Sea Grant
MARYLAND

Coastal Geospatial Horizons Workshop

Workshop Proceedings

California, Maryland

Proceedings prepared by Taryn Sudol and Julissa Murrieta.

Graphic design and layout by Jenna Clark.

Editors: Jenna Clark, Fredrika Moser, Ashley Goetz, and Annalise Kenney.

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Maryland Sea Grant College
University System of Maryland
5825 University Research Court, Suite 1350
College Park, Maryland 20740
T 301.405.7500 / F 301.314.5780
mdsg.umd.edu

Workshop Proceedings

INTRODUCTION

Coastal ecosystems, including marshes, submerged aquatic vegetation, and open water, are observed and monitored for various purposes. Remote sensing—particularly with unmanned aircraft systems (UAS, hereby referred to as "drones")—is one method used to survey and study coastal ecosystems. Over the last decade, interest has grown around the application of drone technology to collect ecological data in coastal ecosystems of the Chesapeake and coastal bays. Though some experts already use drone technology in coastal systems, other potential users are curious how they might apply this tool to their own coastal activities.

The topic of drone application became a focus of discussion in the Chesapeake Bay Sentinel Site Cooperative's (CBSSC) Surface Elevation Table Working Group (SETWG, n=20). Members expressed a lack of guidance regarding selection of equipment and software, associated costs, and how to tailor flight characteristics to a project. Though drone monitoring may reduce labor and make data collection possible in hard-to-access areas, new users may encounter challenges in understanding drone technologies and associated regulations. In addition, this rapidly evolving field makes it challenging to keep user guidance current. These and other discussions with constituents suggested peer learning and information exchange could be an effective method to expand use of drone technology to advance monitoring and research in coastal ecosystems in the Chesapeake Bay region.

In response to these discussions, Maryland Sea Grant hosted a webinar, *Marsh Monitoring with Drones: An Introduction*, in March 2024 and produced a companion StoryMap, *Marsh Monitoring with Drones*, as networking resources for individuals with projects in Maryland and Virginia. Interest and resulting discussion among webinar attendees (n=69) inspired an in-person workshop to discuss current drone projects in the Chesapeake Bay region, share useful information for drone operations, build collaboration among peers, and explore how to make drone technology more accessible to new users.

Maryland Sea Grant held the in-person *Coastal Geospatial Horizons Workshop* August 6, 2024, at the University of Maryland, UAS Research and Operations Center (UROC) in California, Maryland. The workshop attracted 31 participants from Delaware, Maryland, Massachusetts, and Virginia who were employed across industry, academia, and federal and state government, and had varied drone experience (Appendix A).

The workshop goals were to:

1. Scope network and collaboration potential across drone operators (or interested parties) based on current applications for drones in coastal sciences and management
2. Exchange information and resources on how to successfully implement a drone project (i.e., how to overcome challenges of drone project design, deployment, and data post-processing)

Photo credit: Logan Bilbrough, University of Maryland Extension

3. Identify where additional information, resources, and collaboration could support monitoring, research, and data analyzing coastal ecosystems

This report includes the workshop design (Methodology), an overview of the peer learning exchange on drone opportunities and challenges (Results), and participants' desired next steps (Conclusions and Next Steps). Results are solely based on participant input, including pre- and post-workshop surveys and in-person discussions, and do not necessarily reflect the position of Maryland Sea Grant.

METHODOLOGY

Maryland Sea Grant (MDSG) organized the *Coastal Geospatial Horizons Workshop* into four sessions (Appendix B). A pre-survey on level of drone expertise and desired topics helped inform each session's design.

Taryn Sudol, MDSG coastal resilience and Chesapeake Bay Sentinel Site Cooperative (CBSSC) coordinator, introduced the workshop's purpose and format. John Slaughter, University of Maryland UAS Research and Operations Center (UROC) director, followed with a presentation about UROC, including:

- How UROC functions within the University of Maryland
- UROC staff experience with various projects
- UROC past and current projects (e.g., medical delivery, precision agriculture, wildlife outbreaks)
- Current drone challenges (e.g., restrictions regarding visual line of site, 2024 National Defense Authorization Act, Advanced Air Mobility)

Photo credit: Logan Bilbrough, University of Maryland Extension

Slaughter and staff gave a tour of UROC and highlighted some of their projects using drones.

Following a networking lunch, Supriya Khadke, the mid-Atlantic regional geospatial coordinator for National Oceanic and Atmospheric Administration's (NOAA) Office for Coastal Management, facilitated a discussion on best practices regarding drone imagery and data management. The discussion centered around how participants could improve data access across various projects so data could be applied toward different project objectives.

The second portion of the day consisted of two 30-minute sessions for peer learning. The first session focused on drone technology applications in marshes. The second session focused on drone operations. Participants were assigned to small groups of five to six people, including notetakers from MDSG and NOAA, with a mix of new and experienced drone users. Participants' level of drone experience was determined in a pre-workshop survey. In each session, small groups had five minutes to write topics and questions for discussion on sticky notes. The sticky notes were displayed on a flip chart, and after quick introductions, participants used the remaining 25 minutes to discuss the topics and questions displayed.

The workshop concluded with a lightning networking session in which participants were randomly paired together to reflect on the most valuable aspect of the workshop and how to act on an idea generated that day. This exercise was repeated three times with new pairings.

Finally, a post-workshop survey link was shared at the end of the day to encourage participants to provide feedback on the workshop's design and other education or networking needs. MDSG sent two email reminders to complete the survey after the workshop. Nineteen people (61% of workshop participants) responded to the survey.

RESULTS

We summarized results based on workshop goals. Additional workshop details and a glossary of terms are available in the appendices. These results reflect participant comments, rather than a literature review or the expertise of Maryland Sea Grant.

Goal 1. Scope Network and Collaboration Potential Across Drone Operators Based on Current Applications for Drones in Coastal Sciences and Management

Participants creatively use drones to investigate coastal ecosystems. Topics covered around this goal included:

1. Monitoring: Participants discussed using drones to monitor different aspects of a coastal ecosystem, including challenges to drone use.
   a. Types of monitoring include elevation change, condition and spread of vegetation, wildlife presence, water quality, ecological succession, carbon sequestration, and pre- and post-event tracking (e.g., storms, restoration projects).
   b. One monitoring challenge is precision. For example, measuring surface elevation requires millimeter precision, but vegetation can obstruct these readings.
   c. Another challenge is risk of drone damage. Examples include its payload (i.e., the object connected to the drone, such as different sensors) being too heavy and affecting its flight, drone contact with water causing sensor damage, or drones crashing and causing mechanical damage.
2. Surveying: Participants discussed the many surveying applications of using drones in research.
   a. Delineating habitat, wetland, and shoreline boundaries.
   b. Mapping vegetation, including submerged aquatic, marsh, and invasive species.
   c. Using drone vegetation mapping to generate large datasets for estimating biomass and calculating Normalized Difference Vegetation Index (NDVI).

Photo credit: Annalise Kenney, Maryland Sea Grant

3. Future Applications: Participants discussed some emerging areas with growing interest for drone use, including understanding sediment transport, targeting maintenance for ecological restoration, validating flood models, and disaster preparedness and aid.

Goal 2. Exchange Information and Resources on How to Successfully Implement a Drone Project

Efficiently and successfully implementing a drone program requires multiple considerations, each with distinct hurdles. Participants highlighted:

1. Coastal Environment Challenges for Project Implementation: Multiple drone deployment limitations exist in coastal ecosystems.
   a. It can be difficult to access the interiors of large or fragile ecosystems even with drones. Necessary software signals may decrease or be absent in remote areas.
   b. Working with water creates challenges, such as glare interfering with imagery, sensors with limited capability to penetrate below the water's surface, and waves distorting sensor readings.
   c. Vegetation may decrease elevation data accuracy and trees often require additional post-processing for 3-D imaging.
2. New User Implementation: Researchers and managers new to drones seek to learn about drone capabilities and associated costs.

a. Consider creating a "Drone 101" course for new users to quickly learn about the basics of drone application. High value is placed on attending demonstrations or simulations to see flight characteristics.

b. New users' needs when starting a drone program include understanding the scope of work, time allocation, and appropriate tools and equipment (e.g., drone, sensor, software) to use.

c. User guidance is desired on how to address complexities in applying drone technology to a project and recognizing there is not a one-size-fits-all solution. As with any technology, the questions posed will direct data collection and inform the specifics of drone technology use. This creates a challenge for introductory materials to address specificities.

3. Rules and Regulations: Drone safety and other protocols can be extensive and rapidly evolve as new drone uses or safety concerns emerge. Navigating current and emerging rules and regulations for flight approval can be time consuming.

   a. Templates or stock language for common applications to government regulators and permitters could help streamline some of the application processes for project approval.

4. Quality Standards: Workshop participants were particularly concerned with needing protocols to ensure data quality.

   a. Standards are needed for consistency across projects. This has its own complexities, but establishing or working with a Quality Assurance and Quality Control (QA/QC) committee on some standards would improve cross-project comparisons. Funded researchers from several National Estuarine Research Reserves developed an initial set of standards which may be applicable to others.

   b. A repository of case studies (peer-reviewed literature or informal reports) could be a helpful starting point.

Photo credit: Annalise Kenney, Maryland Sea Grant

5. Data Sharing Among Drone Projects: Drone projects generate many images, creating a tradeoff between resolution and ease of data sharing.

   a. Participants shared several data sharing platforms, noting fees, cost structure, interoperability, and trainings as considerations when selecting a platform.

Goal 3. Additional Information, Resources, and Collaboration Needs

During the workshop and the post-workshop survey, participants identified knowledge and resource gaps and potential solutions. Participants highlighted:

1. Additional Information: Participants were eager for more education on drone technology and use.

   a. Participants recommended holding webinars on coastal drone work. In the post-survey, 100% of participants indicated interest in future webinars. Suggested topics included fleet management, flight planning, Federal Aviation Administration (FAA) waivers and airspace authorization, drone-based bathymetry, post-processing, case studies, and best practices to yield good results.

   b. Drone users or future users would benefit from guidance manuals and direct instruction, including "how-to" materials or demonstrations. For instance, survey respondents said they enjoyed and benefited from the University of Maryland UAS Research and Operations Center (UROC) tour and the opportunity to see drone models, especially new and experimental equipment. UROC does not currently offer trainings, but they do have undergraduate internships.

2. Synthesis and Consolidation of Resources: As technology evolves and associated new regulations emerge, keeping track of developments among disparate sources would be helpful.

    a. The United States' stance on using drone models (National Defense Authorization Act) has created uncertainty on which drone models or software products are appropriate to use. Updated guidance on what is allowed, asl well as available options, could assist operators on what equipment to purchase.
    b. Drone laws differ by state. As new issues related to drone safety emerge, understanding what different states are doing may help inform what other state or local governments may decide to enact.
    c. Technical papers on drone hardware, sensors, or software could provide additional guidance, as this can currently feel *ad hoc* or by word of mouth.
3. <u>Networking and Collaboration Benefits:</u> Continued information exchange among peers could aid practitioners and lead to new partnerships. The highlights are best summarized from the post-survey responses.
    a. In the post-survey, 63% said the most valuable part of the workshop was networking with peers. 42% of respondents cited collaborating with peers and 21% said generating potential project ideas (participants could select more than one answer). 37% of respondents stated they would follow up with new contacts for collaboration or further questions.
    b. Most survey respondents (84%) found the peer-learning session of the workshop (in which some participants learned from more experienced drone users and tackled specific questions) was very to extremely valuable.
    c. Comments in the post-survey emphasized an interest for additional in-depth conversations. Themed regional to local working or discussion groups might provide a useful format for in-depth conversations among peers on a range of drone topics (similar to the Drones in the Coastal Zone Community of Practice in the Southeast US).
    d. Eight participants expressed interest in contributing to the *Marsh Monitoring with Drones* StoryMap.

CONCLUSIONS AND NEXT STEPS

Attendance and response to the workshop showcased the need for community-building and education around emerging drone technology and the elements of implementing a successful drone project.

Feedback and review of this workshop suggests that future meetings should have ample time for participants to ask questions and discuss specific issues, as well as the opportunity to connect with other participants. These participants could continue to be a mix of experienced and newer drone users from across the mid-Atlantic with a focus on coastal studies, given the highly contextual nature of each drone project.

As with many research efforts, there is a need for mechanisms that help advance information exchange and problem solving for drone usage in coastal ecosystems. Based on the discussions, webinar, and workshops, Maryland Sea Grant identified next steps to advance the use of drone technology in coastal ecosystems. These include both virtual and in-person opportunities and resources.

1. Explore interest in building a "community of practice" for the Chesapeake and coastal bays to advance understanding and collaboration around drone coastal ecosystem applications. As this workshop demonstrated, in-person time to connect, ask questions, learn from one-another, and see and handle new equipment is highly sought. Thus, a community of practice in the Chesapeake region could have both virtual and in-person meeting spaces. Networking within the group could also allow for new drone users to interact with more experienced pilots, shadow existing projects, and develop mentorship. Beyond peer learning, the community of practice can be a repository for resources such as drone case studies; "how-to" materials for newer users (e.g. videos, technical papers); changes in rules, regulations, or restrictions; and other virtual resources.
2. Explore existing meeting venues, such as the Coastal GeoTools Conference or other meetings that specifically address coastal challenges and opportunities for drone technology. Establishing a main group or consistent meeting would promote networking on a national scale, timely learning about innovations and new regulations, the use of existing data sets, and greater consensus on community-wide best practices.

3. Explore regional user interest in drone trainings, such as webinars or demonstrations, that incorporate in-depth discussions on user experience, troubleshooting and problem-solving, best practices, and brainstorming ways to improve drone operations. Topics include flight planning, post-processing data collection, and available case studies.
4. Raise awareness about the need for improved quality control and best practices for drone use in coastal ecosystems. Consider ways for new standards to have consensus across multiple groups, each with differing project objectives and site characteristics.
5. Investigate sources for funding to support meetings and generation of education materials or other resources.

Appendix A: Participants

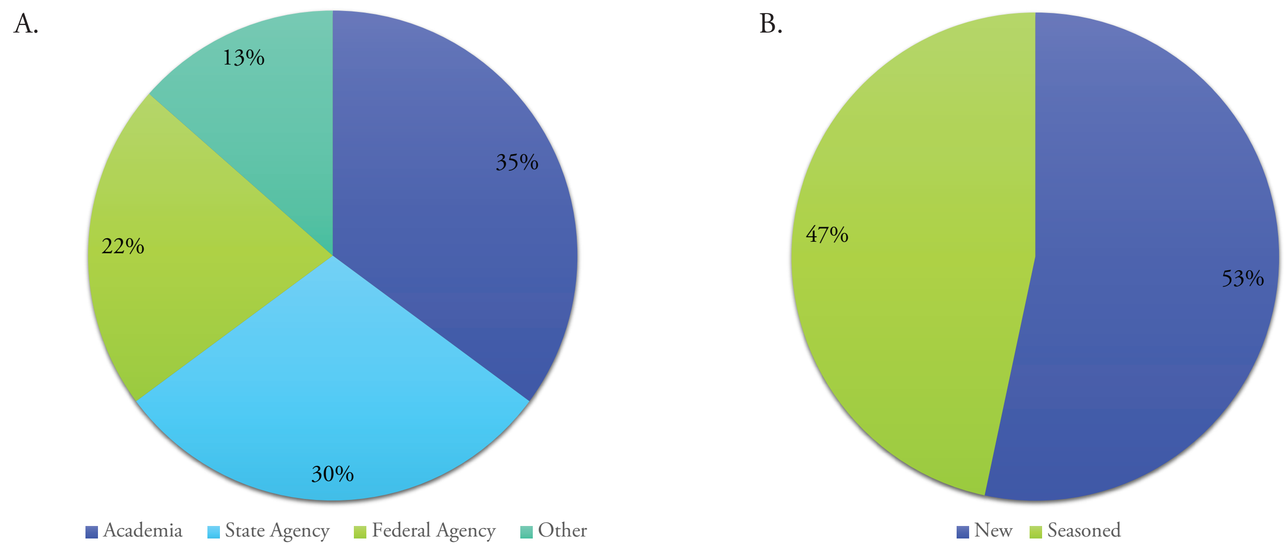

Figure 1. A. *Distribution of participants' professional affiliation.* B. *Distribution of participants' experience with drones.*

Participants

Tom Allen
Old Dominion University

Joe Allman
DNR - Maryland Geological Survey

Kaitlin Beasley-Polko
UMCES CBL

Logan Bilbrough
University of Maryland

Kellie Burdick
EA Engineering, Science, and Technology

Cally Carmello
Maryland Sea Grant

Maggie Cavey
Maryland Department of Natural Resources

Adrianna Celtruda
University of Maryland

Jen Cramer
U.S. Geological Survey - Woods Hole Coastal & Marine Science Center

Will Dorsey
UMCES

Laura Feher
National Park Service

Hailey Glasko
University of Delaware

Elizabeth Hamman
St. Mary's College of Maryland

Ryan Higgins
DNR - RAS - Maryland Geological Survey

Sierra Hildebrandt
NOAA

Annalise Kenney
Maryland Sea Grant

Supriya Khadke
NOAA Office for Coastal Management/Lynker

Nick Kiraly
Underwood & Associates

Ryan Mello
Eastern Shore Regional GIS Cooperative (ESRGC)/ Salisbury University

Laura Mitchell
USFWS

Robert Newton
State of Maryland DNR - CCS

Hannah Nisonson
CCS NOAA NCCOS

Conor O'Hara
EA Engineering

Matt Pombuena
Maryland Department of Natural Resources

Elka Porter
St. Mary's College of Maryland

Alison Santoro
MD DNR

Alison Schulenburg
University of Maryland - College Park

John Slaughter
UMD UAS Research and Operations Center

Julia Smeltzer
Chesapeake Biological Laboratory

Taryn Sudol
Maryland Sea Grant

Alex Thompson
Underwood & Associates

Stephen Van Ryswick
MD DNR Maryland Geological Survey

David Walters
USGS

Claire Windecker
St. Mary's College of Maryland

Appendix B: Agenda

9:30 a.m. **Registration opens**

University of Maryland (UMD) UAS Research and Operations Center
44181 Airport Road, California, MD 20619

10:00 a.m. **Welcome**

Taryn Sudol, *Coastal Resilience Coordinator, Maryland Sea Grant*

10:30 a.m. **UMD UAS Research and Operations Center introduction**

John Slaughter, *Director, UMD UAS Research and Operations Center*

11:30 a.m. **Networking lunch**

12:30 p.m. **Drone imagery into the future: Discussing best practices for data management**

Supriya Khadke, *Mid-Atlantic Regional Geospatial Coordinator, NOAA Office for Coastal Management*

We will discuss ideas for how to manage drone imagery to extend the resource and benefits of the work you invested in. For example:

- When assessments and/or research are complete, where does that data go and how will others be able to access it?

1:30 p.m. **Peer learning sessions**

Applications for drones in marshes and other coastal sciences and management

- How can drones be used to monitor vegetation and track other changes in marshes?
- Discuss how drones can be used in water quality, aquaculture, planetary geology, etc. applications.

Logistics for drone operations

- Discuss best practices and user experience with sensors, image processing, modeling, and drone and software purchasing.

2:30 p.m. **Lightning networking session**

Participants match up to reflect on what was most valuable about the workshop and how they might move forward.

3:00 p.m. **Wrap up and adjourn**

Speaker Biographies

John Slaughter has an extensive background in aviation, both crewed and uncrewed. Before joining the A. James Clark School of Engineering at the University of Maryland in 2022, he was a Senior Program Analyst and Vice President for Business Development at AVIAN, LLC, an aviation and aerospace consulting firm based in Lexington Park, MD, where he also managed a commercial UAS services division of the company. Prior to that, Slaughter had a nearly 30-year career flying helicopters as a US Naval Aviator and serving in various ground assignments, including tours as Commanding Officer of Air Test and Evaluation Squadron One (VX-1) and Helicopter Antisubmarine Squadron 15 (HS-15); as Integrated Product Team lead for the MH-60S helicopter acquisition program; and as Military Director for Systems Engineering at the Naval Air Systems Command. He holds a bachelor's degree in History from the University of California at Berkeley, and a master's degree in Systems Management from the University of Denver.

Supriya Khadke is the Mid-Atlantic regional geospatial coordinator for NOAA's Office for Coastal Management (Lynker). She offers geospatial guidance and acts as a regional connector to organizations and partners in the Mid-Atlantic. Prior to initiating the role in 2022, Khadke was the GIS and land data manager at Scenic Hudson, a land trust in the Hudson Valley. She also worked at Esri for six years, helping customers and working in product development to improve geodatabase functionality across the platform.

Post-workshop survey

List of workshop participants

This workshop was made possible by a grant to Maryland Sea Grant from the National Oceanic and Atmospheric Administration, Department of Commerce, through the National Sea Grant College Program, grant number NA18OAR4170070, and funding from the state of Maryland through the University of Maryland Center for Environmental Science.

CHESAPEAKE BAY

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Appendix C: Workshop Data

Applications of Drones in Marshes

Speakers and workshop participants shared the following projects they are currently engaged with as well as potential future projects, discussion topics, and other ideas.

Monitoring

- Elevation
    - Marshes, dunes, thin layer placement siting, living shorelines, sedimentation and sediment transport (e.g., build-up along banks)
    - Associated challenges: need to see down to millimeters; how to see through vegetation
- Vegetation
    - Reforestation sites
    - Status of marsh grasses
    - Spread of invasive species (e.g., *Phragmites* spp.)
    - Tree stress and mortality
- Wildlife Monitoring
    - Marsh bird nests
    - Large-scale cetacean habitat management
- Water quality
    - Temperature and turbidity
    - Thermal surface temperature for streams
    - Associated challenges: payload size, equipment avoiding contact with water
- Pre- and post-event tracking
    - Storm erosion on coastal ecosystems, beach volume change
    - Restoration projects, living shoreline installments
- Ecological successions and migration
    - Marsh and dune migration
- Carbon sequestration

Vegetation Identification

- Mapping submerged aquatic vegetation (SAV) and invasive species
- Vegetation structure (e.g., biomass estimates)
- Calculating various indices (e.g., Normalized Difference Vegetation Index [NDVI])

Mapping, Categorization, and Delineation

- Different habitat types
- Wetland, SAV, and/or shoreline delineation
- Habitat identification below surface of the water
- Groundwater discharge (and possibly septic discharge)

Ecological Restoration

- Target maintenance

Flooding

- Prediction forecast
- Validate flood model

Disaster Preparedness

Logistics of Drone Operations in Coastal Environments

Speakers and workshop participants shared challenges and possible solutions to various logistics for conducting a monitoring project with drones.

Getting Started with a Drone Program

- Desire for a source on process, project folders, scope of work, etc.
    - How to estimate time allocation and compute power needs
- Data type directs what tools you need (e.g., sensors, software)
- Desire for a decent, affordable, multipurpose drone
    - Consider Da-Jiang Innovations (DJI) bans on drones and National Defense Authorization Act (NDAA) compliant. Skydio, FLIR acceptable under ban; DJI M210 unacceptable
    - Consider payload
    - Consider computer/machine to process data (i.e., high random access memory [RAM] and graphics card for processing)
- Request to get undergraduate students involved, such as a local pilot giving a demonstration or the Zephyr flight simulator mimics flight characteristics

Flight Approval and Regulations

- A lot of rules and regulations regarding permission, authorization, training, and purchasing
- Hard to follow National Environmental Policy Act (NEPA) requirements. Desire for there to be a blanket statement
- Light Detection and Ranging (LiDAR) has a lot of benefits but application collection might require a Land Surveyor Stamp, which can be difficult to maintain

Planning for Flight

- Site access
    - Landowner agreements

    - Tricky logistics when on the border of a restricted area
    - Airspace approval can be time consuming and take multiple communication steps (e.g., Dover Air Traffic Control needed notification three days before, 15 minutes before, and post-flight)
    - Difficult to obtain permits on US Fish and Wildlife Service (USFWS) and National Park Service (NPS) lands (concerns about drone crashes starting a fire, visitors see drones and think they can fly drones without a permit)
- Site restrictions
    - Unable to access interior of fragile ecosystems (e.g., dunes) or large sites (e.g., marshes), making collection of ground control points difficult
    - Some software (e.g., KeyNet) only available in places where you can get a signal
    - Sensor may not penetrate water. Need to accommodate for waves
    - Very difficult to stitch together open water photos (Red, Green, Blue [RGB], not photogrammetry)
    - How do you mitigate glare on lakes?
    - Difficulty in post-processing 3-D data of trees (there must be no wind)
    - Recommend taking oblique pictures, put them in vertical imagery to be used in photogrammetry. The 3-D model then uses them for corrections
    - Desire to obtain wetland elevation Digital Elevation Model (DEM)/Digital Surface Model (DSM) from LiDAR. Most success with sites that have very little vegetation (i.e., bare earth) because there is less to correct when removing vegetation from the model (however, sites often have vegetation)
- Sampling challenges
    - Weight of the payload
    - Drone or probe may have limitations in or be damaged by saltwater environments
    - Sometimes drones get grounded until replacement parts allow for proper functioning
- Each project requires specific equipment
- Generally best time to fly is low tide, midday, and overcast. Is there further consensus on the best time of day, year, tidal cycle to take imagery of marsh vegetation?

Data Collection and Processing Protocols

- Strong desire for protocols and methodologies. While specific, consistent standards would benefit operators and support collaboration, each project determines the level of accuracy needed and the minimum standards necessary
    - Desire to have a repository of use cases and what was collected
- Resource - National Estuarine Research Reserves: Drone the System-Wide Monitoring Program (SWMP)/ Drone the Reserve
- How to ground truth?
    - Difficult to locate the appropriate number of ground truth points in the literature. Group suggests Real-Time Kinematic (RTK) minimum of three fixed points, but the more the better
- How windy is too windy?
- Need to determine repeatable procedures for processing imagery that does not rely on “removing noise by hand,” which is highly subjective

Data Storage and Sharing

- Example databases: United States Geological Survey (USGS) Science database, EarthExplorer, MD iMap, Pix4D, WeTransfer, Global Mapper
- Raw data contains a large number of photos. Tradeoff between resolution and ease of sharing data. Sharing a large amount of images can be a long-time investment
    - Save as a Cloud Optimized GeoTIFF (COG) or ESRI Pro, which reduces size and makes sharing easier
    - Sometimes simplest to mail hard drives or deliver in-person, though this limits access and incurs travel costs
- National Oceanic and Atmospheric Administration (NOAA) has compiled a catalog of available LiDAR data and a US elevation inventory tool to show data available for a specific area
- Software licenses that allow large groups to view products can be expensive. Once you pick one, it can be hard to switch to another
    - Costs may be structured as standalone licensing or subscriptions
    - Resource: examples of free repositories (OpenDroneMap, REDtoolbox, NOAA CORS) and free trials (Data Cube)
- Interoperability between software and government regulations on how to store data. Operators (e.g., federal or state agencies) can be confined to the platforms they can use
- Resource: University of Oklahoma has a database on vegetation spectral signatures that could be referenced for habitat maps

Data Processing

- Programs often misidentify data (e.g., stripping off vegetation and sediment to reach bare earth)
    - Suggestion to export Point Cloud and use LAStools
    - Correct vegetation via the USGS LiDAR Elevation Adjustment with NDVI (LEAN) method but requires multiple parts (multispectral data + LiDAR)

Publication

- Lag time between when data is collected and published (e.g., one year or more)
- What is the publication process?

Table 1. Imaging Techniques: Applications, Strengths, and Weaknesses

Imaging Technique	Characteristics from participants
Hyper/ multispectral imagery	**Application Examples** Identify species (e.g., *Phragmites* spp.), monitor health of crops, coastal vegetation change, mapping shoreline and vegetation, monitoring vegetation health for reforestation and marsh grasses **Weakness/Cons** Can lose information
Red, Green, Blue (RGB)	**Application Examples** Identify species (e.g., *Phragmites* spp.), mapping shoreline and vegetation

Imaging Technique	Characteristics from participants
Red, Green, Blue (RGB) ***(cont.)***	**Question(s)** What is best method to stitch photos of water together (RGB, not photogrammetry)? What is a good RGB drone?
Orthomosaics	**Application Examples** Before and after images for restoration projects
LiDAR	**Application Examples** Coastal applications (e.g., pre- and post-storm erosion), vegetation structure, marsh surface **Strengths/Pros** Marsh 3-D models are better with LiDAR, good for smaller areas, catalog of LiDAR available (repository) **Weakness/Cons** LiDAR processing takes longer compared to photogrammetry depending on site size; everyone wants LiDAR, however, a lot of the application of that collection might require a Land Surveyor stamp which is difficult to obtain; older systems require you fly a mission with a camera and a mission with LiDAR **Question(s)** Suggestions to run LiDAR? How do you process LiDAR point cloud? How to process LiDAR data? How to remove the before and after flight for LiDAR data to remove the "bad data" and only process the "good data"? How to get "bare earth" from LiDAR over marsh? How to do wetland elevation DEM/DSM from LiDAR? How to collect quality marsh LiDAR data?
Thermal	**Application Examples** Map groundwater discharge into coastal bays (focusing on spreading groundwater discharge, but might investigate septic system discharge as well), locate marsh bird nests, monitor carbon sequestration, thermal surface temperature for streams and animals, water temperature **Question(s)** How to do orthos with thermal? Researching what conditions affect the biothermal detection by thermal imagery (i.e., what are the thresholds?)

Appendix D: Definitions

COG: Cloud Optimized GeoTIFF

DEM: Digital Elevation Model

DSM: Digital Surface Model

Esri: Environmental Systems Research Institute, Inc.

FAA: Federal Aviation Administration

GeoTIFF: Geographic Tagged Image File Format

Global Mapper: GIS software tool by Blue Marble Geographics

KeyNetGPS: Service that provides high accuracy positioning

LAStools: Collection of tools for processing LiDAR data

LEAN: LiDAR Elevation Adjustment with NDVI

LiDAR: Light Detection and Ranging; a remote sensing technology that uses lasers to create 3-D maps

Metashape: Software tool that performs photogrammetric processing of images to create 3-D data for GIS

MD iMAP: Maryland's Enterprise Geographic Information System (GIS)

NEPA: National Environmental Policy Act

NDAA: National Defense Authorization Act

NDVI: Normalized Difference Vegetation Index

NOAA CORS: National Oceanic and Atmospheric Administration Continuously Operating Reference Station

OpenDroneMap: Tool for drone image processing

Pix4D: Photogrammetry software suite for drone mapping

Point Cloud: Collection of 3-D data points that represent a physical object or space

RAM: Random Access Memory

REDtoolbox: Software for post processing drone data for high accuracy location

RGB: Red, Green, Blue sensors that capture imagery

RTK: Real-Time Kinematic

SWMP: System-Wide Monitoring Program

UAS: Unmanned Aircraft Systems

USGS EarthExplorer: Online tool for querying remote sensing inventories

WeTransfer: Online cloud system that is known for sending large files

Zephyr Drone Simulator: Online drone flight simulator

Drones named at the workshop*

DJI: Da-Jiang Innovations

DJI M210: Da-Jiang Innovations Matrice 210

Skydio

FLIR

**MDSG does not endorse any particular drone or manufacturer; the listed drones were mentioned during discussions at the workshop*