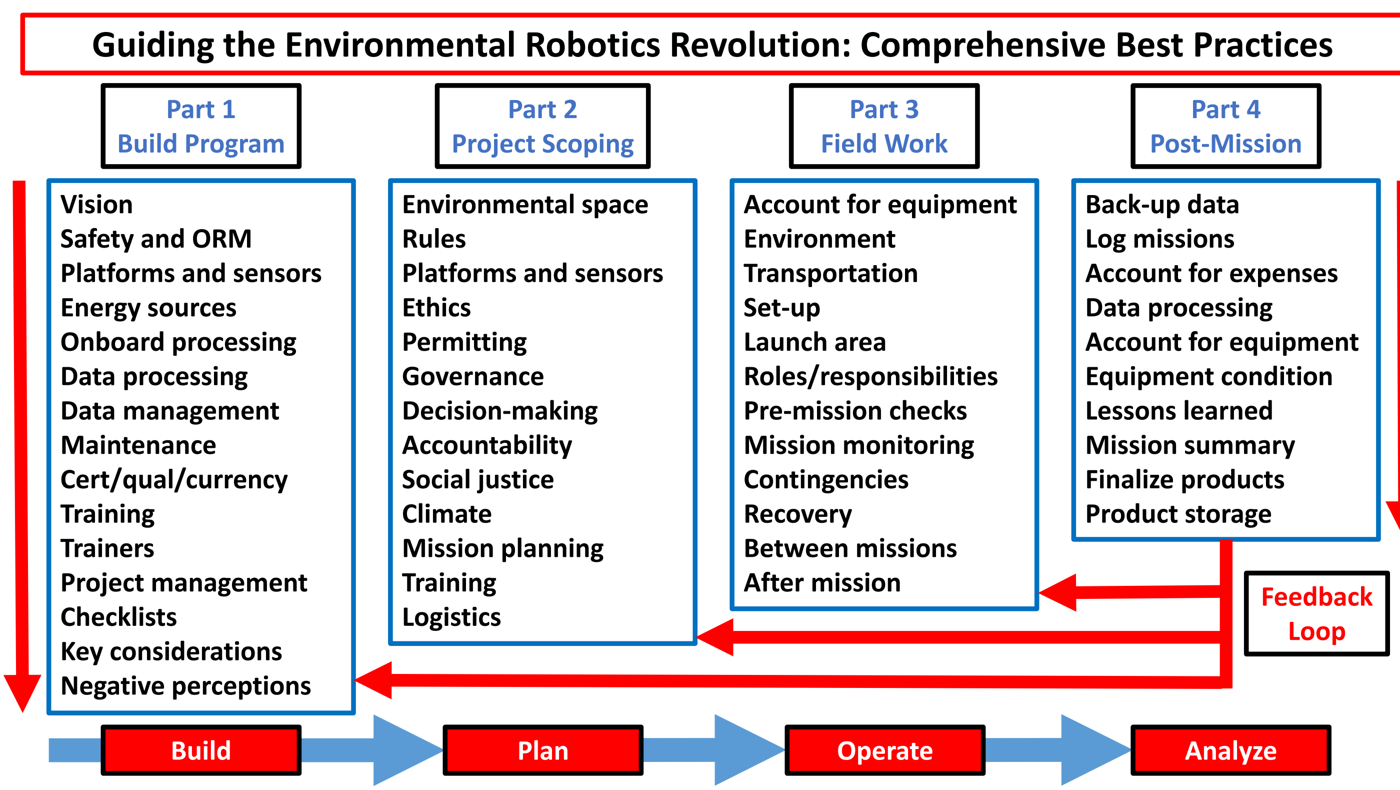


Figure 4. Summary of what's needed to build a credible robotics program. Source: Rett Newton, Duke MaRRS Lab.

Building a responsible and credible drone program is arduous, but can generate powerful science and conservation products. This revolution is just beginning and the future promise includes global video feeds, robotics swarms, and dramatic improvements in on-board processing. These best practices will provide the foundation for incremental expansion as these new technologies are developed. Although some of these suggestions seem bureaucratic, they will help instill the critical processes and discipline required for a credible, successful, and agile robotics program.

Key Considerations for a Successful Drone Program:

1. Keep robotics work as simple as possible
   We have seen and heard of drone operators working outside their capabilities while starting their drone program and the results have not been positive. Flight environments can be demanding, so operators need to understand their operational and technical limitations, set reasonable goals, and incrementally increase complexity at a level commensurate with experience and proficiency.

2. Constantly anticipate "what can go wrong"
   Platforms and sensors are becoming more reliable each year, but inevitably something will go wrong. Operators must prepare for potential failures and remain vigilant and trained to handle contingencies when they arise. The credibility of a scientific program could hinge on how well the operator recognizes and manages contingencies.

3. Build a culture of discipline
   Responsible, safe, and credible robotics programs instill discipline across all facets of the program. These actions may be as basic as tracking the performance of batteries, developing training programs for operators, or establishing solid maintenance practices. This discipline will instill routines that can reduce the potential for accidents.

4. Continually revisit all areas and update
   Robotics platforms, sensors, and applications are rapidly emerging so there is a need to frequently review the status of the program.

4.1 Regulations, Policy and Ethics

NOAA Policies & Regulations

LT Nicole Chappelle, NOAA Office of Marine and Aviation Operations

NOAA's Office of Marine and Aircraft Operations (OMAO) has the regulatory responsibility and requirement to maintain the safety of UAS operations for NOAA. The director of the UAS Division of OMAO is required to sign off on all UAS operations; operational safety is their responsibility. As of October 2016, UAS Division's operations utilizes Part 107, which is the FAA's operational rules of UAS under 55 pounds. Part 107 is essentially the traffic laws for the sky, rules and regulations that you have to follow when flying your drone.

For NOAA operations there are two pathways of approvals: **wide area operations** and **NOAA projects**. Regardless of approval pathway, operations must have:

1. NOAA Mission commander who is responsible for the operation;
2. Pilot-in-command;
3. Signed Federal Policy Checklist – how NOAA deals with NEPA, cybersecurity, and privacy issues;
4. Flight authorization memo (FAM) – the office's director approval to conduct operations; and
5. Operational Risk Management document.

Part 107

Part 107 applies to all commercial operations of drones and requires users to register their drones.

Drone registrations last for three years and cost $5.

You can register your drone on the FAA website: https://faadronezone.faa.gov/#/

For questions regarding NOAA UAS policy and procedures contact: uas@noaa.gov

For **wide area operations**, you have to submit a Notification of Intent to Fly. Most NOAA operations fall under this approval. NOAA approves commonly used UAS platforms and has already conducted airworthiness tests of these platforms. NOAA has looked at hazards that exist through those approved platforms and describes common hazards. Anyone in NOAA with a wide area authorization, proper pilot credentials, and proper approvals can operate that aircraft.

Allows access to the airspace through Part 107, FAA LAANC, and NOAA Class G Blanket COA:

- **FAA UAS Low Altitude Authorization and Notification Capability (LAANC) System** – real time airspace authorization in pre-approved zones and altitudes. Use by downloading an approved app.
- **Class G Blanket Certificate of Waiver or Authorization (COA)** – allows users to operate up to 1200 feet above ground level, with controlled airspace restrictions.

For **NOAA projects**, FAMs are specific to the project and its dates. Authorization expires when the project dates are complete. There may be other federal restrictions on the use of drones, depending on location.

For each state and Puerto Rico, the FAA's Part 107 applies for UAS operations. And be mindful of your airspace, there are various restrictions in the Southeast and Caribbean region (Table 3).

Table 3. Examples of some regulations and policies related to UAS use that are specific to states and territories in the Southeast and US Caribbean

	North Carolina	South Carolina	Georgia	Florida	Puerto Rico
Need Additional Certification	Yes, free permit through the NC Department of Transportation	No	No	No	No
State Legislation?	Cannot use drones for surveillance, cannot photograph private property without consent (N.C. G.S. 15A-300.1 and N.C. G.S. 14-401.25).	South Carolina's Title 24 makes it unlawful to operate drones near correctional facilities	HR Bill 481 modified official aviation code allowing drone use	Florida House Bill 1027 preempts local regulations, only the Florida legislature can make laws concerning UAS operations A Florida Senate bill prohibited use of drones to capture images of private property, consent required to do so.	None
Other Considerations?	Military airspace: Letters of agreement for crewed aircraft have been adapting for UAS operations. Pilots can be added to this agreement. You still have to call to get authorization to go in those areas, but this streamlines the process and in many instances you can fly the day of.			State lands have a few administrative codes. Includes Forest Service, State Parks, and Division of Water Management. You can obtain special use authorization, which is also required for launch and recovery within the boundaries of these areas.	

Privacy, Ethical and Legal Issues

Michelle Nowlin, J.D., Duke Environmental Law and Policy Clinic, Duke University

As UAS operations become more widely used, and the technology becomes more sophisticated, there is a need to be mindful of safety, privacy and ethical concerns, research needs, and potential for misuse of data incidentally collected. Federal agencies or regional authorities may have specific privacy policies, such as https://www.omao.noaa.gov/learn/aircraft-operations/about/noaa-unmanned-aircraft-systems-privacy. A few key definitions were presented:


frontiers in Marine Science

Applying Unoccupied Aircraft Systems to Study Human Behavior in Marine Science and Conservation Programs

Michelle B. Nowlin, Stephen E. Roady, Everette Newton and David W. Johnston

The declining costs of Unoccupied Aircraft Systems (UAS, aka drones), their ease of use, and their ability to collect high resolution data from a variety of sensors has resulted in an explosion of applications across the globe. Scientists working in the marine environment are increasingly using UAS to study a variety of topics, from counting wildlife populations in remote locations to estimating the effects of storms and sea level rise on shorelines. UAS also provide transformative potential to study the ways in which humans interact with and affect marine and coastal ecosystems, but doing so presents unique ethical and legal challenges. Human subjects have property rights that must be respected and they have rights to privacy, as well as expectations of privacy and security that may extend beyond actual legal rights. Using two case studies to illustrate these challenges, we outline the legal and regulatory landscapes that scientists confront when people are their primary study subjects, and conclude with an initial set of legal best practices to guide researchers in their efforts to study human interactions with natural resources in the marine environment.

OPEN ACCESS

Keywords: drones, UAS, legal, marine conservation, human behavior

INTRODUCTION

The use of Unoccupied Aircraft Systems (UAS, aka drones) in marine science is rapidly increasing. Researchers across a range of disciplines are now using drones to collect data on a variety of natural features and phenomena, from counting seals and measuring whales, to improving the assessment of coastal habitats. This rise in the use of drones in marine science stems from the growing availability of affordable and easy-to-use systems, coupled with their ability to collect high resolution information in an essentially on-demand manner.

Refer to Nowlin et al. (2019) for more information on UAS privacy and ethics.

Privacy: The definition of privacy varies depending on the law in question. Most people think of it in terms of the right to be let alone, to avoid public scrutiny or view, or be free from unwarranted publicity.

Curtilage and Open Fields: Curtilage is the private area within a home and includes the area that immediately surrounds a dwelling, such as a porch. The curtilage is entitled to protection, a place where a homeowner or occupant of the home has a reasonable expectation of privacy and one that society is prepared to protect. Things not part of that curtilage, such as a back yard or a park, are considered "open fields." Within that open field, regardless of whether it's on public or private land, there's a diminished expectation of privacy. There may be some conflict in a private landowner's idea of what is entitled to protection as curtilage, particularly if the area or facility is fenced in, and what constitutes open fields.

Civil Law: Civil law considers wrongful acts or an infringement of non-contractual rights leading to civil legal liability for invasion of privacy. Similar to Constitutional protections, civil law assumes a reasonable expectation of the right to privacy. In addition to location, the sophistication of the technology used could be a factor in determining "reasonableness." Different technologies have different abilities to "see through" enclosures and to analyze various environmental factors and may inadvertently collect private information. Some technologies in this category Include infrared and thermal imaging, biological sensors, particle sensors, and chemical sensors. States have different laws governing the use of UAS and protections of individual privacy, so it's important that the UAS operator understands and follows those state-specific requirements.

Best practices for ensuring privacy, ethical and legal standards:

- *Develop a privacy plan*
- *Understand requirements for public notice*
- *Acquire landowner consent*
- *Use geofencing technology to screen private areas*
- *Use technologies to blur/remove identifying data such as faces and license tag*
- *Develop a cyber-security plan for how you are going to retain and store that information, how it will be shared with others, and how it will be destroyed*
- *Understand local government and cultural requirements of your study area. That's particularly important for working outside the continental U.S. where different cultural practices and sensitivities may be important*

4.2 Mission Planning, Data Management and Data Sharing

The Mission Planning session sought to capture the complex, multifaceted process of managing systems and data collection and storage. Effective mission planning will serve to generate higher quality data, and effective data curation (good organization and metadata) helps to enhance a drone-based research program by optimizing data storage and access, which enriches product delivery. Several professionals representing different institutions/agencies (academic, federal, state, and private) presented their perspectives on the evolving best practices for managing drone data. Some of the important metadata discussed included aircraft and sensor, flight path (geolocation details), and data types. The common theme among the presentations was the importance of being thoughtful about how you manage your drone data and the rising need to have a community of practice to help guide data standards.

The session was wrapped up with a "choose-your-own-adventure" style mission planning exercise led by Justin Ridge from the Duke MaRRS lab. He provided two regional examples of science missions, a barrier island storm impact assessment and a mangrove health study. The exercise walked the participants through a series of polls to think about regulatory and operational considerations at each site, aircraft and sensor selection, survey design, and preflight checks.

Metadata Checklist: Managing a complex set of variables for a successful operation

Julian Dale, Duke Marine Robotics and Remote Sensing Lab, Duke University Marine Laboratory

Dale discussed the important information for managing a drone program including fleet maintenance and pilot status information as well as project, data, and inventory management. He demonstrated the utility of flight logging software (specifically DroneLogbook) and talked about using an inventory management system. He showcased some of the packing and preflight checklists Duke's Marine Robotics and Remote Sensing (MaRRS) lab uses and the specific naming convention that encompasses some flight metadata to help with project/data management.

Data stewardship and archiving at NOAA

Sharon Mesick, Ocean and Geophysical Information Services, NOAA National Centers for Environmental Information

Mesick discussed data management strategies they've established from the digital media that NOAA handles. NOAA is experiencing an exponential rise in digital data, and there are new directives through the NOAA Science and Technology initiative to develop better strategies and pathways for managing data. She talked about different levels of data stewardship and associated costs based on what the data manager is looking to achieve (types of resources and level of access). This entails curating the data, and a data management plan greatly benefits from including data curation to streamline the outputs for optimal delivery (e.g, embedding as much metadata in the actual files instead of just an external record). An artificial intelligence tool is being developed to ingest media and create a robust metadata record. She provided a great example of the top tier data stewardship where users can find media by searching a metadata catalogue, access a lower resolution preview hosted in the catalogue, and then use another service to retrieve the original file from deep storage to use for their research. NOAA is working to build the community of practice to help better integrate the various formats and archiving styles used in the science community.

Internal South Carolina Interagency Specific UAV Database

Evan Cook, South Carolina Department of Natural Resources

Cook presented some of the developments from the South Carolina Interagency Drone Users Consortium (SCiDUC, pronounced Sky-Duck, www. sciduc.org; Figure 5). One of the organization's main goals involves developing a database, which required understanding the types of data, accessibility, and funneling through representatives. They have used ESRI's ArcGIS Online's hosted feature layer that interfaces with the Survey 123 application. Survey 123 acts as a data entry service to submit flight metadata, so the ArcGIS Online feature layer displays flight data (footprints and other input information) and contact information to allow users to contact the data managers to potentially obtain the data. SCiDUC is

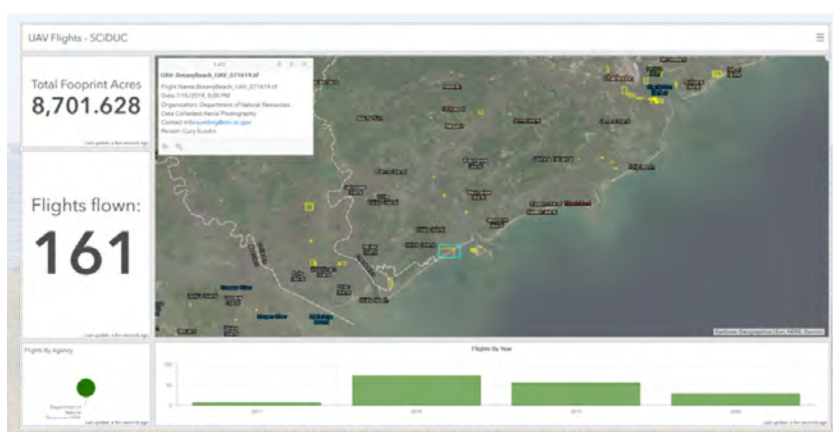


Figure 5. An example from the South Carolina Interagency Drone User Consortium flight summary data viewer. Source: Evan Cook, SC Department of Natural Resources

working to increase functionality, potentially looking at cloud storage options instead of locally hosting data and creating a public facing version (right now it's only accessible by the agency representatives).

Assembling Digital Image Data in One Location for Easy Access

Kyle Wilcox, Axiom Data Science

Wilcox discussed data management strategies from the perspective of their firm, which works with a variety of agencies. He began by outlining their data lifecycle model which includes a variety of stages: collection and quality control, storage, description, archive and preservation, access and discovery, and reuse and transformation (Figure 6). While skipping some of these stages is perfectly natural during portions of a project, the overall lifetime of a project (and beyond) will greatly benefit from going through each stage and appropriately curating the data. Kyle provided the example of different levels of storage based from a national archive (raw data), local (more processed), and something even more distilled for broader distribution. He reiterated the need to develop more standardized metadata for this technology. He provided a great example of some work conducted along the Alaska coastline taking static images all along the shore. They had to use YouTube to host the petabytes of data and link to it from within the Alaska Ocean Observing System (AOOS) user interface.

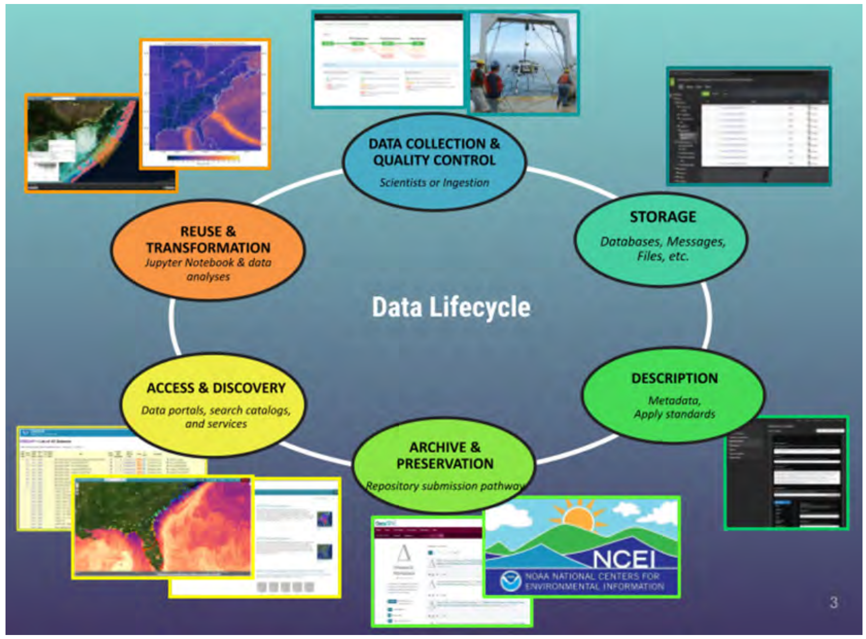


Figure 6. Example of data stewardship for UAS research and operations. Source: Kyle Wilcox, Axiom Data Science

Key Point from the Data Management Panel Discussion

- The Duke MaRRS lab uses mostly commercial software products that have been modified to suit their needs (like DroneLogbook and CHEQROOM [inventory management]). This software allows for drone info to be linked to the data in some capacity, especially with the ability to upload flight logs, and flights using a naming convention help match project data with logged flight data.
- NOAA's strategy for managing digital data is attempting to reach across organizations to find best practices, but there is currently limited information in that regard. A community of learners held a discussion on what drives the requirement. If the science mission drives the requirement, the scientists are looking for the platform and sensors that are best needed for the science. But data management has its own requirements. What they are looking for is a balance, which has yet to be achieved. This likely requires a broader community of practice.
- Survey 123 (used by SCiDUC) is a versatile tool that can be used in offline mode and will upload the data input once the connection is reestablished. It is available for iOS and Android.
- An overwhelming (90+%) of the participants are in favor of a centralized location for drone imagery. But if such a centralized location for imagery is not obtainable, at least one that catalogs data (e.g., metadata portal like what SCiDUC currently has for South Carolina)

4.3 Incorporating Training Into Your Drone Program

Acquisition of data via UAS has become a common practice. There are countless companies and individuals willing and able to collect these data. The ability to collect and process these data in a legal and professional manner is a topic of great importance. The success of a drone program of operation is dependent on a solid training base and continued professional development. Training helps practitioners understand the science, ensure legal and ethical requirements are followed, best practices are used, jobs are planned and completed safely and successfully, and resulting data can be used to achieve stated goals. In addition to training for practical and legal purposes, certification through third party entities can help further the success and growth of UAS. This session focused on UAS training requirements, certification, and professional growth through varying organizations.

NOAA's UAS Training Requirements

LT Nicole Chappelle, NOAA Office of Marine and Aviation Operations

Lt. Chappelle presented on the Unmanned Systems Operation Program within NOAA OMAO which promotes the safe, efficient, and economical operation of uncrewed systems NOAA uses to collect high-quality environmental data for the agency's science, products, and services. There are three requirements for NOAA UAS operators, which includes holding a FAA Part 107 Certification, UAS platform specific training, and providing a Pilot in Command (PIC) designation letter. Details for each of these three requirements were discussed. In-depth questions and answers were included regarding the platform specific training (who may teach it, hands-on requirements, specific to drone being used, topics covered in the training, etc.). Once obtained, NOAA certified operators must maintain their proficiency through a minimum of three take-off and landings every 90 days. If their proficiency lapses, NOAA operators may regain proficiency via training simulator, under approved PIC supervision, or dedicated training flights. NOAA is working towards its own training program to reduce reliance on outside trainers. Training will be for specific platforms, as well as working through the NOAA UxS system.

Examples of Regulatory and Technical Training Curriculum

Troy Walton, Attollo LLC

Walton presented on the development and delivery of custom UAS training programs, focusing on governmental agency needs. Attollo provides training courses that meet the Department of Defense (DoD) Basic Unmanned Qualifications level II and an operational training course with data processing and standard operating procedures in conjunction with Duke MaRRS lab and University of North Carolina Chapel Hill. Attollo's training for DoD clients covers not only the FAA Part 107, but also the Joint Unmanned Aircraft Systems Minimum Training Standards (CJCSI 3255.01). This training allows DoD personnel to obtain their Basic Unmanned Qualifications (BUQ) needed to fly in DoD airspace. Non-DoD personnel may fly in DoD airspace, but with many cybersecurity hurdles. BUQ has varying levels, with higher levels allowing flights in more restricted airspace. It is important to note that this training generally incorporates a week of classroom learning and a week of field training, allowing students to gain the technical/legal knowledge, but also have hands-on, real world training. In developing their training, Attollo follows, and recommends, the ADDIE model of training:

- **Analysis:** determine audience, delivery options, timelines
- **Design:** storyboards, prototype module development
- **Develop:** create and assemble content
- **Implement:** delivery content (classroom and field time)
- **Evaluation:** always happening and refining full process

Photo: Attollo LLC

Photo: Duke MaRRS Lab

Environmental and Ecological Drone Systems Training

David Johnston, Duke Marine Robotics and Remote Sensing Lab, Duke University Marine Laboratory

David Johnston demonstrated a modular training system developed by Duke MaRRS lab, focused on science, applications, and best practices of UAS, in addition to legal and regulatory requirements. The course sequence is designed to train users to be critical thinkers and good scientists, alongside being capable remote pilots. Although virtually presented, it uses multimedia to engage participants, allowing for a variety of on-line content, including remote access to real world UAS data sets for processing and analysis. The ultimate goal of this training system is to have a series of modular sections which could be extracted and used for targeted clients (e.g., undergraduate, graduate, executive). Content includes material on:

- Drone basics (including power, controls, sensors, etc.)
- Real world applications and uses
- Access to software systems for processing and analysis of real world data including structure from motion (SfM), photogrammetry, and CNN
- Best Practices, including planning, maintenance, record keeping, metadata, legal and ethical issues, environmental justice

American Society for Photogrammetry and Remote Sensing Certification Programs

John McCombs, Lynker, LLC on contract at NOAA NOS Off ce for Coastal Management

McCombs presented on the American Society for Photogrammetry and Remote Sensing (ASPRS) Certification Program, specifically the Society has a UAS Certification. ASPRS is a professional peer-organization dedicated to advance knowledge and improve understanding of mapping sciences to promote the responsible applications of photogrammetry, remote sensing, geographic information systems (GIS) and supporting technologies. Certification is different than licensure, in that a license grants legal authority for an activity, while certification sets a higher standard that conveys an exceptional level of credibility and expertise recognized by peers. ASPRS maintains two levels of UAS Certification (Professional and Technologist). To become certified, an application must be completed, including letters of recommendation, which is then reviewed by a panel of peers. Upon approval of the application package, a test must be passed. Certification must be renewed over time through demonstrating continued professional activities and continued learning. The program is voluntary and open to all qualified individuals.

Chapter 5: Calling for a Southeast and US Caribbean Drone Community of Practice

The workshop highlighted a diversity of expertise in UAS operations applied to coastal management issues. Many of the coastal management concerns were shared across the southeast continental US as well as among US Caribbean partners.

5.1 Benefits of Regional Collaboration in UAS

The webinar series lightning talks and breakout groups/panels highlighted emerging technologies or approaches addressing a wide range of coastal science and management challenges, from water quality to several aspects of enumerating or assessing wildlife population on land and over water. New machine learning and artificial intelligence methods are available to conduct automated counting of organisms or even to identify individuals using marks as natural tags detected from images. New sensors and photogrammetric techniques are providing novel measures of body condition for individual animals. Mapping coastal habitat conditions using drones is significantly improving the efficiency in mapping remote areas or conducting repeated mapping to detect change. Participants learned about new methods for estimating biomass of vegetation using high-resolution point clouds to estimate canopy and shoot densities. They also learned about surveys conducted in remote areas in Puerto Rico and surprising recovery of mangrove habitats following significant hurricane damage. UAS have also been used to successfully detect and map ocean currents in nearshore environments to better understand sediment dynamics and beach erosion or accretion processes.

While inspiring, this range of new equipment and applications, and the varied ways in which people are using drones in the coastal zone, highlights a key foundational challenge for widespread use of UAS in coastal science and management: the lack of organization amongst labs and researchers using this technology. This issue is leading to deficits in essential standardization, calibration, and validation work and reinforcing a large interoperability gap that limits comparative work across space and time. It became clear that guiding principles and best practices are needed for data collection with these sensors, including independent validation of their performance across a range of locations, operational protocols, and environmental conditions. Although efforts are underway (e.g., Slocum et al. 2019), a regional network will help overcome these challenges and allow for robust and efficient collaborations amongst coastal researchers and managers.

During the webinar series, experienced UAS practitioners shared several best practices in developing a drone program as part of an agency or institution. From these presentations and discussions, it became clear that regional coordination would help researchers develop a program that is: 1) robust scientifically, 2) rooted in legal and ethical best practices, 3) accounts for other social dimensions including issues of social and environmental justice, and 4) addresses program governance and accountability. At present there are no comprehensive best practices for the use of drones in environmental science, and a regional effort will help to collectively develop them.

Photo: Duke MaRRS Lab

Keeping up with regulations and policies

The rapidly evolution of technology, particularly in commercial-off-the-shelf drones, is also creating challenges in how government agencies are able to use systems that may not meet strict security or cybersecurity standards to protect sensitive information. In fact, government agencies across different federal departments have not found consensus in the interpretation of federal legislation related to drones. For example, the draft American Security Drone Act recommended banning the procurement or use of drones assembled by entities that may be subject to control laws. Federal agencies may have varied interpretations of this act whether the drone is operated by a government contractor providing data services versus government employees operating the drones. Airspace over government facilities or managed areas like national parks or marine reserves also have specific regulations regarding use of drones. A broad network of experts could continue to share experiences leading to broader community awareness.

Photo: Attollo LLC

Improved data sharing

Advances in the drone platforms including increased navigation and motion precision, the flexibility in cameras and other sensors creates a near-infinite combination of datastreams. Challenges remain in the recording of metadata to ensure proper context for surveys as well as stewardship and preservation of the data. With the numerous types of data collected, and across diverse agencies, there is a general lack of standardization in data records. A network of practitioners could advise on best practices for data stewardship and standards that would allow for integration across agencies and industry.

Facilitate education and training opportunities

Basic training and certification requirements, such as FAA Part 107 are readily available through numerous venues and online. While there are requirements to achieve Part 107 certification, and manufacturer-specific drone operational training, there is a greater need in training operators and practitioners in the comprehensive best practices shared above. This includes the awareness of policies and regulations, but also proficiency in operating specific aircraft. Equally important is the understanding in planning and executing appropriate survey designs to meet the requirements for the coastal management need.

A few academic institutions in the southeast already have mature courses within undergraduate or professional education curriculum. Duke University Marine Lab hosts a number of UAS and remote sensing courses for undergraduates in environmental sciences, and will soon be offering a combined UAS Applications and Operations course sequence focused on training scientific remote pilots. Clemson University provides several courses under the Applied Drone Technology program, though the applications in these programs appear focused on civil engineering and related services. Professional societies are also including drone certifications as achievements of record for members. Through a regional community of practice, stronger connections could be facilitated between the academic institution curricula so that it also meets requirements for certification recognized by professional societies such as ASPRS. Similarly, agreements could be established between academic institutions or private industry to provide training in operations and specific science applications for state and federal agencies.

5.2 Proposed Components of a DITCZ Community of Practice

Through the course of the workshop, participants learned about local or state-led efforts to coordinate drone activities. A regional community of practice would not supercede these local or state efforts, but instead coalesce the numerous coordinated activities into a regional working group. The regional entity would recognize the local variation in coastal management priorities, but provide a regional system to support common areas of interest or aspects of regulatory or best practices that may be universally applicable. As an example, the state of South Carolina has already formed the South Carolina Interagency Drone Users Consortium (SCiDUC). SCiDUC comprises UAS practitioners, data users and managers from federal, state and local government agencies (and state university institutions). SCiDUC would occupy a node in the regional network. In fact, the framework of SCiDUC has many qualities that may be suitably replicated in other states and across the region.

The collection of regional experts, data users and managers has analogs with NOAA's Integrated Ocean Observing Systems Regional Associations (RA). The Southeast Coastal Ocean Observing Regional Association (SECOORA) and the Caribbean Coastal Ocean Observing System (CariCOOS) now have over a decade of experience in networking ocean observing practitioners, stakeholder communities and regional experts. This regional association structure has enabled sharing of best practices, leveraging of resources, and improvements to the national system/program while maintaining strong connections to local communities. Additionally, the regional RA 'infrastructure' that includes administrative, communication, fiscal and data management capabilities has supported the growth of affiliate networks/communities of practice focused on ocean acidification, animal telemetry and resilience. A drone community of practice could likewise take advantage of the established regional associations as a mechanism for long-term administrative and/or operational support.

A key component of this community of practice is to engage and grow partnerships among government, academic, and industry that may already have stakeholder groups. Key elements of a drone community of practice include:

- Support state/territory nodes by facilitating exchange of information and best practices from federal government agencies
- Facilitate training through academic and industry partnerships
- Encourage data sharing through data assembly centers and interactive visualization tools
- Assemble members and stakeholders to update gaps and needs for UAS applications, technological advances and areas for potential collaboration
- Connect partners within southeast and across US Caribbean organizations

At the conclusion of the DITCZ workshop, participants registered interest in forming a steering team to develop a scope of activities for a future regional community of practice. As this report is being published, workshop organizers will convene calls to develop a scope and framework for a community of practice inclusive of government agencies, academia, industry and conservation organizations spanning the US Southeast and Caribbean.

Photo: Duke MaRRS Lab

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