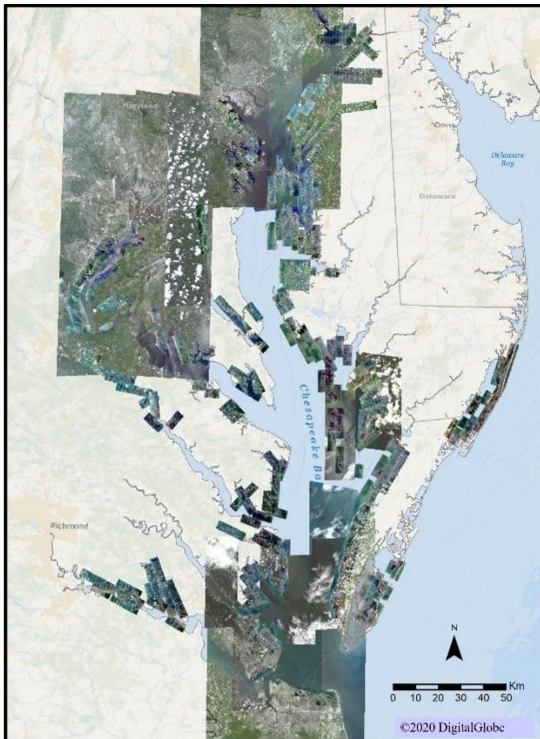
Exploring Satellite Image Integration for the Chesapeake Bay SAV Monitoring Program



A Scientific and Technical Advisory Committee Workshop Report

Session 1. October 2019. Gloucester Point, VA
Session 2. December 2019 – Gloucester Point, VA
Session 3. February 2020 – Gloucester Point, VA

STAC Publication 21-001

About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in 1984, STAC has worked to enhance scientific communication and outreach through the Chesapeake Bay watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the watershed. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

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Cover graphic: Satellite and aerial imagery acquired in 2020 to monitor SAV in Chesapeake Bay. ©2020 DigitalGlobe

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Executive Summary

Since 1984, the Chesapeake Bay Program has worked with the Virginia Institute of Marine Science (VIMS) to conduct an annual survey of submerged aquatic vegetation (SAV) throughout the Chesapeake Bay and its tidal waters. The Chesapeake Bay SAV Monitoring Program (hereafter the SAV monitoring program) collects, interprets, and synthesizes both aerial imagery and ground survey data to report SAV acreage and density throughout the Bay annually and reliably, and is the most successful and consistent large-scale, long-term SAV monitoring program in the world. SAV scientists and managers across the Chesapeake Bay watershed have grown to depend upon the data for a variety of purposes, from basic research and education to regulatory decision-making to annual public communications on the health of the Chesapeake Bay ecosystem.

Like many large-scale and long-term monitoring efforts, funding for the SAV monitoring program has become difficult to sustain and avenues for ensuring the longevity of the program are being explored. As such, the Chesapeake Bay Program's Scientific and Technical Advisory Committee (hereafter STAC) supported this workshop to explore the integration of high-resolution commercial satellite imagery (CSI) into the SAV monitoring program. The overarching purpose of the workshop was to determine if CSI (i) could be obtained and processed in a more efficient and cost-effective manner than aerial imagery collected from fixed-wing aircraft, and (ii) could provide imagery of sufficient quality and spatial cover to monitor SAV populations in the Chesapeake Bay. Adoption of monitoring and assessment approaches with significant cost and programmatic efficiencies are needed to ensure the long-term sustainability of the SAV monitoring program.

The workshop convened technical and management personnel to consider pathways to achieve the aforementioned goals. Acquiring CSI at no cost is an option under the NextView License agreement between the National Geospatial-Intelligence Agency (NGA) and Maxar (previously DigitalGlobe, Inc). The NextView License was developed by the NGA to accommodate United States Government (USG) agencies, contractors, partners, and other entities that require CSI to support USG interests. The basic premise of the agreement is that any federal agency that *requires* satellite imagery from contracted commercial sources can request and obtain said imagery at no cost to the local agency. As 2017 updates to the Water Resource Development Act, which amends Section 117 of the Clean Water Act, called for the U.S. Environmental Protection Agency (EPA) to carry out an annual SAV survey in Chesapeake Bay, this makes it theoretically feasible for the EPA to now request and obtain the high-resolution CSI necessary for the annual SAV assessment.

During the three-session workshop and in the months since, we learned that targeted acquisition of CSI through the NextView License is possible, and that under optimal conditions, CSI is comparable to aerial photography for conducting SAV acreage assessment. Rather than whole-heartedly endorsing the incorporation of CSI into the SAV monitoring program at this time, the steering committee recommended that additional steps be taken to answer lingering questions that will determine whether incorporating or transitioning to CSI is realistic, feasible, and advantageous to the SAV monitoring program.

To determine the exact steps and contacts necessary to begin tasking and data acquisition, the steering committee recommended that VIMS GIS analysts conduct two primary exercises: test tasking of the whole Bay and a calibration/match-up exercise. These exercises have already been funded as addendum to the VIMS scope of work for the existing annual aerial survey.

The recommended whole-Bay ***tasking exercise*** began in spring 2020 and continued throughout the summer 2020 SAV growing season. Tasking for the whole Bay will establish acquisition zones based on tides and peak biomass, provide an estimate of the time needed for assembling task orders, promote familiarity with the steps involved, allow calculation of a failure rate (i.e., the percentage of the Bay that was not able to be captured with CSI for various reasons), and facilitate the opportunity to conduct a calibration exercise with 2020 SAV data obtained during the aerial survey.

The recommended ***calibration study*** will take place during winter 2020/2021 using CSI from the tasking exercise and the aerial photography from the 2020 survey. Up to six unique test sites for comparison will be selected from the satellite imagery that was acquired under sufficiently comparable conditions. This calibration exercise will allow analysts to determine if tasking with specific requirements (e.g., during low tide, peak biomass, off nadir, etc.) - rather than relying on imagery that had already been incidentally captured for other reasons - improves the quality of the CSI and produces a closer match to the aerial photography.

Regarding the use of artificial intelligence (AI) for image processing as a potential means to reduce program costs, AI/algorithm development was set aside as an objective that could not be realized during this workshop. Regardless, the steering committee recommends that progress towards AI/machine learning/algorithm development for Chesapeake Bay SAV assessment continues. The Chesapeake Bay is a very complex ecosystem with four salinity regimes, as many SAV community types, and a diverse physical environment, so a great deal more field data will be necessary to train algorithms for the unique environments all over the Bay. A potential avenue for collecting this data may be the Chesapeake Bay SAV Sentinel Site Monitoring Program. Additional funding is required, however, for data collection and algorithm development. One potential source of internal funding is the Goal Implementation Team Project Initiative, but these funds are limited, competitive, and would not be available for over a year. As such, it is recommended that the steering committee continue looking for external sources of funding to assure this important work continues.

Following completion of these tasks, the steering committee recommends that the committee and principle participants reconvene to assess progress and, based on that progress, make more definitive recommendations for the long-term evolution of the SAV monitoring program. If it is discovered that any barriers that currently exist can be alleviated or at least accommodated, the steering committee and workshop co-chairs will recommend incorporating CSI into the SAV monitoring program first as a hybrid effort and eventually to a full Bay effort, with aerial photography eventually reserved as back-up. Following the reconvening of the steering committee, an addendum with final recommendations will be submitted to STAC to attach to this report. Workshop participants recognize the incredible value and potential that no-cost CSI could have for the Chesapeake Bay Program and our partners. Aside from SAV assessment, learning exactly how to order and access high resolution satellite data from the most technologically advanced satellite constellations that exist will be a boon to all of the CBP's resource assessment programs.

1. INTRODUCTION

1.1 Workshop Background and Purpose

Since 1984, the Chesapeake Bay Submerged Aquatic Vegetation (SAV) Monitoring Program (hereafter the SAV monitoring program) has used aerial imagery, coupled with ground-based surveys, to map and assess the distribution and abundance of underwater bay grasses, also known as submerged aquatic vegetation (SAV), throughout the Chesapeake Bay and its tidal tributaries. This program is globally esteemed, and its products have been instrumental in guiding the assessment, management, and restoration of the Bay since the program began. For more than 30 years, annual SAV acreage assessment results have provided citizens, managers, scientists, and policy-makers with the information necessary to advocate for, manage, and restore this quintessential indicator of bay ecosystem health. Consequently, in 2017, Chesapeake Bay SAV reached a Bay-wide acreage of nearly 105,000 acres – 57% of its restoration goal – representing the largest known example of SAV recovery and response to management actions in the global literature (Lefcheck et al. 2018).

Since its inception, the SAV monitoring program has evolved its assessment approach with updates to equipment and interpretation protocols consistent with the latest advances in aerial image acquisition and mapping technology. Presently, SAV monitoring through aerial image assessment makes use of aerial digital photographs with a spatial resolution of 24 cm. While the aerial platform provides a great deal of logistical flexibility, coordinating the imagery acquisition to take advantage of optimal imaging conditions (clear skies, low tides, low winds, low turbidity) is logistically complicated, time consuming, and costly – coordinating image acquisition constitutes 20% of the annual project budget. Image acquisition can be interrupted by extended periods of poor water quality resulting from high winds and storm events, and success is further dependent on gaining access to restricted airspaces around Washington D.C. and the multiple military-controlled zones over the Bay. Further, the lack of radiometric calibration for aerial imagery may hinder the ability to develop automation techniques based on radiometric models that could potentially process the images and quantify SAV distributions more efficiently.

In response to chronic budgetary concerns, alternative monitoring approaches were evaluated during *The Chesapeake Bay Program Partnership's SAV Aerial and Ground Survey Design Workshop*, coordinated by the Chesapeake Bay Program's SAV Workgroup and held on March 29th, 2017 in Annapolis, MD. Based on responses to a comprehensive SAV data user questionnaire distributed in advance of the workshop, and input from participants during the workshop, three alternative design options for the aerial survey were identified for further exploration. These three design options were: 1) maintain the existing annual survey design but upgrade to a semi-automated imagery processing routine; 2) collect Bay-wide annual imagery but only process a subset of regions of the Bay annually with the entire Bay being mapped every three to four years; and 3) collect Bay-wide imagery annually but only process a statistically random subset and interpolate the results to get a Bay-wide estimate of SAV acreage

The first option - keeping the existing survey design but upgrading to a semi-automated imagery processing routine – was explored by a postdoctoral researcher at the Virginia Institute of Marine

Science (VIMS) (Pham, 2020). Ideally, this option would have maintained use of aerial imagery and reduced the cost of the program by decreasing the number of staff and man-hours necessary to interpret the imagery collected during flights. Unfortunately, methods researched for this approach did not result in an improvement in the current monitoring process. Improvements to the methods that were evaluated continue to be researched and will be incorporated if they are found to be effective. It is possible that radiometrically calibrated imagery may better facilitate a semi-automated approach, but this has not yet been evaluated for these data. The second option - collecting Bay-wide annual imagery but only processing regions of the Bay annually (i.e., one year the polyhaline would be mapped, the next year the mesohaline would be mapped, etc.) with the entire Bay being mapped every three to four years – has been accepted as an "if all else fails" option because the management needs of the community would be greatly interrupted if Bay-wide SAV coverage is unavailable each year. And finally, the third option - collecting Bay-wide imagery but only processing a statistically random subset – was explored by a statistician at the University of Maryland Center for Environmental Science (UMCES) (Liang, 2018) and deemed unlikely to generate any actual cost savings while ultimately reducing the quality of the annual assessment.

One option that was not fully explored for the SAV monitoring program was the use of satellite imagery for assessing annual SAV acreage in the tidal waters of Chesapeake Bay. At the time, this option was generally dismissed because it was thought that high-resolution (i.e., 1 meter or less) satellite imagery of the Bay was either unavailable or obtaining it was financially prohibitive. Recently, however, we have learned that acquiring high-resolution, commercial satellite imagery (CSI) either at a reduced rate or at no cost may be a viable option under the NextView License agreement between the National Geospatial-Intelligence Agency (NGA) and Maxar (previously DigitalGlobe, Inc). The NextView License was developed by the NGA to accommodate United States Government (USG) agencies, contractors, partners, and other entities that require CSI to support USG interests. The United States Geological Survey (USGS) assists with this arrangement by serving as the conduit to advance the CSI needs of the federal scientific community. The basic premise of the agreement is that any federal agency that *requires* satellite imagery from contracted commercial sources can request and obtain said imagery at no cost to the local agency. As 2017 updates to the Water Resource Development Act, which amends Section 117 of the Clean Water Act, called for the U.S. Environmental Protection Agency (EPA) to carry our an annual SAV survey in Chesapeake Bay. This makes it theoretically feasible for the EPA to now request and obtain the high-resolution CSI necessary for an annual SAV assessment in the Chesapeake Bay.

The ability of CSI to provide a reasonable alternative for Bay-wide SAV acreage assessment comparable to the current SAV monitoring program, which uses high resolution (24 cm) digital imagery captured by fixed-wing aircraft flying at low altitudes, is, thus, the question at hand. Maxar (previously DigitalGlobe), is a commercial satellite data provider that owns and operates the WorldView satellites. This constellation generates data and radiometrically calibrated images with resolution scales of ~1 m and these are the data available to the USG and partners through the NextView License. These advancements in satellite-based image acquisition technology give CSI higher spectral resolution and slightly lower spatial resolution compared to the aerial imagery used in the present SAV monitoring program. The process of tasking and obtaining the imagery is not simple, however, and publication/distribution restrictions apply. Regardless, incorporation of CSI into the SAV monitoring program may provide logistical and financial advantages over the current system based on digital aerial photography provided by fixed-wing aircraft.

An opportunity to begin exploration of CSI for the SAV monitoring program occurred in 2018 when 26% of the Bay remained unmapped for a variety of reasons following the summer's Bay-wide aerial survey. Data gaps prompted VIMS analysts to explore alternative imagery for use in the 2018 assessment. They were able to reduce those gaps using alternative aerial imagery, publicly available satellite imagery and private CSI. Ultimately, VIMS program analysts interpreted SAV acreage and density from a mosaic of images collected from traditional fixed-wing aircraft, publicly available satellite imagery, and CSI to complete the 2018 SAV acreage assessment, leaving only 8% of the Bay unmapped for that year. Where available, high-resolution CSI acquired under ideal conditions was found to be adequate for photointerpretation and delineation of SAV. Concern remained, however, that obtaining all of the imagery necessary for a Bay-wide SAV assessment using CSI may be difficult because there were large portions of the Bay where usable CSI was not available.

In addition to the SAV monitoring program at VIMS, Chesapeake Bay Program (CBP) partners at Old Dominion University (ODU) are working to develop new techniques for the task of mapping SAV beds using artificial intelligence (AI)/machine learning algorithms. These efforts are generating advances in SAV acreage assessment protocols that may support a partial or complete transition to CSI-based assessment of Chesapeake Bay SAV in the future.

This workshop, described in detail below, was both timely and necessary to conduct a thorough review of the science, technology, and economics associated with the use of CSI for maintaining and evolving the Chesapeake Bay SAV monitoring program. The overarching objective was to conduct a thorough review of the science and technology associated with the use of satellite imagery for Chesapeake Bay SAV acreage assessment. Further, we aimed to identify scientific, logistical, and/or financial benefits and constraints related to the integration of satellite data into the SAV monitoring program.

Specifically, we aimed to:

- establish the institutional and agency relationships and related protocols necessary for successful high-resolution satellite image access, acquisition, storage, and management,
- demonstrate and document the comparability between historical fixed-wing aerial image-based data outputs and proposed satellite image-based assessment results, evaluating magnitude of differences, bias, and any geographic limitations on satellite image assessment,
- establish community agreement on algorithms implemented for image interpretation and outputs of results since the indicator of acreage is also a regulatory based endpoint to water quality standards attainment in the tidal bay jurisdictions.

1.2 Workshop Format

A non-traditional format was adopted for this workshop. Rather than a series of presentations, plenaries, and breakout sessions, we convened three two-day meetings from October 2019 to February 2020 focused on specific discussion topics. Participation in these three workshop sessions was typically limited to no more than fifteen participants to maximize participation from all attendees. The sessions took place in the Owens-Bryant Board Room in Davis Hall at VIMS in Gloucester Point, Virginia. Each workshop session opened with a review presentation by the workshop co-chairs. Following the opening review, workshop participants presented a range of subjects related to the workshop topics (e.g., data availability, data acquisition, data storage, data interpretation methods, etc.). Most importantly, ample time was reserved for discussion each day during all three sessions.

A fourth workshop session was planned as a one-day event in Annapolis, Maryland to serve as a "report out" to SAV monitoring partners and the management community. However, it was cancelled due to the global Coronavirus pandemic and workshop results will instead be communicated through the release of this report and a series of presentations to CBP STAC, STAR, the Management Board, the Habitat Goal Implementation Team, and various interested agencies and CBP workgroups.

2. WORKSHOP RESULTS

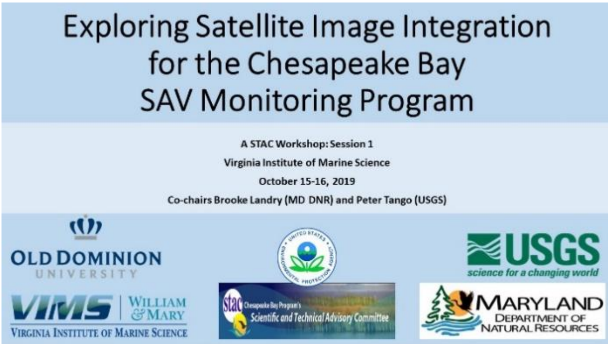
2.1 Session 1: October 15th-16th, 2019; VIMS, Gloucester Point, VA

The first session of this workshop took place on October 15th and 16th, 2019. Participants included SAV monitoring and mapping experts, Chesapeake Bay Program management personnel, and experts in satellite data acquisition and interpretation. See Appendix A for a workshop participant list.

In the first session, participants (i) reviewed the workshop proposal and assured that all participants understood the intent and objectives of the workshop, (ii) reviewed the current state of the programming and science for assessing Chesapeake Bay SAV, and (iii) developed a plan for each of the subsequent workshop sessions that would inform the workshop objectives and support development of the workshop report product. See Appendix B for workshop session agendas.

2.1.1 Presentations: Workshop Objectives and State of the Programming and Science for Assessing Chesapeake Bay SAV

2.1.1.a Exploring Satellite Image Integration for the Chesapeake Bay SAV Monitoring Program



During an introductory presentation, ***Exploring Satellite Image Integration for the Chesapeake Bay SAV Monitoring Program,*** Brooke Landry and Peter Tango, workshop co-chairs, reviewed the workshop proposal, assured all participants understood the intent and objectives of the workshop, and laid out the objectives for the first session.

Workshop and Session 1 Objectives

1. Review the original STAC workshop proposal to establish a common understanding of workshop objectives among participants. Workshop objectives:

    a. establish the institutional and agency relationships and related protocols necessary for successful high-resolution satellite image access, acquisition, storage and management,

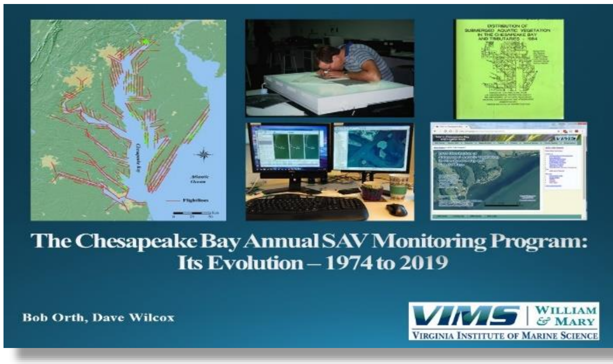
    b. demonstrate and document the comparability between historical fixed-wing aerial image-based data outputs and proposed satellite image-based assessment results, evaluating magnitude of differences, bias, and any geographic limitations on satellite image assessment,

    c. establish community agreement on algorithms implemented for image interpretation and outputs of results since the indicator of acreage is also a regulatory based endpoint to water quality standards attainment in the tidal bay jurisdictions.

2. Review of the state of the programming and science for assessing Chesapeake Bay SAV.

3. Collaborate on details for the remaining sessions that will inform workshop objectives and support development of the workshop report product.

2.1.1.b The Chesapeake Bay Annual SAV Monitoring Program: Its Evolution – 1974 to 2019



To establish a common understanding of the existing Chesapeake Bay SAV monitoring program and its 30+ year evolution, Dr. Robert "JJ" Orth and Dave Wilcox, VIMS, presented ***The Chesapeake Bay Annual SAV Monitoring Program: Its Evolution – 1974 to 2019.*** This presentation is available as Appendix C and is summarized below.

The SAV Monitoring Program

The Chesapeake Bay SAV monitoring program began unofficially in 1974, with annual assessments beginning in 1984 and continuing to present. The only year Bay-wide SAV acreage was not documented was in 1988 when funding shortfalls prevented data acquisition.

Coordination of the annual monitoring program starts in the winter of the year the imagery will be acquired. Coordination involves determining which part of the Bay can be mapped on which day, based on the expected sun angle and predicted tides. For ease of coordination, VIMS analysts divide the Bay into mapping sections based on tide windows and SAV species present.

The actual survey starts in the polyhaline reaches of the lower Bay in May when Zostera is at peak biomass. The survey continues over the course of the summer growing season and moves north and into fresher water as the summer progresses and those SAV communities reach their successive peaks in biomass. Survey activities generally end in late September or October with the decline of bay grasses at the end of the growing season.

Air Photographics, based in Martinsburg, West Virginia, is the flight contractor that collects the aerial imagery. VIMS and Air Photographics have been coordinating the SAV aerial survey together since 1984. VIMS coordinates with Air Photographics on timing, flight lines, and all elements of image acquisition. To ensure efficiency during the acquisition phase, wind and tides are monitored daily so that the flight contractor can cancel the flight if conditions become unfavorable. Because of the plethora of military installations throughout the Chesapeake Bay watershed, extensive coordination with the Department of Defense and Homeland Security is also required. Flight activity over the Potomac, Patuxent, and Gunpowder Rivers, as well as over the Honga River and Tangier Sound, are subject to both military and Homeland Security airspace restrictions.

Air Photographics acquires imagery under pre-specified conditions (i.e., winds, tide, water clarity, all monitored closely) (Figure 1), and sends VIMS a digital copy. Once imagery is collected and transferred to VIMS for review, VIMS analysts assess the image quality to determine if the area needs to be re-flown. Reasons for repeating data acquisition of a previously conducted flight line primarily result from low image quality caused by sun glint, cloud cover, and/or water column turbidity. Once an image is approved for acreage assessment, it is orthorectified, mosaicked, and finally a GIS analyst manually delineates the SAV beds as polygons using ArcGIS mapping software. Photointerpretation guidelines include:

- Map only what you see
- Mapping scale is 1:2,500
- Minimum mapping unit is 0.1 hectare (approximately 0.25 acres)
- Use stream mode to create a smooth outer bed edge
- Split SAV bed areas into density classes based on established classification protocols and professional judgement
- Map SAV beds via 'lumping' instead of 'splitting’
- Evaluate and compare with historic (composite) SAV bed extent, historic imagery, and field data and observations
- Document exceptions

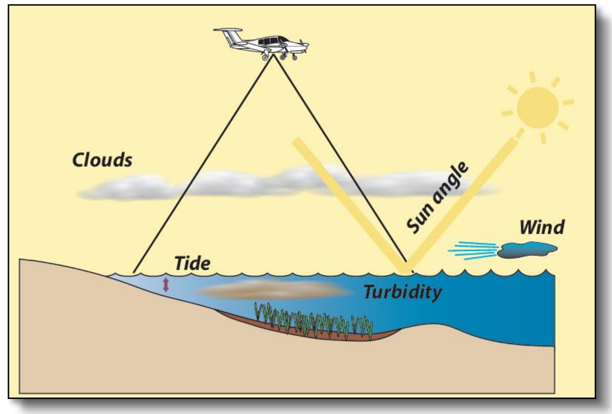


Figure 1. Conceptual diagram of optimal conditions for aerial image acquisition and SAV bed delineation.

Each SAV polygon is assigned a density class based on classification protocols and professional judgement of percent cover (Figure 2). Cover classes range from 1 to 4 and are as follows: 1 = <10% SAV (Very sparse); 2 = 10% - 40% SAV (Sparse); 3 = 40% - 70% SAV (Moderate); 4 = 70% - 100% cover (Dense). Each image and SAV polygon are then reviewed by the program lead or manager and one additional analyst. To the extent feasible, ground surveys validate interpretation and any field observations made are added to the VIMS SAV maps online.

Figure 2. SAV polygon with assigned density classes based on classification protocols and professional judgement of percent cover. Cover classes range from 1 to 4: 1 = <10% SAV (Very sparse); 2 = 10% - 40% SAV (Sparse); 3 = 40% - 70% SAV (Moderate); 4 = 70% - 100% cover (Dense).

If aerial imagery could not be obtained for an area of the Bay, analysts attempt to acquire imagery for that area from other sources, such as the National Agricultural Imagery Program (NAIP) or, more recently, from commercially or publicly available high-resolution satellite data. If imagery is not available via alternative sources, the area is marked as not completely mapped and is excluded from year to year analyses. An estimate of full SAV coverage in the Bay is, however, generated by substituting the previous year's data for the missing area.

After imagery for the entire Bay has been acquired and all imagery has been analyzed for SAV acreage, the survey data and an annual report summarizing SAV status, trends, and progress toward the Bay-wide SAV restoration goal are released in coordination with the Chesapeake Bay Program in late spring/early summer the following year. The data and report released at that time are considered preliminary. The *final* report is submitted after the following year's flights have taken place; this delay of finalization allows for analysts to assess the newer SAV data and in essence, proof the previous year's mapping efforts with the new data. All of the data, SAV maps, and reports are available on the VIMS SAV monitoring program website at: https://www.vims.edu/research/units/programs/sav/access/index.php

For additional details of the current program, please see https://www.vims.edu/research/units/programs/sav/methods/index.php

Trial Use of Satellite Imagery in 2018

During this presentation, trial integration of satellite data was also discussed. Problems with weather, water quality, and aircraft logistics presented many challenges that prevented 26% of the Bay from being mapped with traditionally sourced aerial photography during the 2018 SAV monitoring season. In an attempt to ensure full Bay-wide survey coverage for the year, VIMS analysts identified alternate sources of imagery including:

- National Agricultural Imagery Program (NAIP) aerial imagery
- WorldView 2 satellite imagery acquired from Digital Globe (now Maxar) through the NGA NextView license
- Worldview 3 satellite imagery acquired from Digital Globe (now Maxar) through the NGA NextView license,
- WorldView 4 imagery purchased from Apollo Mapping, and
- PlanetScope satellite imagery from Planet Labs.

Each set of resources was evaluated and the best images for estimating SAV coverage were used in portions of the Bay where overflight imagery was not acquired. The additional aerial and satellite imagery acquired from multiple sources used for this very challenging year reduced the unmapped portion of the Bay to 8%.

Lessons learned from the incorporation of satellite imagery in 2018 included:

- The WorldView image archive (available through NextView License) did not provide full coverage of the Bay in 2018 (because it had not been previously tasked for this purpose).
- The NextView License allows tasking and ordering of specific images, so increased coverage of Chesapeake Bay is possible.
- The process to orthorectify satellite imagery is different than used for traditional aerial imagery.
- Pan sharpening can help provide multispectral imagery with a spatial resolution of approximately 1 m for WorldView 2 and 30 cm for WorldView 3.
- More spectral bands provide more information that can take more time to process visually.
- Planet could not be used as a primary source due to the "low" resolution (4m) compared with present aerial survey resolution (<1m). However, it was helpful in identifying the presence or absence of grass throughout the growing season.
- Satellite overflight time was typically midday, requiring off-nadir imagery to avoid sun glint.
- The USG/NGA NextView License Agreement may have limits on how to publish or share the satellite imagery, or how the contractor may retain imagery after the project period. Permission for sharing must be authorized by NGA.

The Budget

Following the information presented on the integration of satellite-based data to fill gaps in the annual aerial survey, Dr. Orth and Mr. Wilcox presented on the SAV monitoring program's budget. This information is vital to the objectives of the workshop because program funding difficulties are one of the primary reasons alternative options have been explored over the past several years. With decreasing budgets and increasing expenses, it has been necessary to explore all options in an effort to keep this vital program solvent and sustainable.

In 2017, the total cost of the SAV monitoring program was approximately $690,000. This figure included $140,000 for the aerial contract with Air Photographics, $281,688 in analyst salaries, $112,747 for fringe benefits, $139,651 in IDC, and $15,000 for miscellaneous expenses including hardware, licenses, and travel.

The funding sources that same year included $342,356 from the CBP/EPA, $72,000 from Va DEQ, $60,000 from the Va CZM program, $45,000 from Md DNR, and $100,000 in match from VIMS, totaling $619,356. The approximately $70,000 budget shortfall, which had been an on-going issue for several years, prompted the *2017 SAV Monitoring Program Survey Design Workshop* mentioned earlier. Materials from that workshop are the source of this budget information.

An additional financial concern arose when the flight contractor that has been conducting the survey for the past 32 years, Air Photographics, restructured their operation in 2018. Following restructure, Air Photographics has acted as the flight coordinator for flights carried out by a subcontractor, Midwest Aerial Photography, a firm based in Ohio. Midwest Aerial Photography agreed to honor the existing five-year contract with VIMS, but once the contract is complete in 2021, were the relationship to continue, a new price would be negotiated that may be significantly higher than the previous contract. This uncertainty has prompted VIMS to explore other options and all indications point to a 1.7-2.1X increase in the annual cost of Bay-wide photo acquisition. Such an increase may affect the continuity of the program.

Fortunately, in 2018, following the Survey Design Workshop, the Maryland Department of the Environment initiated an annual contribution to the program of $50,000 per year, closing part of the funding gap. And in 2019, the Virginia General Assembly provided $250,000 in annual funds for the SAV monitoring program, completely closing the current funding gap, although because of that increase in funding, Va DEQ discontinued their annual contribution. Currently (2020), annual funding for the SAV monitoring program is as follows:

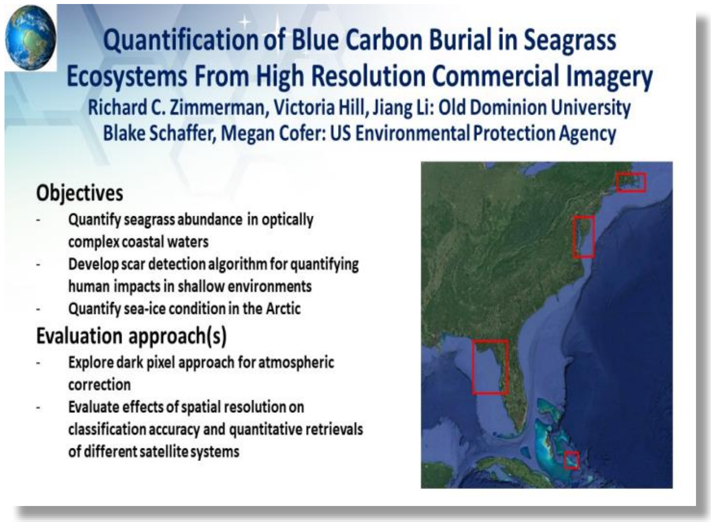
- EPA - $360,000
- VA CZM- $68,000
- MD DNR- $44,000
- MDE - $50,000
- Commonwealth of VA - $250,000 (NEW with caveat*)

* Requires imagery that can be viewed by VA regulatory agencies (VMRC)

These funding sources total $772,000 and at an approximate program cost of $700,000 in 2020, the program was completely solvent in 2019 and 2020, was able to cover previous year's debts, and will remain solvent in 2021. An additional cost savings is projected to come in the form of reduced salary support associated with the retirement of Dr. Orth and with Dr. Patrick assuming Directorial responsibility for the program, reducing annual costs by $30,000 per year, bringing the approximate program cost to $670,000 per year. With the projected increase in aerial contract cost after 2021, however, the long-term future of the program remains in financial uncertainty. If the aerial flight contract increases more than 1.7X the current expense in 2022, that increase will put the program in deficit again, which is why it is necessary at this time to consider fiscally prudent adaptions of the monitoring program and explore our options acquiring and using satellite imagery to help supplement the aerial imagery to support annual SAV assessments.

The presentation given by Dr. Orth and Mr. Wilcox was followed by a tour of their labs and facilities at VIMS that included a demonstration of SAV mapping by their analytical staff (protocols previously described). This demonstration showed just how much personnel time and focus goes into manual delineation of the Bay's SAV beds and suggests that increasing the efficiency of the SAV delineation portion of the workflow is an important mechanism for reducing costs. Provided they can produce comparable data records that preserve the integrity of the time series, automated methods such as machine learning and the use of artificial intelligence may eventually enhance SAV mapping in the Chesapeake Bay.

2.1.1.c Quantification of Blue Carbon Burial in Seagrass Ecosystems from High Resolution Commercial Imagery



Following the tour of the lab and mapping facilities at VIMS, Drs. Richard Zimmerman and Jiang Li presented on the possibilities of mapping SAV in the Chesapeake Bay using satellite-acquired data and AI in a presentation titled: ***Quantification of Blue Carbon Burial in Seagrass Ecosystems from High Resolution Commercial Imagery.*** Presentation co-authors include Dr. Victoria Hill, Dr. Blake Schaeffer, and Megan Coffer.

This presentation provided a review of new research at Old Dominion University (ODU) on tests of satellite-based SAV coverage assessment in estuarine settings including Chesapeake Bay. While the VIMS-based annual SAV survey uses hand-drawn delineation of SAV beds, Dr. Zimmerman showed how machine learning algorithms are being used for interpreting satellite images for SAV cover.

Study objectives were described as follows:

- Quantify seagrass abundance in optically complex coastal waters (i.e., those with turbidity, color, and tidal fluctuations)
- Develop scar detection algorithm for quantifying human impacts in shallow environments
- Quantify sea-ice condition in the Arctic (not relevant to Chesapeake Bay)

Evaluation approach(s) included the following:

- Explore dark pixel approach for atmospheric correction
- Evaluate effects of spatial resolution on classification accuracy and quantitative retrievals of different satellite systems

Study sites included New England Coastal Bays, Chesapeake Bay (Smith and Tangier Islands – mesohaline waters), Mid-Atlantic Coastal Lagoons (Chincoteague, Spidercrab, and South Bays – polyhaline waters), Florida Gulf Coast, and Great Bahama Bank. For the purposes of this workshop, results concentrated on SAV mapping in Chesapeake Bay and Mid-Atlantic Coastal Bays, but comparisons were made to the other sites to put into perspective the relative difference in mapping SAV in the clear, oligotrophic waters of Florida or the Bahama Bank compared to the turbid, eutrophic waters of the shallow, estuarine Chesapeake Bay.

During the presentation, Drs. Zimmerman and Li discussed the various advantages of different satellites, including those owned by Maxar (previously Digital Globe). These satellites, World View 2 and 3, as well as GeoEye, approach the imagery resolution necessary to accurately map SAV in the Chesapeake under ideal conditions, particularly World View 3. World View 3 includes eight spectral bands and 1 m spatial resolution + 0.3 m pan. This satellite has pointing capability to avoid sun glint.

Important considerations to using images collected by WorldView 3 are that they must be radiometrically calibrated and atmospherically corrected. Once calibrated and corrected, there are two potential approaches for analysis of the images: physics-based classification and machine learning classification. Physics-based classification of SAV beds requires extensive background knowledge and ancillary data. This approach is not highly portable when attempting to apply it to SAV in different waterways without significant additional work. Machine-learning classification starts with the same atmospherically corrected image and then applies training datasets to the machine learning algorithm. This classification and assessment approach is preferred but proves difficult in a highly variable environment such as the Chesapeake Bay. To successfully map SAV using this method, an analyst would – in theory - train the model with data from one site and then take it to another and add additional data, making it a cumulative process. For the Chesapeake Bay, regional training appears necessary and could use the previous year's data as the training dataset as well. Aside from simply mapping the extent and density of SAV beds in the Bay, presenters demonstrated the additional utility of automated mapping as it applies to human impacts. Propeller scars and scars created by hydraulic clam dredging were clearly visible and easily mapped from WorldView 3 satellite imagery (Figure 3) and can be detected using this artificial intelligence (AI) technology.

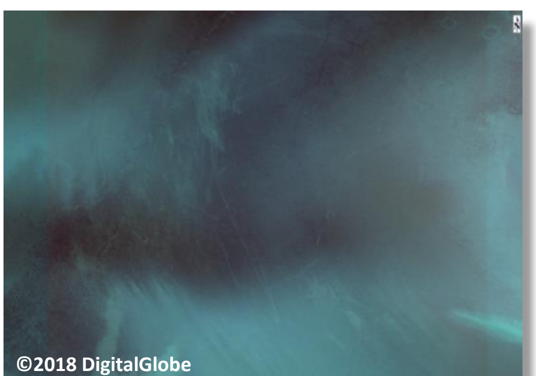


Figure 3. Propeller scars (left) and hydraulic clam dredge scars (right) detected using satellite imagery. (Imagery ©2018 DigitalGlobe)

Based on participant discussion following this presentation, however, it was determined that the final objective of the workshop - to establish community agreement on algorithms to use for AI mapping - remains an actively pursued research question that is outside the scope of this workshop.

While extensive scientific progress has been made using artificial intelligence and machine learning algorithms to interpret satellite image data for mapping SAV in proof of concept studies such as the one described by Drs. Zimmerman and Li (Coffer et al. 2020; Islam et al. 2020; Perez et al. 2020), it was evident that the portability of algorithms assessing SAV between systems remains an ongoing challenge for AI/ML users. Unique conditions in the tidal waters of Chesapeake Bay include, for example, turbidity, color, tidal fluctuations, and variation among SAV species in terms of spatial patterns, color, and canopy height impact the tuning of algorithms from one system to the next. Additional research is still necessary to support the broad use of satellite data with AI-based interpretation as an effective, operational SAV monitoring and assessment tool.

2.1.2 Discussion Sessions

2.1.2.a Review and Conclusions from State of the Programming and Science Presentations

A great deal of information was presenting during this first day of the workshop. Major points from the ensuing discussion are summarized here:

> **1. Not all satellite data are created equal.** See Table 1 below for specifications regarding Maxar's WorldView 2 and 3. WorldView 3 satellite data and imagery is preferable to other publicly or privately available satellite data for CBP purposes because 1) ***it can be obtained at no cost through the NextView License agreement, 2) it is high resolution*** and comparable to the digital imagery currently used for the SAV monitoring program and 3) ***the satellite can be tasked with directions for pointing off nadir to avoid sun-glint,*** thereby improving image quality and the likelihood of seeing well into the water column. However, as is also the case with aerial photographs, clouds and other atmospheric distortions, as well as wind, unusual high tides, and turbidity plumes have been shown to impede image interpretation with these sensors. Unlike aerial acquisition, where there is flexibility to switch flight plans and take advantage of optimal conditions as they appear, satellite acquisitions are pre-planned and we must recognize that not every image taken will be usable for SAV monitoring purposes.
>
> **2. Obtaining good data (WorldView 3) will be difficult.** Although Maxar works with the NGA and has an agreement with the USG to provide requested data at no cost, requests for that data will not necessarily be prioritized when other more critical and time-sensitive missions are scheduled or when paying customers have also requested data. Additionally, similar if not more restrictive windows of opportunity for data acquisition may be as cumbersome for satellite tasking as for aerial acquisition tasking from a fixed-wing aircraft. Further discussion in subsequent workshop sessions may yield more information or recommendations regarding this issue.
>
> **3. Use of high-resolution CSI is a viable option for the SAV monitoring program and assessment of SAV cover if accessible.** Existing high-resolution CSI imagery is on par with aerial imagery collected from fixed-wing aircraft and can be used for hand-delineation of

SAV beds. The use of satellite imagery has multiple advantages and disadvantages, but it was agreed upon that where and when WorldView 3 satellite data/imagery is available or can be ordered and obtained, that it's comparable in usability to aerial imagery, especially if the primary objective remains hand delineation of SAV beds and density classification.

4. Hand mapping would follow the same protocol and yield the same results. There is no difference in protocol for hand delineation of SAV beds from aerial photographs and satellite imagery. A smooth transition to or incorporation of CSI into the SAV monitoring program would likely yield the same results as have been obtained from aerial imagery collection.

5. Algorithms/AI/machine learning will eventually make it easier and cheaper by reducing labor costs but there's significantly more work to do before algorithms are ready for the Chesapeake Bay. The algorithms necessary to fully map SAV throughout Chesapeake Bay from satellite imagery are several years out in terms of development. Significant additional financial resources will be necessary to fully develop the necessary AI, and even then, impediments such as turbid water will remain a confounding issue.

6. Using AI may yield more precise, but different measurements that may not be comparable with current SAV goals and may skew long-term trends and results. The methods and protocols used to hand-delineate SAV beds from aerial imagery result in a generalized product that assigns a single density class to continuous regions of SAV of similar density. Using some AI algorithms, SAV may be mapped in more precise detail by delineating each tiny patch of SAV within these regions (i.e. "splitting" rather than "grouping"). A bed that was mapped as 100 hectares of sparse SAV using the current method could be mapped as 10 hectares of dense SAV using an AI approach. Although some recent publications do use a density-weighted approach like this for SAV classification (Lefcheck et al. 2018), changing management goals or long-term classification methods should not be considered in order to accommodate AI. Rather, protocols must be developed for AI to more closely replicate methods employed for hand delineation.

7. A hybrid approach may still be necessary if we can't get satellite data for whole Bay. The likelihood of getting usable, Bay-wide data from Maxar/NGA on a consistent, annual basis remains an open question. Continuous Earth observation missions for environmental science are not Maxar's highest priority – they follow a for-profit model of high-tech space cameras for hire. A hybrid approach – using both aerial imagery from fixed wing aircraft and CSI obtained by tasking specific high priority and difficult to acquire locations (e.g., restricted airspace) – will most likely be necessary for the foreseeable future.

8. Details regarding satellite tasking, data acquisition, and publication need to be worked out before moving forward. It was made clear during discussions that there remain obstacles to tasking, obtaining, and publishing satellite imagery for use in mapping Chesapeake Bay SAV. The use of satellite imagery has tradeoffs. The NextView License prohibits the publication of CSI on any public domain, such as a website that would provide a platform for annual SAV cover assessments, *without explicit permission for each frame published*. This is not the case with aerial imagery. VIMS publishes both the digital image of the SAV bed and the hand-delineated map of the SAV bed (the GIS data file). Some regulatory agencies that provide funding for the monitoring program require access to the imagery itself when using the data to either allow or deny permit applications (i.e., for aquaculture leases, dock or pier construction, shoreline structures, etc). If an SAV bed is mapped from satellite imagery acquired from Maxar/NGA, that imagery would be subject to copyright and permission to publish it online is not guaranteed; but the GIS layer that resulted from its interpretation may be readily published. Permission for publication of the original imagery may be granted on a frame by frame basis, but this was recognized as an integral question to answer before assuming that integration of satellite imagery into the Chesapeake Bay SAV monitoring program was a viable option.

9. Coming to an agreement on algorithm use will not be possible at this time. During the presentation by Drs. Zimmerman and Li, it became clear that our anticipated decisions on algorithm employment was premature. During the course of this workshop, it will not be feasible to "decide upon and come to agreement on" which algorithms to use or not use because they simply aren't available for the entirety of the Chesapeake Bay at this time. Instead, the steering committee and Session 1 participants determined the path forward needed to begin with agreeing on clear protocols targeting the details of satellite tasking, acquisition, and publication. Research on algorithm development is occurring on a parallel track to the process of documenting and testing how to reliably obtain CSI from Maxar/NGA. Combined progress can be folded into developing and implementing a transition plan with the SAV monitoring program.

Table 1. Specifications of WorldView 2 and WorldView 3 satellites.

	Overview	Uses	Spectral Band	Date Range	Products available through GBDX
WorldView 2	WorldView 2 has collected high-resolution, 8-band multi-spectral imagery since its launch in October 2009. This satellite is capable of collecting up to one million square km of 8-band imagery per day.	WorldView 2's highly detailed imagery is ideal for in-depth image analysis, change detection, and precise map creation.	Panchromatic band; Multispectral 4-band: 4 standard VNIR colors are blue, green, red, near-IR; Multispectral 8-band: 4 additional VNIR colors are coastal, yellow, red edge, and near-IR2.	October 2009-present	DigitalGlobe Basic (Level 1B imagery)
WorldView 3	GBDC provides access to WorldView 3's high-resolution, super-spectral 30 cm imagery that allows for fast and precise mapping of various features anywhere in the world. 31 cm panchromatic resolution, short-wave infrared (SWIR) resolution are available for processing.	With industry-leading geolocation accuracy and superiou haze penetration, WorldView 3 imagery is ideal for many new and enhanced applications, including mapping, land classification, disaster preparedness and response, oil and gas, identificatioon of man-made materials, and more.	Panchromatic band; Multispectral 4-band: 4 standard VNIR colors are blue, green, red, near-IR; Multispectral 8-band: 4 additional VNIR colors are coastal, yellow, red edge, and near-IR2; Shortwave infrared resolution: 8 SWIR bands that penetrate haze, fog, smog, dust, and smoke.	August 2014 - present	DigitalGlobe Basic (Level 1B imagery)

Data source: https://gbdxdocs.digitalglobe.com/docs/worldview-2 and https://gbdxdocs.digitalglobe.com/docs/worldview-3

2.1.2.b CSI Availability

The first scheduled discussion on Day 2 focused on CSI availability and determining if availability is the primary limitation now that resolution is comparable between plane and satellite-based images/data. The consensus from the steering committee and session participants was that yes, availability was the primary limitation. There was concern that the process to obtain the CSI would be cumbersome to the extent that it would make incorporation of satellite data non-advantageous, both financially and logistically. Participants were reminded that the point of the exercise was to ensure long-term sustainability of the Chesapeake Bay SAV monitoring program and that image tasking and data acquisition, as well as permission to publish, may prove more difficult than beneficial. Regardless, it was agreed upon that in the long-term, determining the steps necessary to acquire satellite data at no cost through the NextView License would in fact help ensure the long-term sustainability of the program by providing back-up options, if nothing else. Relying solely on one flight contractor for the entirety of the monitoring program puts the program at the mercy of that flight contractor and consequently, at risk.

2.1.2.c Asking the Right Questions

The second scheduled discussion was dedicated to reviewing and amending a list of 25 guiding questions that the workshop co-chairs drafted the evening of Day 1. Answers to these questions were identified as integral to support integration of CSI into the SAV monitoring program. During the review and editing of the questions, it was agreed upon by the entirety of the steering committee and participants that the ultimate objectives of the workshop had shifted. The question evolved from "Will satellite data work for mapping SAV in the Chesapeake Bay?" to "How do we obtain (good/usable) satellite data for mapping Chesapeake Bay SAV?" This shift reflects information presented during the first day of Session 1 by Drs. Orth, Zimmerman, and Li, and Mr. Wilcox.

There was consensus that high resolution CSI can provide the information necessary to hand delineate SAV beds throughout the Chesapeake Bay and its tributaries. Simply moving from fixed-wing based aerial imagery to no-cost CSI would theoretically produce a cost savings of $170,000-$300,000 per year if acquiring CSI was as straight-forward as obtaining the digital imagery. The glaring truth of the matter was, however, that the trick was going to be getting the satellite data, tasking Maxar/NGA to obtain it during optimal conditions, re-tasking Maxar/NGA for repeat imagery if necessary due to cloud cover/turbidity/etc., and publishing the images themselves as required for funding by some regulatory agencies.

Closing thoughts for this discussion focused on the need to thoroughly answer the 25 questions and outline the requirements and work flow needed among coordinating agencies and institutions to address issues identified during the workshop. The three-year period from 2020-2022 will be critical because the existing aerial survey contract only covers data collection through 2021. This introduces uncertainty into the future financial cost of data collection for the SAV monitoring program. The next year thus provides a window of opportunity to test, refine and document the process necessary for integrating CSI into the SAV monitoring program. Testing elements include 1) scheduling and tasking image collection by satellites, 2) conducting the SAV area assessment in the lab, 3) studying comparability of results when using aerial imagery versus satellite imagery, 4) documenting any impacts from using a new data source and its processing and assessment protocols on SAV acreage and density estimation, and 5) determining how to get approval for CSI retention and publication. Accounting for method change impacts on results is essential to maintaining historical continuity in understanding the status, trends, and progress toward meeting SAV restoration goals in Chesapeake Bay and its tidal tributaries.

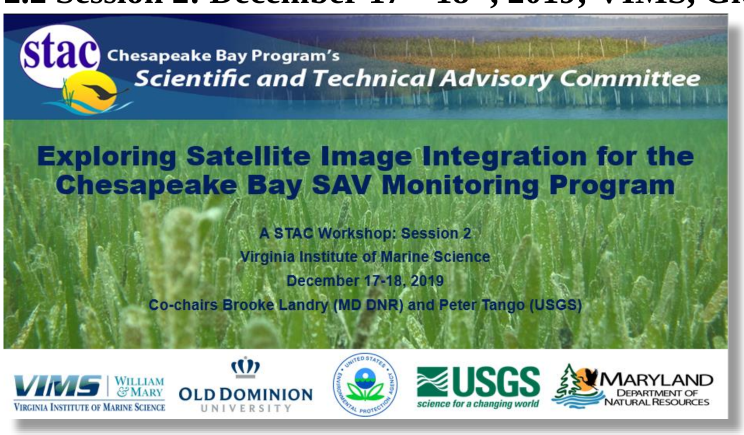
Although the questions and answers are not listed in the body of this report, the information gleaned is distributed throughout. The questions and answers themselves can be referenced in Appendix D.

2.1.3 Session 1 Wrap-up and Conclusions

Finally, planning for Session 2 took place at the end of Session 1, Day 2. The goals for Session 2 were identified as follows:

- Review information and challenges identified in Session 1.
- Determine the logistics of satellite image tasking and acquisition.
- Identify possibilities for image publication.
- Work with DoD to decrease overflight restrictions.
- Discuss plans for a comparison study and establish calibration needs.
- Discuss potential hybrid assessment design.
- Determine workflow and timeline for FY20 to FY22.

2.2 Session 2: December 17th-18th, 2019; VIMS, Gloucester Point, VA



Session 2 included a brief presentation and four discussions over the course of the two-day meeting. Most of the discussion time was dedicated to answering the questions identified during Session 1. Previously determined discussion themes were also honored and followed the agenda, including a discussion on how to approach and deal with increasing air space restrictions imposed over the Bay's military installations. Todd Beser, an Environmental Protection Specialist at Aberdeen Proving Grounds and Kevin DuBois, the DoD's Chesapeake Bay Program Coordinator joined us for Session 2 to help identify ways in which we can work together to more efficiently gain access to military airspace for the purpose of mapping SAV.

2.2.1 Presentation: NextView Licensing Information and Image Publishing Guidelines

Workshop participant Blake Schaeffer, EPA, provided overview handouts and discussed NGA's CSI publication restrictions. The three handouts are titled *NextView License Information Paper*, *NextView License Sharing and Release Guidance*, and *Framework for Public Release: Reviewing requests to release NextView licensed imagery into the Public Domain*. These handouts are attached as references in Appendix E, F, and G respectively. The key information is summarized here but all information in the handouts is relevant:

- Any satellite-based images that will be published on the VIMS or CBP website or used in reports need to be submitted to the NGA for copyright or license approval prior to publication. Approval is not guaranteed.
- There are four levels of release for the data and imagery. NextView License and License Uplift are the two levels of release most relevant to the SAV monitoring program. NextView License allows use and sharing by the USG and its partners in support of USG purposes if the USG uses its reasonable best effort to minimize effects on commercial sales. For License Uplift, full public dissemination is allowed by USG without restrictions. There are no product type or format restrictions, but annual volumetric limits apply. Both require marking on images when published.
- There is a difference between true-color imagery and the derived products. The derived products (i.e., SAV bed outlines and shapefiles) are not an issue for publication. The actual satellite-based image provided by Maxar/NGA is of more importance and has publication restrictions.
- When the use agreement between the Chesapeake Bay Program and NGA ends, source imagery must be deleted. This may pose a problem for the SAV monitoring program.
- Under security considerations, students working in a University setting have access only until they graduate, a project ends, etc.
- Data storage is in GeoTIFF format – satellite images are provided for upload to password protected FTP sites.
- When in doubt, users should contact NGA's EnhancedView Program Management Office: NextView_License@coe.ic.gov; NGANextView_License@nga.mil

These handouts clarified some of the concern over publication restrictions but testing the process of getting approval to publish imagery on the VIMS SAV Monitoring Program website will be necessary when considering the path forward.

2.2.2 Discussion Sessions

2.2.2.a Assessing Feasibility of CSI Integration

Following the presentation of information on NextView licensing and data publication, we moved onto a scheduled discussion period. The first scheduled discussion of the session was planned to address *Assessing Feasibility of Satellite Image Integration for the SAV Monitoring Program: Tasking and Logistical Issues*. The second scheduled discussion was dedicated to *Assessing Feasibility of Satellite Image Integration for the SAV Monitoring Program: Scientific and Technical Issues*. Most of the questions identified during Session 1 fell into one of these two topic areas, therefore, the rest of the day was dedicated to discussing and drafting responses to each question. One of the workshop co-chairs led the discussion while the other typed up the answers in real-time. Rather than including this list of questions and draft responses here, the questions and their complete/final answers are in Appendix D with relevant information included throughout this report. Please refer to the appendix for details.

2.2.2.b Additional Challenges and Opportunities - Working with the Department of Defense

This discussion addressed the challenges and opportunities related to working with the Department of Defense (DoD). One of the most time consuming obstacles encountered by VIMS analysts each year is obtaining permission and scheduling flights over military installations. There was concern that moving to CSI use might also be an issue, so two members of the DoD participated in this session of the workshop to discuss options. This conversation was guided by the questions: What restrictions are most important and need solving? Where do we need help from Department of Defense (DoD)?

In 2019, VIMS analysts had the most difficulty accessing and scheduling flights over the St. Mary's River (a tributary of the Potomac) and the Honga River on the mid to lower Eastern Shore of Maryland due to restrictions in airspace controlled by the Patuxent Naval Air Station. VIMS worked extensively with the individual military installations to work around airspace restrictions by scheduling flights on weekends rather than during the week. This solution is acceptable if both parties are willing to work on weekends, but for future sustainability of the program, it would be preferable that weekend work is not necessary.

Kevin DuBois, DoD's Chesapeake Bay Program Coordinator worked with VIMS to ensure they had the access they needed and liaised with DoD flight operations on their behalf but ultimately it is up to the individual installations to either allow overflights or not and frequently it's a challenge to get individuals at the installations to understand that CBP goals are part of the DoD mission.

When asked if drones might be used to map SAV along DoD installation shorelines, the consensus was that no, drones would pose an even larger problem than overflights.

Todd Beser, with Aberdeen Proving Grounds (APG), has been quite helpful over the last several years to ensure that flights in the vicinity of APG and over the Gunpowder River system and the upper Bay are flown without incident. In his case, he must fly along with the flight contractor as well as a police escort (generally one of Maryland's Natural Resource Police) during the overflight to collect SAV imagery.

There are over 60 major military facilities and approximately 130 DoD properties including installations and annexes within the Chesapeake Bay watershed. Coordinating flights through restricted airspace is challenging and time consuming for VIMS, personnel at the installations themselves, and the police that must accompany the flights. Use of CSI over the military installations should be strongly considered for the Chesapeake Bay SAV monitoring program even if Bay-wide CSI acquisition is not possible because it would alleviate some of the difficulty associated with flights in restricted airspace.

2.2.2.c Determining Requirements for a Tasking and Calibration Exercise

Throughout the first and second sessions of the workshop, it was repeatedly made clear that testing the flexibility of the tasking process would be necessary before long-term decisions were made. VIMS has a tried and true protocol setup with the aerial flight contractors to collect aerial imagery over the Bay each summer. A similar protocol would be necessary for tasking WorldView-3 satellites via NGA /USGS if we are to progress along this path. The agreed-upon plan for tasking is as follows:

> *Satellite Tasking Plan Development and Implementation:* Working with EPA, Maxar, and USGS, VIMS will develop a plan for tasking WorldView and other Maxar satellites to acquire imagery of SAV in the entire Bay under acceptable tide, weather, and turbidity conditions, and when each species assemblage is at maximum biomass. The satellite tasking plan will be implemented to acquire imagery of the entire Chesapeake Bay. Each set of imagery that is acquired will be assessed carefully to determine it is acceptable for SAV interpretation

The steering committee and workshop participants also determined that a calibration study between aerial imagery and CSI would be necessary to fully determine if incorporating CSI into the monitoring program would yield an equivalent result and allow SAV acreage assessment in all or part of the Chesapeake Bay. The decided-upon plan for calibration is as follows:

> *Interpret and compare test sites*. Up to six test sites for comparison will be selected from the satellite imagery that is acquired (2020 tasking exercise) under sufficiently comparable conditions. Each site will be interpreted from the satellite imagery by one analyst and from the aerial imagery by another analyst. After mapping the scene from one imagery source, the analyst will save the results for comparison and review the other imagery source, noting where changes would be made based on the additional information.

Given the concern over logistics, the group made a basic timeline to organize what needs to be accomplished in the near term and over the next several years to ultimately and successfully incorporate CSI into the SAV monitoring program as a supplemental resource or eventually as a primary resource. The basic timeline determined is as follows, but was fleshed out more thoroughly during the third session:

2018: Use(d) Satellite data to fill gaps in aerial imagery (VIMS)

2019-2020: Conduct STAC Workshop and Complete Workshop Report (CBP/STAC)

2020: Aerial acquisition with complimentary CSI tasking exercise to determine flexibility and calibration study (VIMS)

2021: Reconvene to determine if 2020 exercises were a success or failure, determine long-term recommendations (VIMS/CBP)

2022-2032: If recommended, incorporate CSI into SAV monitoring program, continuing working to perfect AI for eventual automated mapping.

2.2.3 Session 2 Wrap-up and Conclusions

Following the development of the flow chart, time remained for a final discussion to review our progress, plan for the next session, and make final points. Important points from the discussion are highlighted here and underscore the importance of this exercise:

Regarding CBP and partner data needs:

1. **CBP only requires derived map products and SAV acres to track progress towards the restoration goal.** It is important to remember that, technically speaking, the necessary product for the CBP is the Bay-wide acreage total and the segment acreage totals. That is the data necessary and required by the EPA to track progress towards restoration goals and eventually delist the Bay.

2. **Funding partners require imagery as well as the derived map product.** VMRC requires the actual aerial photograph for accepting or denying aquaculture lease permit applications. The mapped SAV bed is insufficient and the agency may pull funding for the monitoring program if the imagery is not accessible. Maybe the images can be provided to VMRC through password protection so that they can satisfy their grant but still meet potential restrictions on commercial imagery release.

3. **A scope of work will be required by NGA.** The scope should include all potential data uses and needs. All federal agencies should specify their data needs.

4. **The aerial contract is a minimal portion of the total SAV monitoring program cost.** Most of the funding for the program goes to processing and reporting. Regardless, if we can get satellite data at no cost, that would reduce the overall program budget and improve sustainability of the program. The eventual use of AI/ML algorithms will also reduce the cost by decreasing processing time.

5. Maxar imagery of the Bay could be purchased for ~$310,000 annually. Actual costs of WorldView imagery for the entire Chesapeake Bay is approximately $310,000 based on a back of the envelope estimate. This is potentially higher than the projected possible increased in cost ($238,000 - $280,000) for aerial imagery acquisition. If acquiring the data and imagery at no cost proves to be too difficult (i.e., Maxar/NGA doesn't prioritize it because we're not a paying customer), there is an option to purchase it, albeit one that may increase rather than decrease programmatic costs in the near term.

Regarding the SAV Monitoring Program:
6. The SAV Workgroup will not change the SAV goals. There was concern that the CBP SAV Workgroup may consider adjusting the SAV restoration goals to accommodate the new technology, but it is not the intent of the SAV Workgroup or the CBP to do so. Progress tracking needs to maintain its functionality.

7. Details are necessary. It is important to maintain the detailed level of SAV mapping in the Bay. It is not the goal of the CBP to reduce the comprehensive value of the SAV monitoring program.

Regarding the science and tech:
8. The technology will only get better. CSI spatial resolution will continue to improve and already approaches cm-scale resolution. WorldView Legion may accomplish this within the next year, in fact. This will make CSI more closely comparable to current aerial imagery. Aerial imagery technology is also developing quickly with the high demand for custom targeted imagery.

9. Funding is needed for additional AI research. We project that we are 2-5 years away from having an operational pipeline for AI use to create raster-based maps, assuming all of the required funding and imagery necessary is available. Funding is not currently available.

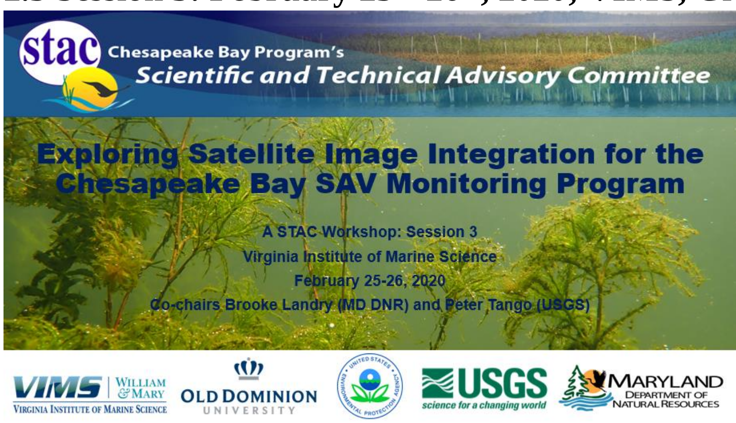
10. Confounding water-column effects. Regardless of advances in algorithms, there will always be confounding water column effects. You cannot see through mud. This limitation applies to aerial photography as well, but the flexibility associated with aerial photography – that is lacking with CSI - alleviates some of this concern.

11. Chesapeake Bay will be particularly challenging for AI development. Currently with AI, across 5 years of data, researchers are getting consistent classifications, meaning AI is working. However, reliability varies across locations. Algorithm portability is an obstacle and will be a particular challenge in the extremely diverse setting of the Chesapeake Bay. As the largest estuary in the United States, the system spans a range of salinities, water column constituents, and SAV species with differing signatures.

12. There are benefits of CSI regardless of AI advancements. A benefit of CSI is that issues with illumination can be corrected, whereas with aerial digital imagery, those issues cannot currently be fixed. This may enable enhanced viewing of SAV beds.

13. AI and hand-delineation approach from different scales. AI takes a pixel-based approach whereas hand delineation looks at an entire area. These two approaches should be combined for consistency in reporting.

2.3 Session 3: February 25th-26th, 2020; VIMS, Gloucester Point, VA



By Session 3, workshop participants had a thorough grasp of what was known and what remained unknown regarding accessing and using CSI for the SAV monitoring program and plans moving forward beyond the scope of the workshop were taking shape. As such, session 3 of the workshop included a summary recap of the two sessions, progress update presentations and presentations on remote sensing technology development that may be relevant to this effort, scheduled discussions, and time for writing.

2.3.1 Presentations: Participant Updates and Research

2.3.1.a Potential Collaboration with NASA

Dr. Schaeffer leads a team at EPA Office of Research and Development in Durham, NC and was integral to all aspects of this workshop. He and his team collaborate regularly with steering committee member Dr. Richard Zimmerman on seagrass mapping projects using remote sensing, satellite imagery, technology, and artificial intelligence. Dr. Schaeffer has familiarity with and expertise in the process of obtaining satellite imagery from Maxar and other sources, working with NGA, and with liaising with NASA. Between Sessions 2 and 3, Dr. Schaeffer facilitated a phone meeting that included Brooke Landry, Carin Bisland, Dr. Bradley Doorn, and Dr. Laura Lorenzoni. Dr. Doorn is the Applied Sciences Program Manager in the Science Mission Directorate in the Earth Science Division at NASA Headquarters in Washington, D.C. and Laura Lorenzoni is a Program Scientist for the Ocean Biology and Biogeochemistry Program (OBB), also part of the Science Mission Directorate at NASA Headquarters in Washington, D.C. The meeting involved discussions of the STAC workshop, its purpose and intent, and an explanation of why the Chesapeake Bay Program is moving towards the use of CSI in environmental monitoring. NASA is supportive and enthusiastic about the work being done, keen to see the recommendations that result from this workshop, and will consider supporting the work in the future, either at the program level or by releasing an RFP to support AI and algorithm development.

During the phone meeting, participants also discussed contingency plans should World View 2 and 3 get decommissioned. World View Legion will be launched in 2021 and may provide an alternative source of even more sophisticated data (29 cm resolution) for SAV assessment purposes. Preliminary tests indicate any high-resolution satellite imagery may be suitable for classification.

2.3.1. b Performance across WorldView 2 and RapidEye for seagrass mapping

Ms. Coffer is a PhD candidate in Dr. Schaeffer's lab. She presented preliminary findings associated with three research objectives: generating a reproducible workflow for processing commercial satellite imagery from WorldView-2 and RapidEye, assessing the radiometric performance of WorldView-2 and RapidEye data, and presenting a comparison of a pixel-based seagrass classification in a single WorldView-2 scene and a single RapidEye scene to an aerial photointerpretation at St. Joseph Bay in Florida, USA. A semi-automated workflow was created using the ENVI/IDL software to take Basic Level 1B imagery, as delivered from each commercial satellite imagery company, and process it into an analysis-ready product suitable for a variety of scientific applications, including seagrass classification. A standardized processing regime allows for bulk processing of satellite imagery, a limitation of previous studies. This workflow is available in Coffer et al. 2020. Performance across WorldView-2 and RapidEye for reproducible seagrass mapping. Radiometric performance was assessed through comparison to field-based reflectance measurements; WorldView-2 exhibited increased error, particularly in shorter wavelengths, compared to RapidEye. RapidEye had lower overall error and a slight positive bias compared to field observations. A pixel-based classification using a machine learning algorithm known as a deep convolutional neural network (DCNN) was used to classify the WorldView-2 and RapidEye scenes into five classes, including seagrass. Results were compared to an aerial photointerpretation. The datasets demonstrated high agreement (approximately between 96% and 97%), suggesting commercial satellite imagery can be used for seagrass delineation. This approach was also applied to WorldView-2 and WorldView-3 images at two additional sites: St George Sound and Tampa Bay, both in Florida. Current efforts focus on testing the efficacy of this approach across space and time.

2.3.1.c Prelimary findings on the adaptation of a semi-automated workflow

Ms. Lebrasse is a PhD candidate in Dr. Schaeffer's lab. She presented preliminary findings on the adaptation of the semi-automated workflow developed by colleague and workshop participant Megan Coffer to process Landsat 8 imagery. She used a combination of atmospheric correction via the dark object subtraction (DOS) method and a machine learning classification technique to construct a time series of seagrass areal coverage in St. Joseph Bay, FL from 2013 to 2019. The DOS atmospheric correction method for Landsat 8 imagery was found to be sufficient for seagrass detection by the CNN. Overall accuracy ranged between 90% and 94% for our classification approach, with the kappa coefficient ranging between 0.67 and 0.79, compared to aerial imagery. Her initial results suggested a dynamic change in seagrass area in St. Joseph Bay, with a statistically significant decline from 28 km^2 in 2013 to 20 km^2 in 2019. This study was further scaled up to a 30-year time series of seagrass area, leaf-area index (LAI) and belowground carbon in St. Joseph Bay using both Landsat 5 and Landsat 8 imagery. Subsequent analysis through a Mann-Kendall trend test revealed that seagrass area (mean=23±3 km^2), LAI (mean=1.9±0.3 m^2 m^{-2}) and belowground carbon (derived from LAI; mean=197±20 g C m^{-2}) were temporally stable over the 30-year period, with no significant trend. A manuscript describing this work was submitted to *Estuaries and Coasts*, and is currently under review.

2.3.1.d Innovative methods for mapping SAV on the Susquehanna Flats

Though not scheduled in advance, Morgan Jones, PhD candidate in remote sensing at University of Maryland, provided a summary of her work and research at this time. In addition to working on her PhD, Ms. Jones is the Manager of the Havre de Grace Environmental Center and Director of the Head of the Bay Alliance, a non-profit conglomerate of watershed organizations that provide environmental outreach and education, environmental monitoring, and conservation advocacy. As part of her management of the Environmental Center, she leads their participation in the CBP's SAV Watchers Program by coordinating volunteers to collect SAV data throughout the lower Susquehanna River and Susquehanna Flats. She has combined that activity with her academic research in an effort to assess SAV in the freshwater area of the lower Susquehanna River and the upper Chesapeake Bay using a combination of remote sensing, drone scans, and ground data. Jones's methods involve subtracting sediment from the water column to examine the spectral characteristics of each individual SAV species present; there are 16 different species of SAV in that region. They are a nonprofit organization partnering with universities, so rely on open source programing. They add drone scans to NIAP imagery and stack onto LANSAT 5 data and from there assign values (from SAV Watcher data) to pixels on fixated GPS points registered to those pixels. So far, results are encouraging and very low cost. No commercial data is used.

Jones's research is looking at SAV and remote sensing from the sedimentation aspect because that is a problem they are facing in that region of the Bay: TSS coming down the Susquehanna and over the Conowingo Dam threaten the SAV beds along the mouth of the river and throughout the Susquehanna Flats. Total suspended solids in 2019 exceeded the two-year allocation during a single abnormally wet season. They are trying to figure out where washout is occurring so they can target better put-in practices. Additionally, SAV watchers program relies heavily on citizen science and with the increase in drone technology, they are working on designing a web-based app to schedule flight plans for drones with prescreening that will gather and process data in real time. Issues or errors in the image could be rejected and re-photographed quickly.

Although the majority of the focus during this workshop evolved into determining how exactly to task, acquire, process, store, and publish CSI for SAV assessment through the NextView

License, the additional methods presented during this session are valuable alternatives to consider and advancements in technology and processing to keep track of in the event that data provided by NGA is ultimately not accessible.

2.3.2 Discussion Session

2.3.2.a Review of the Workshop to Date

Participant updates and research presentations were followed by an open discussion during which participants and steering committee members reviewed progress to date, discussed the day's presentations, and considered what our final recommendations will include. Major points are summarized here:

1. All satellite data have value. A variety of satellite sources were used in 2018. All sources should be kept on the table moving forward and used when necessary. These include NAIP, WorldView, GeoEye, LandSat and others.

2. Begin the tasking exercise in 2020. In 2020, attempt to task the entire Chesapeake Bay. This will allow an early estimation of failure – or how much of the Bay was unable to be mapped with satellite for reasons including scheduling conflicts, turbidity, clouds, glint, etc. (i.e., "Roughly 10% of the time re-imaging was necessary for X reason.") This information can also be used by Maxar to determine why their data wasn't usable. Intended use of imagery needs to be clearly defined so that they know in advance what conditions will and will not work.

3. Begin the calibration exercise in 2020. In a calibration study, determine bias by matching the aerial imagery to satellite imagery and evaluating the difference. It is recommended that two analysts assess areas where they have no previous knowledge, if possible. During the calibration study, it is important to consider that increased visualization of SAV beds from atmospheric and water column corrections might skew long-term trends. Is there more SAV or can analysts just see it better? Correction might not be appropriate if we want to maintain continuity. On the other hand, all monitoring programs evolve and improve as techniques are perfected. Accuracy should not necessarily be sacrificed for continuity. Five areas of the Bay were recommended for the calibration: Chester River, York River, Susquehanna Flats, Tangier Sound/Smith Island, South-eastern shore. These are recommended areas, not required.

4. Funding is required for the recommended tasking and calibration exercises. Although the basic steps for acquiring CSI through the NextView License were identified during the workshop for existing CSI, it's necessary to pinpoint the exact steps to tasking and acquisition. Accessing archived data and acquiring new data appear to be on two different levels of difficulty. VIMS analysts don't have the time to incorporate this extra work into their schedule, so it will require a funded follow-up exercise to work out the details. They will need to hire a technician to assist with other tasks so that Mr. Wilcox can spend at least some of his time on this effort. This was noted during the previous session and Carin Bisland, at the time of the third session, was working to allocate funds.

5. Helpful hints for tasking. Dr. Schaeffer, based on experience, suggested that when tasking Maxar/NGA, task for the immediate timeframe. Do not say that you need the data "this year" – it will fall out of the queue. They recommend ordering specific dates, requirements, in a specific time frame.

6. The workshop steering committee should reconvene in 2021. Following full-bay tasking and the calibration exercise, the steering committee should reconvene in 2021 (late spring/summer) to discuss the results and hone recommendations and next steps.

7. When tasking Maxar satellites, prioritize the areas difficult to acquire with aircraft (i.e., military installations). When considering the incorporation of CSI for the SAV monitoring program, it was suggested that VIMS begin incorporation by prioritizing CSI acquisition of tributaries near the watershed's military installations, such as Aberdeen Proving Grounds. Dr. Schaeffer's team has been able to access data from these areas, so it appears that access will not be an issue.

8. Publication issues. In the event that CBP/VIMS cannot get approval to publish the CSI imagery on the VIMS SAV monitoring program website, the steering committee needs to determine which regulatory agencies require the imagery to be published and what the repercussions are to not being able to publish (i.e., loss of funding from that agency).

9. Keep the conversation going. Once the report is complete, it is vital to have follow up conversation with NASA and other agencies interested in this work. It was acknowledged that this workshop report will not provide all the instructions for CSI acquisition because the work will have to take place after the completion of the workshop, and that additional research will be necessary.

10. AI development should continue on a parallel track. Work on AI/machine learning and algorithms should continue on a parallel track if funding is available. There should be continued development of atmospheric correction routines, algorithms for classification, classification schemes, and atmospheric correction in turbid coastal waters. Dr. Zimmerman also clarified that algorithms will give you aboveground SAV biomass (abundance and density) but core samples and biomass data are necessary for overall carbon sequestration calculations. Funding for this work should be pursued. If AI is incorporated into the SAV assessment, ground-truthing and verification data would be increasingly necessary. Data from the Chesapeake Bay SAV Watchers and SAV Sentinel Site Programs could serve this purpose, as well as the ground-survey data routinely collected by VIMS and their partners.

11. Bay-wide transects would improve SAV delineation methods. Regardless of the source, it is difficult to delineate the deep edge of SAV beds in the Chesapeake Bay from an image as well as areas where SAV cover is very low, e.g. following a dieback when plants are very sparse. There are several transects surveyed by VIMS each year in the lower bay, however transect work in the middle and upper Bay is more limited. The SAV Workgroup's SAV Sentinel Site Program will benefit this effort by surveying SAV transects throughout the entire Bay.

12. Consider patenting the workflow. The steering committee and participants discussed the possibility of patenting the workflow once developed. This would be a challenge but worth revisiting during the 2021 steering committee check-in. A patent would not make this team the owners of the workflow, but rather the inventors.

13. Data retention and management requires a password-protected FTP site for local files. The CSI data and images are large and get corrupted. UMCES uses Amazon Cloud for modeling, so that may be an option to consider. It was also suggested that the CBP (in addition to VIMS) should maintain copies of the data and imagery, so they should have an account to save files as well. It would also be an advantage to have historical imagery (from aerial surveys) in the same place. USGS could potentially provide a third copy for backup through EROS.

14. A hybrid design may be necessary. The workshop participants and steering committee recognized that a hybrid design in which the Bay's SAV is mapped using both aerial photography and CSI may always be necessary for the SAV monitoring program. This could create issues with potential flight contractors that may be unwilling to negotiate contracts for less than whole-bay acquisition. Ideally as technology continues to improve, cost will be reduced with both CSI and aerial photography.

15. There will be an upfront cost associated with this current effort to integrate CSI into the SAV monitoring program, but long-term gains will likely make the SAV monitoring program more stable and sustainable. The workshop took place to determine if we can replace some if not most of the aerial photography with CSI for the SAV monitoring program. It will cost more upfront but will eventually lead to cost savings and increase the sustainability of the program.

2.3.2.b Detailed Timeline Development

During this discussion, steering committee members and workshop participants fleshed out a flowchart and timeline of potential CSI incorporation. The timeline begins in 2018, when VIMS supplemented aerial photography with CSI and other available imagery to fill data gaps, and continues through 2032 as an estimated date of full transition. Transition, of course, is dependent on the results of the recommended tasking and calibration studies.

2018: Use(d) Satellite data to fill gaps in aerial imagery (VIMS)

- Used existing imagery – it was not tasked for the purpose of SAV acreage assessment
- Hand delineated; same methods as with aerial imagery
- Issues with satellite included glint, cloud cover, lack of peak biomass data, turbidity
- Future satellite fixes: request off nadir, adjust viewing angle, task specific days for tide
- Overall where data were good, CSI was a completely comparable product

2019-2020: Conduct STAC Workshop and Complete Workshop Report (CBP/STAC)

- In 2019 and 2020, the entire Bay was mapped with aerial imagery through flight contractor.

2020: Aerial acquisition with complimentary CSI tasking exercise to determine flexibility and calibration study (VIMS)

- Write Federal Agency scope of work/requirements
- Task for FULL BAY as back-up and mimic.*
- Conduct a calibration exercise to determine if imagery produces similar results using 2020 CSI and aerial imagery.*
- Determine steps to obtain approval for CSI retention and publication.
- Continue conversations with NGA/EPA/DOD
  ***This work was funded following this STAC workshop and VIMS has been working through the steps since spring 2020.**

2021: Reconvene steering committee in 2021

- Review progress and make final recommendations

2022-2032: If recommended, incorporate CSI into SAV monitoring program and continue working to perfect AI for eventual automated mapping. Incorporation may be best as a gradual shift from aerial imagery with CSI as back up to CSI with aerial imagery as back up, gradually reducing the budget necessary for aerial imagery acquisition.

- Map using CSI and, once available, incorporate use of AI
- Hand delineate SAV beds where necessary

2.3.3 Session 3 Wrap-up and Conclusions

Session 3, Day 2 was reserved primarily for Session 4 planning. At this point in the workshop it was clear that the steering committee had gone as far as they could in determining the feasibility of satellite data incorporation into the SAV monitoring program without moving forward with test tasking and imagery calibration exercises. As the VIMS team was already maxed out on their time and research commitments, these tasks were not something they could complete between sessions and prior to the end of the workshop, but rather required funding to bring in additional support. It also wasn't considered a productive use of everyone's time to gather in one spot (using travel funds and time) simply to work on writing the report. As such, it was decided that instead of holding a fourth session for the previously intended purpose, that time would instead serve as a report out to the Chesapeake Bay community. The steering committee has received much interest in this topic, so our intention was to gather for a one-day meeting at the Chesapeake Bay Program Office in Annapolis, MD, or equivalent meeting space, in April 2020 to present the workshop results and the steering committee's recommendations for moving forward. A forum such as this would have been ideal for answering questions about CSI capacity and receiving feedback.

Unfortunately, shortly after the third session, the global coronavirus pandemic reached the United States. Most of the workshop participants and steering committee began teleworking and all meetings were cancelled or moved to a virtual platform. Workshop co-chairs initially considered moving the fourth session to a virtual platform as well, but ultimately along with other steering committee members, decided that workshop results could instead be conveyed during a series of presentations to STAC, the Management Board, and other interested CBP goal teams and workgroups as soon as the report was complete and presentations could be scheduled.

3. MOVING FORWARD: CSI-based assessment integration

There was significant deliberation regarding the feasibility of incorporating CSI into the SAV monitoring program. In this portion of the report, we review concerns and potential solutions, provide summary information from the post-workshop progress made to date [in summer 2020, CBP was able to allocate funding for the tasking and calibration exercises recommended], and make recommendations in order to move forward at this time.

First, we address the concerns. Concern about CSI incorporation was based on several factors:

1. Satellite imagery resolution – is it comparable to currently used aerial photography?
2. Ease of tasking – will tasking WorldView be more labor intensive than tasking aerial acquisition?
3. Storage – will storage require increased space and security? Are there access limitations?
4. Processing – are there additional steps involved in turning satellite data into a product from which SAV can be mapped?

5. Publishability – can the satellite images be published on the VIMS website or are there licensing restrictions?

Several of these questions and concerns were answered or alleviated over the course of the three-session workshop, but not all.

3.1 Concerns and Solutions

1. Satellite imagery resolution – is it comparable to currently used aerial photography?

Much of the publicly available satellite imagery is too coarse to use for SAV assessments in Chesapeake Bay. This is because a large portion of the SAV acreage is made up of relatively small, fringing beds in narrow tributaries. With low-resolution imagery, these important resources are lost. Some satellite options, such as Sentinel and PlanetScope imagery, have medium range resolution and have been useful in delineating larger, continuous beds, but CSI with resolution finer than 1 m is better suited to capture the small, fringing SAV beds in tributaries throughout the Bay – provided water clarity is sufficient.

Although CSI is used on public platforms that purchase the imagery (e.g., Google Earth), use by the scientific community has been uncommon and use on the scale that we’re hoping to accomplish has been seemingly non-existent. Use of CSI may be particularly beneficial in the coastal environment, especially data from the WorldView constellations, as they capture a broader spectrum of color bands than RBG-based aerial photography, and radiometric calibration facilitates automated processing. During the workshop, it was suggested that this may be an advantage in mapping SAV in moderately turbid waters.

While CSI does not have as high resolution as the current aerial photography, the broader spectrum of color bands may make up for the slightly decreased resolution, making it comparable to aerial photography. Maxar’s WorldView 3 is the best option for incorporation currently and has sub 1m resolution. Maxar’s WorldView Legion constellation, which will be launched in 2021, promises to offer 29 cm resolution and may be an option under the NextView License if it is successfully deployed.

2. Ease of tasking – will tasking WorldView data through NGA/USGS be more labor intensive than tasking aerial acquisition?

Initially, tasking and ordering image captures may be labor intensive, especially for the volume of images required to cover the Chesapeake Bay and its tidal tributaries. For aerial photography, VIMS analysts begin planning flight lines months in advance based on predicted tide windows and peak SAV biomass. Because SAV in the Bay reaches peak biomass gradually from the southern portion of the Bay to the northern portion, essentially peaking in a wave up the Bay from May through August, VIMS analysts have divided the Bay into acquisition zones with bracketed time frames for survey. As each time frame is approached, weather and turbidity are closely monitored to ensure imagery is captured on days with the highest chance of success. If the weather isn't advantageous over the target area, VIMS works with the flight contractors up to shortly before the flight to reschedule or move to a secondary target. Similar advance planning will be necessary for CSI, but the task orders themselves will be more complicated than making a schedule and calling the flight contractor to determine whether to fly or not and last-minute changes will likely not be possible.

At the time of publication, a supplementary scope of work had been written and submitted for funding consideration to the VIMS grant manager at CBP. Funding was approved and funds had been allocated for the tasking and calibration exercises recommended in the previous section, and both exercises had been initiated. Full Bay tasking was attempted during the summer 2020 field season and VIMS analysts are currently working to review the usability of each image and to determine a failure rate for the imagery if possible. The calibration exercise will be performed once all imagery has been reviewed. A preliminary report for this work will be submitted along with the 2020 SAV survey results in early summer 2021. A draft of the steps necessary for CSI acquisition was written to include in this report, however, and documents the steps taken to obtain authorization from NGA, target acquisition of Chesapeake Bay areas, and access the resulting imagery. The steps are summarized here, but a more detailed account submitted by Mr. Wilcox is attached as Appendix H and includes additional details, sample correspondence, and text.

Summary of Steps Necessary to Obtain Authorization from NGA, Target Maxar Satellites, and Access Imagery (learned during post-workshop tasking exercise).

1. To obtain authorization from NGA, a USG employee must authorize all temporary users, contractors, or volunteers. Carin Bisland served this role and submitted the request for VIMS access as an EPA employee. David Wilcox at VIMS requested access using the G-EGD online application. Bisland then received an email request for confirmation. Following confirmation, Wilcox received DigitalGlobe (now Maxar) credentials from rdoghelp@digitalglobe.com and access to https://evwhs.digitalglobe.com/myDigitalGlobe/.

2. Targeting Maxar satellites is done through consultation with USGS staff and via the CIDR Tool (https://cidr.cr.usgs.gov/login). Detailed target regions for particular dates were created in consultation with Steven Hak at USGS and shared as KML files. Level 1B (radiometrically corrected) GeoTiff imagery with less than 50% cloud cover was requested.

For SAV coverage, tide stage is critical. The Maxar Worldview satellites seem to capture the Chesapeake Bay close to solar noon and cover a swath approximately 10 nautical miles in width. Therefore, a set of rectangular targets similar to the previously mentioned acquisition zones were created to cover SAV in the Bay. These areas were then targeted to coincide with low tide, developing a schedule for the first month of acquisition. Since the images were being acquired near solar noon, off-nadir imagery is important to avoid sun glint. Many factors control whether an area will be acquired. Commercial and emergency response targets are given higher priority. Cloud-free days are relatively rare. For example, there were approximately eight relatively cloud-free days in June. Targets and dates were configured for one month at a time. USGS would like at least one week notice of any requested changes in the schedule.

3. Imagery from the Maxar commercial archive or imagery ordered from Maxar is available using the https://evwhs.digitalglobe.com/myDigitalGlobe/ website with the above granted credentials OR through USGS and the EROS data center using the https://earthexplorer.usgs.gov/ website. To get access, complete the user registration at: https://ers.cr.usgs.gov/register/. See Appendix H and the email from Steven Hak at USGS for additional details. VIMS used Earth Explorer to download imagery used for the SAV project.

3. Storage – will storage require increased space and security? Are the access limitations?

VIMS currently houses all of the archived SAV aerial photography on an enterprise file server with an addition backup on external hard drives. The data and CSI received from Maxar will require security and increased storage (the CSI data and GeoTiff images are large). Data retention and management requires a password protected FTP site for local files. UMCES uses Amazon Cloud for modeling, so that may be an option to consider for this purpose. It was also suggested that the CBP (in addition to VIMS) should maintain copies of imagery, so they should have an account to save files as well, and it would be an advantage to have historical imagery (from aerial surveys) in the same place. USGS could provide a third copy for backup through EROS.

Once VIMS analysts have made more progress on test tasking and the calibration study, they will have a better idea of the storage capacity necessary.

4. Processing – are there additional steps involved in turning satellite data into a product from which SAV can be mapped?

Aerial photographs require orthorectification and mosaicking, but those are generally the only steps necessary prior to analysis. Depending on your analytical intentions, CSI may require additional processing. When VIMS analysts ordered CSI during the test tasking exercise, they requested Basic 1B* Imagery (https://www.maxar.com/products/optical-imagery), the least processed of the Core Imagery product series. From that they created a set of pan-sharpened images that were then orthorectified. They did not atmospherically correct the imagery because they did not intend it for automated processing methods. If AI automation is eventually incorporated, atmospheric correction would be necessary.

5. Publishability – can the satellite images be published on the VIMS website or are there licensing conflicts?

A significant portion of the workshop was spent discussing publication restrictions. It was initially thought that CSI received via the NextView License was restricted from any form of publication and that only the maps derived from the imagery could be published. For the purposes of SAV acreage assessment and goal progress tracking – technically CBP's only requirements – this is not an issue. Funding partners in Virginia, however, require the actual imagery itself for reviewing aquaculture permit applications and lease approval. Their goal is transparency; if a permit applicant is denied based on current and historical SAV cover, that applicant must be able to go onto the VIMS website and see the imagery itself, not just the derived SAV bed. For this reason, it was recognized early on that CSI may not be a feasible option for at least a portion of the Bay where aquaculture is common.
Research soon led to the information contained in Appendices E, F, and G: the NextView License Information Paper, NextView Sharing and Release, and the NGA Framework for Public Release. These documents indicate that CSI users can in fact publish the imagery if they receive prior approval and provided the images include markings that indicate DigitalGlobe (now Maxar) ownership or copyright. There are multiple levels of release and it appears as though License Uplift is the appropriate level for the needs of the SAV monitoring program. We do not know at this time, however, whether NGA will approve the hundreds of images needed to be published each year for this program or if the images are approved for permanent publication on the VIMS website. This will be determined as part of the tasking and calibration study VIMS is conducting in 2020 and 2021.

3.2 Recommendations

At this time, rather than whole-heartedly endorsing the incorporation of CSI into the SAV monitoring program, the steering committee is recommending that additional steps be taken to answer lingering questions that will determine whether incorporating or transitioning to CSI is realistic and feasible for SAV acreage assessment and the Chesapeake Bay SAV monitoring program.

Based on the 2018 SAV survey when it was necessary to fill data gaps with multiple sources of imagery, we know that CSI can be used for SAV assessment if it is available. VIMS analysts stated that there was no difference between aerial photography and CSI when using their standard hand-delineation techniques. Extensive searches of the archived data, however, indicated that it would be impossible to map SAV throughout the Bay without a coordinated targeting and tasking operation. Issues such as glint, cloud cover, timing (not taken during peak biomass), and turbidity rendered many of the archived images inadequate for mapping SAV. Fortunately, many of those issues may be alleviated with targeted acquisition. When ordering imagery, you can request off-nadir capture, adjust the view angle, and task specific days to accommodate the tide and biomass.

To determine the exact steps and contacts necessary to begin tasking and data acquisition, the steering committee recommends that VIMS analysts conduct two primary exercises: test tasking of the whole Bay and a calibration/match-up exercise. It was the steering committee's original intent that much of this information would be determined or obtained during and between sessions, but once the complexity of the tasking became clear, we realized that it would require additional, funded time and effort beyond the capacity of this workshop. Fortunately, funding has already been allocated and the work has been initiated by VIMS analysts.

The recommended whole-Bay ***tasking exercise*** began in spring 2020 and continued throughout the summer SAV growing season. Tasking for the whole Bay at this time is important for several reasons: 1. It will establish acquisition zones based on tides and peak biomass. 2. It will provide an estimation of the time needed for assembling task orders. 3. It will promote familiarity with the steps involved. 4. It will allow calculation of a failure rate – the percentage of the Bay that was not able to be captured with CSI for various reasons. 5. It will facilitate the opportunity to conduct the calibration exercise because 2020 SAV data was also obtained via aerial photography.

The recommended ***calibration study*** will take place during winter 2020/2021 using CSI from the tasking exercise and the aerial photography from the 2020 aerial survey. Up to six test sites for comparison will be selected from the satellite imagery that was acquired under sufficiently comparable conditions. SAV beds from each site will be interpreted and hand delineated from the satellite imagery by one VIMS analyst and from the aerial imagery by another VIMS analyst. After mapping the SAV from one imagery source, the analyst will save the results for comparison and review the other imagery source, noting where changes would be made based on the additional information. This calibration exercise will allow analysts to determine if tasking with specific requirements (i.e. during low tide, peak biomass, off nadir, etc.) - rather than relying on imagery that had already been incidentally captured for other reasons - improves the quality of the CSI and produces a closer match to the aerial photography.

The steering committee recommended the Chester River, the York River, the Susquehanna Flats, Tangier Sound/Smith Island, and a tributary along the southern Eastern Shore for the calibration exercise, but recognizes that it will depend on what CSI acquired during the 2020 test tasking are adequate for SAV assessment. We know, again based on the 2018 SAV survey, that the two sources do provide comparable imagery that can be mapped with the same techniques, but the subtle differences are important to note in a formalized study. If a transition to CSI does occur, all potential differences in photo interpretation must be accounted for. This calibration exercise will allow analysts to determine if tasking with specific requirements (e.g., off nadir) improves the quality of the CSI and produces a closer match to the aerial photography.

The steering committee recommended that this work begin as soon as funding could be allocated through the CBP grants office, and fortunately that occurred in time for the summer 2020 SAV growing season. Working under that time frame and depending on the duration of the calibration study, the steering committee then recommends that the committee and principle participants reconvene in 2021 to assess progress and, based on that progress, make more definitive recommendations for the long-term evolution of the SAV monitoring program. After completing the recommended exercises, if it is discovered that any barriers that currently exist can be alleviated or at least accommodated, the steering committee and workshop co-chairs will recommend incorporating CSI into the monitoring program first as a hybrid effort and eventually to a full Bay effort, with aerial photography reserved as back-up. Incorporation may be best as a gradual shift from aerial imagery with CSI as back up to CSI with aerial imagery as back up, gradually reducing the budget necessary for aerial imagery acquisition.

Although the topic was discussed at length during the first session, AI/algorithm development and consensus was set aside as an objective that could not be realized during this workshop. While algorithms that have been developed for specific areas of the Chesapeake Bay work well when used in the same area during different times, those same algorithms do not work well on different areas or regions of the Bay. The Chesapeake Bay is a very complex ecosystem with four salinity regimes, as many SAV community types, and a diverse physical environment, so a great deal more field data will be necessary to train algorithms for the unique environments all over the Bay. One avenue for collecting this data would be to employ the SAV Sentinel Site Program. The SAV Workgroup developed an SAV Sentinel Site Program for Chesapeake Bay that will collect long-term SAV, habitat, and physical data at twenty locations throughout the Bay – five sites in each salinity regime. The SAV Sentinel Site Program was developed to require very little funding, so taking physical samples – core samples – may require additional funding for collection and processing. It also may be necessary for additional sites to be established, if the 20 Bay-wide sites are not adequate. There is a possibility that some data needs could also be met through the Chesapeake Bay SAV Watchers Program – the CBP's volunteer SAV monitoring program. The data collected by SAV Watchers are more superficial than that planned at SAV Sentinel Sites, but it should be considered regardless.

As such, the steering committee recommends that progress towards AI/machine learning/algorithm development for Chesapeake Bay SAV assessment continues while other details regarding the feasibility of satellite image integration are being worked out. As noted, funding is required for both data collection and algorithm development. One potential source of internal funding is the Goal Implementation Team Project Initiative, but these funds are limited, competitive, and would not be available for over a year. Consequently, it is recommended that the steering committee continue exploring external sources of funding to assure this important work continues.

When the steering committee reconvenes in 2021 to review the progress made and lessons learned during the tasking and calibration exercises, VIMS's report and an addendum with more detailed instructions and final recommendations will be submitted to STAC to attach to this report. The steering committee and workshop participants recognize the incredible value and potential that no-cost CSI could have for the Chesapeake Bay Program and our partners. Aside from SAV assessment, learning exactly how to order and access high resolution satellite data from the most technologically advanced satellite constellations that exists will be a boon to all of the CBPs resource assessment programs.

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APPENDIX A:

Workshop Participant List with Association and Contact Information

Workshop Participants

Name	Email	Affiliation
Brooke Landry	brooke.landry@maryland.gov	DNR/CBP
Peter Tango	ptango@chesapeakebay.net	USGS/CBP
Anna Kenne	kenne@vims.edu	VIMS
Blake Shaeffer	Schaeffer.blake@epa.gov	EPA
Carin Bisland	bisland.carin@epa.gov	EPA/CBP
Cindy Lebrasse	Lebrasse.Marie@epa.gov	EPA/NCSU
Dave Wilcox	dwilcox@vims.edu	VIMS
Dick Zimmerman	RZimmerm@ODU.EDU	ODU
Erica Smith	ericssmi@vims.edu	VIMS
Jenny Whiting	jenny@vims.edu	VIMS
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JJ Orth	jjorth@vims.edu	VIMS
Kevin DuBois	kevin.dubois@navy.mil	DOD
Lien Pham	phamlien24@gmail.com	VIMS
Megan Coffer	coffer.megan@epa.gov	EPA/NCSU
Morgan Jones	mjones.hdgmm@gmail.com	HdGMMEC
Peter Whitman	whitman.peter@epa.gov	EPA/NCSU
Stephanie Uz	stephanie.uz@nasa.gov	NASA
Todd Beser	Todd.Beser@US.ARMY.MIL	DOD
Victoria Hill	VHill@odu.edu	ODU

APPENDIX B:

Workshop Session Agendas

Chesapeake Bay Program's
Scientific and Technical Advisory Committee

Exploring Satellite Image Integration for the Chesapeake Bay SAV Monitoring Program
-A STAC Workshop-

Background: This is a STAC workshop with invited technical and management personnel convened to review and determine the science and technology essential to integrate satellite image assessment into the Chesapeake Bay SAV Monitoring Program. During the workshop, we will define the feasibility of the integration (related to the science), and document costs, benefits, and any potential disadvantages of the integration (logistical, financial, scientific). With that, we will then determine the steps, information necessary, and timeline in which to officially integrate satellite data and imagery into the SAV monitoring program.

This workshop will include three separate two-day sessions that will take place every other month between October, 2019 and February, 2020 and culminate in a final two- to three-day synthesis effort that will take place in April, 2020 (four sessions total). The proposed schedule is below. Timing is, of course, flexible. We anticipate no more than fifteen participants at each of the first three sessions and up to twenty-five at the final session.

Session 1: Oct 2019 – Initial meeting of the minds. Review proposal for a common understanding of workshop objectives. Review of the state of the programming and science for assessing Chesapeake Bay SAV. Develop game plan details for the remaining sessions that will inform our objectives and support development of the workshop report product.

Session 2: Dec 2019 – Review of remote sensing approaches and assessment methods successfully used elsewhere to measure and report on SAV. Bring in outside experts. Include review of satellite alternatives (e.g., drone-, kite-, balloon-based sensor applications) to consider their potential role for inclusion in hybrid assessment design.

Session 3: Feb 2020 – Review approach and comparisons of recent SAV survey results (between satellite-based and plane-based assessments). Establish calibration needs, method needs, limits in space and time on satellite based assessments as well as value-added benefits of repeated image availability throughout the year to inform SAV condition and trend assessments.

Session 4: Apr 2020 – Final Meeting. Develop final product and review materials. Develop an integrated strategy for the overall program, including defining data acquisition responsibilities and pathways, data storage responsibilities, MOU development if necessary, initial data processing approach and targeted data processing modifications, historical data calibration with changes to satellite based imagery, add-on assessment applications (e.g. drone sensed SAV in sub-estuaries/small waterways/previously unassessed refuge areas, and data synthesis/communication.)

Each meeting will follow the two "half-days" format, commencing at approximately 11:00 am the first day and adjourning at approximately 3:00 pm the following.

STAC SAV/Satellite Workshop
Session 1 Agenda

Where: VIMS
Owens-Bryant Board Room, Davis Hall
7539 State Rte 1203
Gloucester Point, VA 23062

When: October 15th -16th, 2019

Recommended Lodging:
Duke of York Hotel

Day 1, Oct 15th, 2019

11:00 am – Welcome and Introductions

11:15am - Review our session agenda, proposed workshop objectives, expected outputs from this session and product development from the overall workshop. (Brooke Landry, Peter Tango)

11:30 am – **Chesapeake Bay Program Annual SAV Survey: How it works. (Bob Orth and Dave Wilcox)** This presentation will provide some of the survey's background, evolution, and an in-depth description of the logistics of the program, including data acquisition, processing, interpretation and mapping, costs, grant management, flight sub-contractors, etc.

1:00 pm – Lunch, provided

1:45 pm – Tour of the VIMS SAV computer lab space and demonstration of data interpretation.

2:30 pm – Break, coffee provided

3:00 pm – **Using satellite imagery for mapping SAV habitats in Chesapeake Bay (Dick Zimmerman)** This presentation will review the process used at ODU to map SAV habitats in Chesapeake Bay, including satellite image acquisition, processing, interpretation and mapping, AI/machine learning, etc.

4:00 pm – **Discussion 1:** Why satellites, why not before and why now? Given publicly available products such as Google Earth maps, why haven't we already jumped on this bandwagon? Discuss data gaps, technical and logistical barriers, etc.

5:00 pm – Adjourn. Group dinner.

Day 2, October 16th, 2019

9:00 am – Regroup. Coffee provided.

9:15 am – Recap of Day 1

9:30 am - **Discussion 2:** Based on the information presented on Day 1, what can we do today to use satellite image assessment for estimating annual coverage of bay grasses? Is image availability the primary limitation now that resolution is comparable among plane and satellite based images?
10:30 am – Break, coffee provided

11:00 am – **Discussion 3:** Planning. Revisit objectives: recommend revisions based on discussions to help focus the remaining sessions and product development. This time will be dedicated to mapping out the rest of the workshop and determining who should be included in each session. We will set an agenda for each of the remaining sessions, draft their content and outputs, determine potential dates and locations for each session, develop an invite list for each session, and draft an outline for the final report product.

12:30 pm – Lunch, provided

1:30 pm – **Final thoughts.** During this time we'll make sure all topics have been covered and any additional thoughts or concerns are addressed prior to departure.

2:00/2:30 pm - Adjourn

STAC SAV/Satellite Workshop
Session 2 Agenda

Where: VIMS
Owens-Bryant Board Room, Davis Hall
7539 State Rte 1203
Gloucester Point, VA 23062

When: December 17th -18th, 2019

Recommended Lodging:
Duke of York Hotel

Day 1 (12.17.19)

11:00 am – Welcome and Introductions

11:20am – **Review of SAV Monitoring Program and Workshop Objectives (Brooke Landry, Peter Tango)**

11:45 am – **Review of information and challenges identified in Session 1 (Brooke Landry, Peter Tango)**

12:15 pm – Lunch, provided

1:00 pm – **Discussion 1: Assessing Feasibility, Part 1_Tasking and Logistical Issues**
During this discussion, we'll tackle satellite tasking and logistical issues associated with using satellite data for the Chesapeake Bay SAV Monitoring Program. Topics will cover working with Maxar and NGA and will include perspectives and guidance from Blake Schaeffer and his team on satellite data acquisition, processing, and publication.

2:30 pm – Break, coffee provided

3:00 pm – **Discussion 2: Assessing Feasibility, Part 2_Scientific and Technical Issues**
During this discussion, we'll delve further into artificial intelligence, machine learning, algorithm development for image interpretation to extract SAV cover, data storage, and image processing capacity.

4:30 pm – **Exercise 1: Determine specific questions for Maxar.** During this brief session we'll identify exactly what questions remain for Maxar and NGA that would facilitate data acquisition and use of satellite imagery for assessing, monitoring and reporting on SAV distribution and abundance for the tidal waters of Chesapeake Bay and its tributaries.

5:15 pm – Adjourn. Regather for group dinner at the Yorktown Pub at ~6:00 pm.

Day 2 (12.18.19)

9:00 am – Regroup. Coffee provided.

9:15 am – **Recap of Day 1 (Brooke Landry, Peter Tango)**

9:30 am – **This time is reserved for conversations with Maxar**

10:30 am – Break, coffee provided

11:00 am – **Discussion 3: Additional Challenges and Opportunities_Working with the DoD**
During this discussion, we'll determine what opportunities are available for collaboration or coordinating with the Department of Defense and CB Watershed military installations to address existing limitations to baywide coverage in monitoring and assessing SAV.

12:00 pm – Lunch, provided

1:00 pm **– Discussion 4. Determining specific requirements for a comparison and calibration study.**
Assuming we move forward with satellite data integration into the CB SAV Monitoring program, a comparison and calibration study will be required by the CBP. During this discussion, we'll determine in detail what this study will look like and require.

2:00 pm – **Discussion 5. Final Thoughts.**
During this time we'll make sure all topics have been covered and addressed prior to departure. We will also set an agenda for the two remaining sessions, draft their content and outputs, determine potential dates and locations for each session, and develop an invite list for each session.

3:00 pm – Adjourn

STAC SAV/Satellite Workshop
Session 3 Agenda

Where: VIMS
Owens-Bryant Board Room, Davis Hall
7539 State Rte 1203
Gloucester Point, VA 23062

When: February 25th-26th, 2020

Recommended Lodging:
Duke of York Hotel

Day 1 (2.25.20)

11:00 am – Welcome and Introductions

11:20am – Review of information, timeline, and challenges identified in Session 2 (Brooke Landry, Peter Tango)

12:00 pm – Lunch, provided

1:00 pm – Progress update presentations and discussion
- Blake Schaeffer: Report out of recent conversation with NASA HQ
- Cindy Lebrasse: Landsat 8 and RapidEye imagery processing progress from Florida and South Bay
- Megan Coffer: Worldview v. aerial imagery comparison
- Dave Wilcox: update on test tasking exercise

3:00 pm – Break, coffee provided

3:30 pm – Discuss and determine recommendations for satellite incorporation based on lessons learned.

4:30 pm - Report and manuscript planning and drafting assignments

5:00 pm – Adjourn. Regather for group dinner at the Yorktown Pub at ~6:00 pm.

Day 2 (2.26.20)

9:00 am – Regroup. Coffee provided.

9:15 am – Recap of Day 1 (Brooke Landry, Peter Tango)

9:30 am – Breakout Session 1 for Group Writing Assignments

10:30 am – Break, coffee provided

11:00 am – Breakout Session 2 for Group Writing Assignments

12:00 pm – Lunch, provided

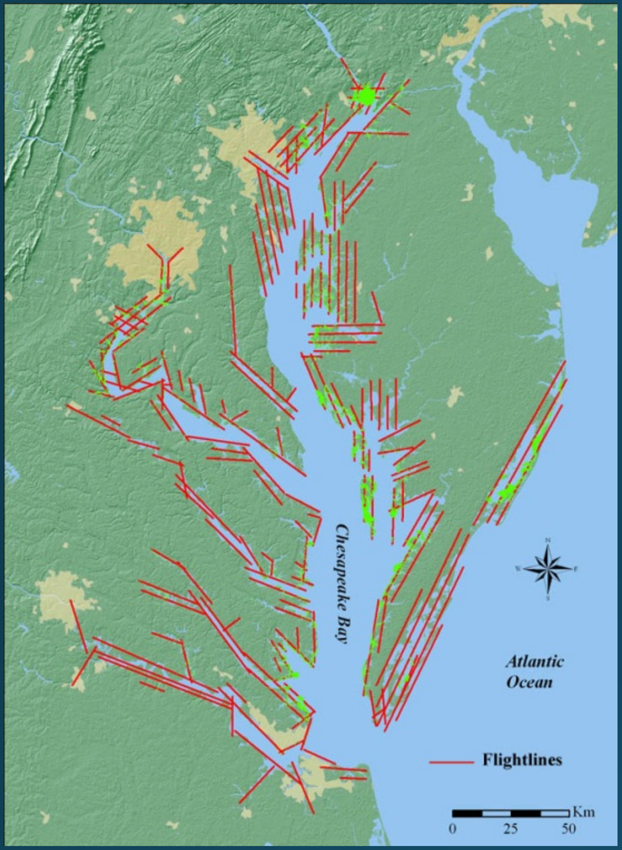
1:00 pm – Session 4 objectives and planning.

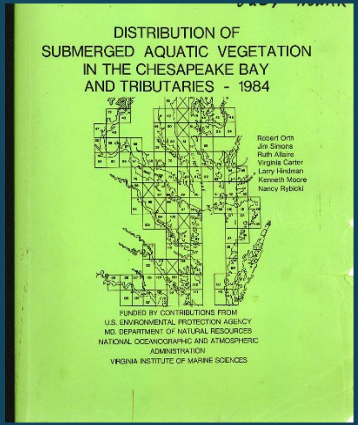
2:30 pm – Adjourn

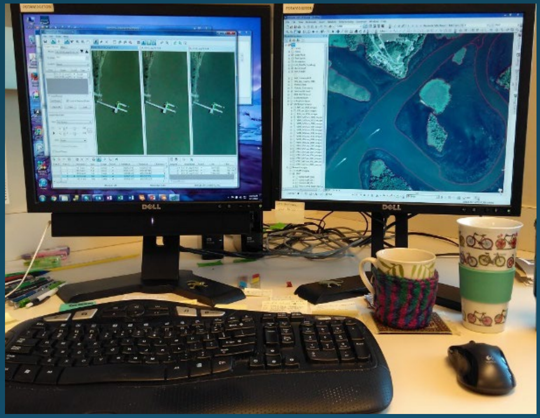
APPENDIX C:

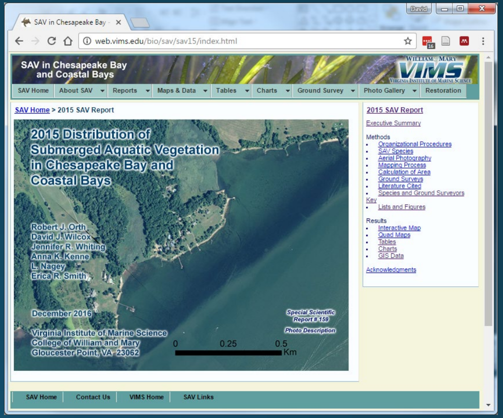
The Chesapeake Bay Annual SAV Monitoring Program: Its Evolution – 1974 to 2019

Presented by Dr. Robert Orth and Mr. David Wilcox









The Chesapeake Bay Annual SAV Monitoring Program: Its Evolution – 1974 to 2019

Bob Orth, Dave Wilcox

VIMS | William & Mary
Virginia Institute of Marine Science

Outline of Talk

- Significant Milestones
- Current SAV Survey Process
- Major Changes in the Process
- The Budget (Grants Supporting the Survey)
- Factors Influencing Costs Over Time
- Significance
- Conclusions

Significant Milestones

1974	First aerial survey of western shore Virginia tribs by VIMS
1978	First baywide survey of SAV. 2 groups: VIMS for VA; Aeroeco & American Univ. for MD. 2 separate reports
1979-1982	Various local surveys, primarily VA waters
1984-1986	Baywide survey of SAV: 2 groups- VIMS for VA, EPA-EPIC for MD; 1 report coordinated by VIMS
1987-2016	Baywide survey of SAV now coordinated by VIMS*
2006	SAIC external review of SAV Program
2008	Comparison of Black and White vs Color Film

* No survey in 1988; same aerial contractor 1989-2016.

Current SAV Survey Process

Pre-Planning – VIMS coordinates with Air Photographics on timing, flightlines, and all elements of acquisition .

Acquisition – Air Photographics acquires imagery under correct conditions (monitored 24/7), and sends VIMS a digital copy. VIMS reviews imagery to ensure SAV is clearly captured. If not the area must be re-flown.

Orthorectification and mosaicking – All images with SAV are orthorectified and mosaicked by VIMS.

Photo-interpretation –SAV beds are delineated manually from the imagery into four density classes by experienced VIMS analysts.

Field Surveys – Volunteers and science groups collect field species data and submit their results to VIMS.

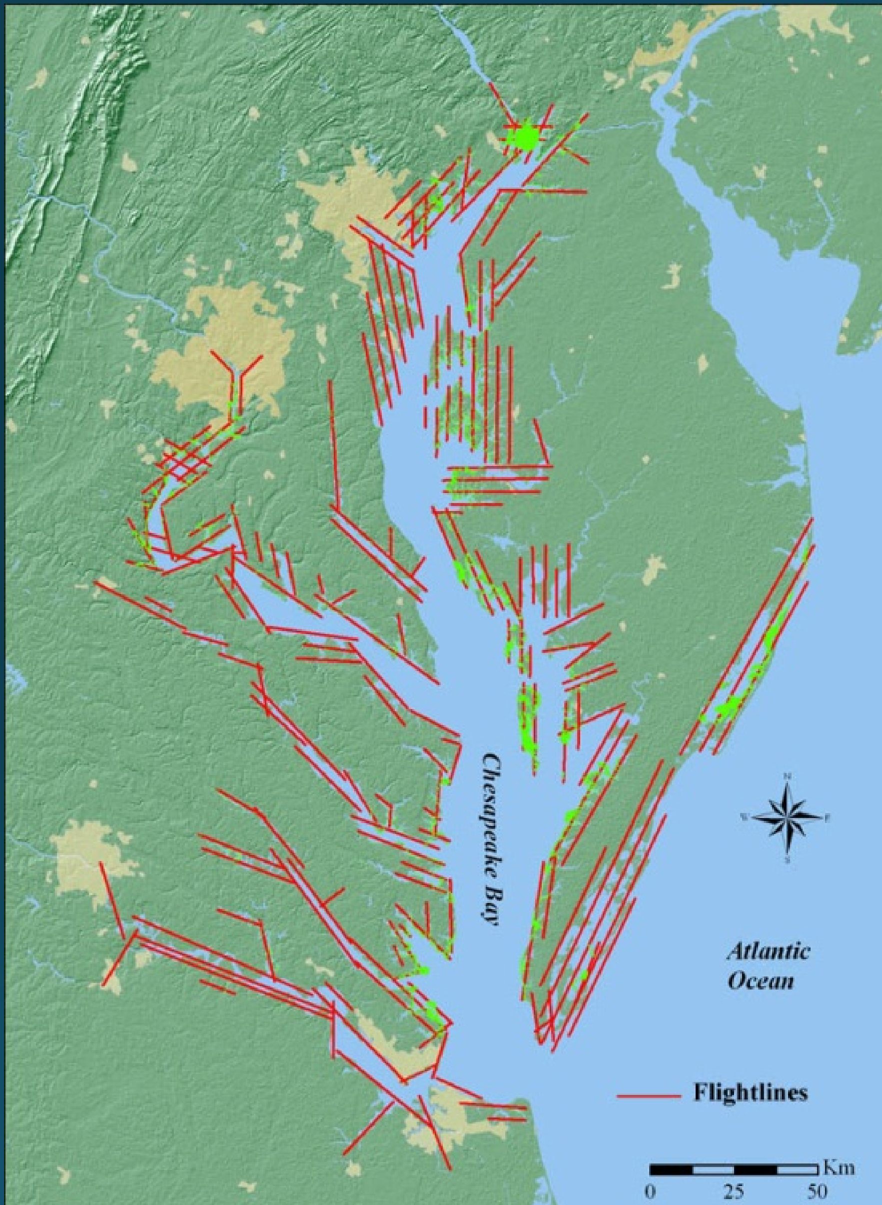
Data Submission and Press Release – SAV Survey data is analyzed by VIMS and released in coordination with EPA to spread the word.

Final Report – A final web-based report is produced, including all SAV aerial and field species data submitted to VIMS

Annual Survey Tasks by Month

TASK	2017									2018										
2017 SAV Survey	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Pre-Planning	x	x																		
Acquisition		x	x	x	x	x	x	x												
Orthorectification and Mosaicking			x	x	x	x	x	x	x	x										
Photo-Interpretation			x	x	x	x	x	x	x	x	x	x								
Field Surveys		x	x	x	x	x														
Data Submission and Press Release												x	x							
Final Report																	x	x	x	x

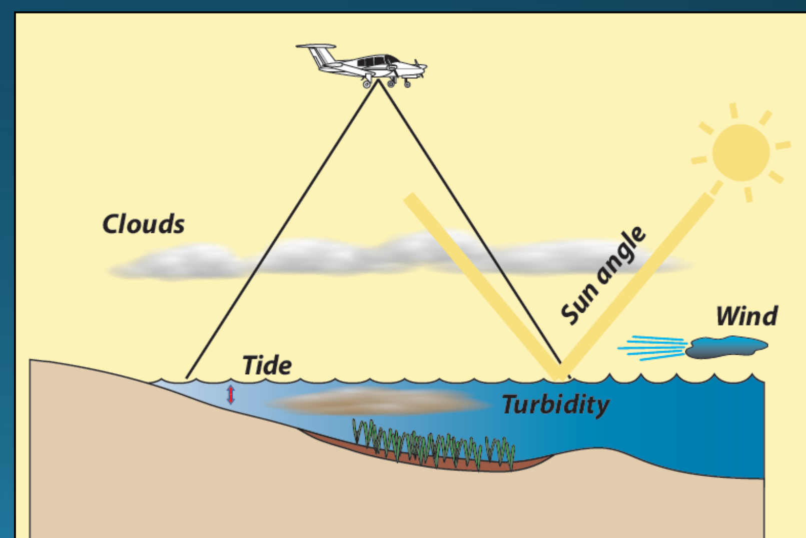
Acquisition of Aerial Imagery



Aerial multispectral digital imagery is acquired from flight lines flown over the entire bay

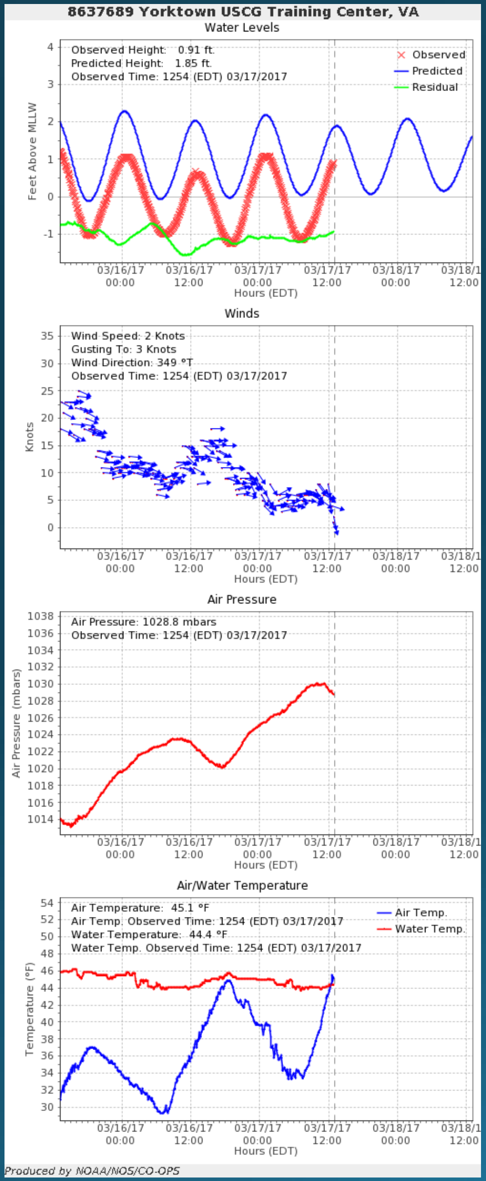
Flights require low wind, minimal cloud cover, low tide,
low turbidity, low sun angle.

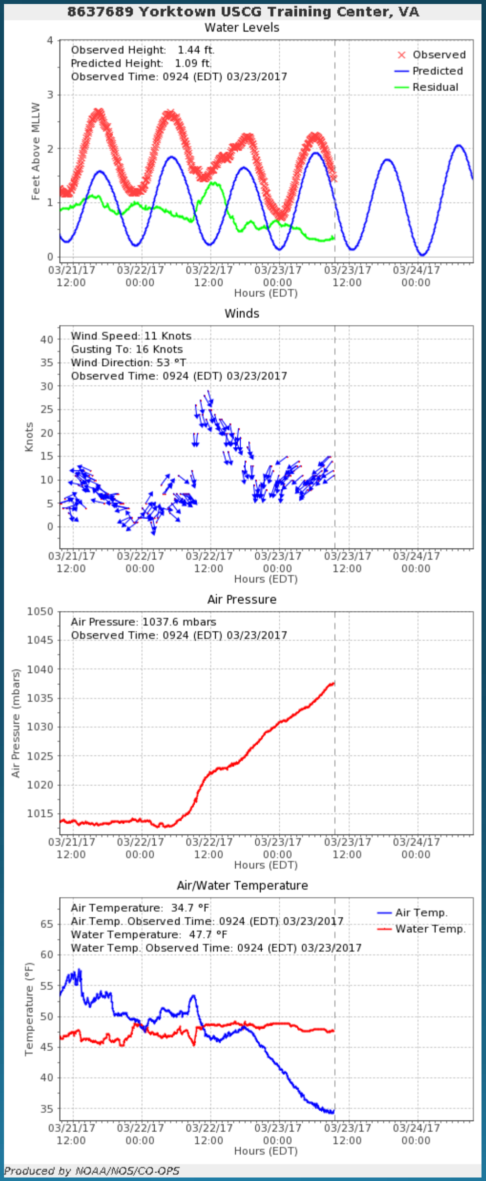
VIMS and Air Photographics staff monitor these conditions 24/7



Wind and Tide = monitored daily for changes

NOAA Tides Online (https://tidesonline.nos.noaa.gov/geographic.html)





Other Acquisition Bottlenecks

Washington, DC

- Prior TSA approval (30 days in advance)
- Armed Police Officer in plane on day of flight

Aberdeen Proving Ground

- Prior approval (shooting live ammo on weekdays)
- APG personnel in plane on day of flight
- APG personnel preprocesses and censors all APG imagery

Patuxent Air Base

- Approval day before flight (Pax now doing drone work)

Dahlgren Navel Support Facility

- Approval day of flight (shooting live ammo)

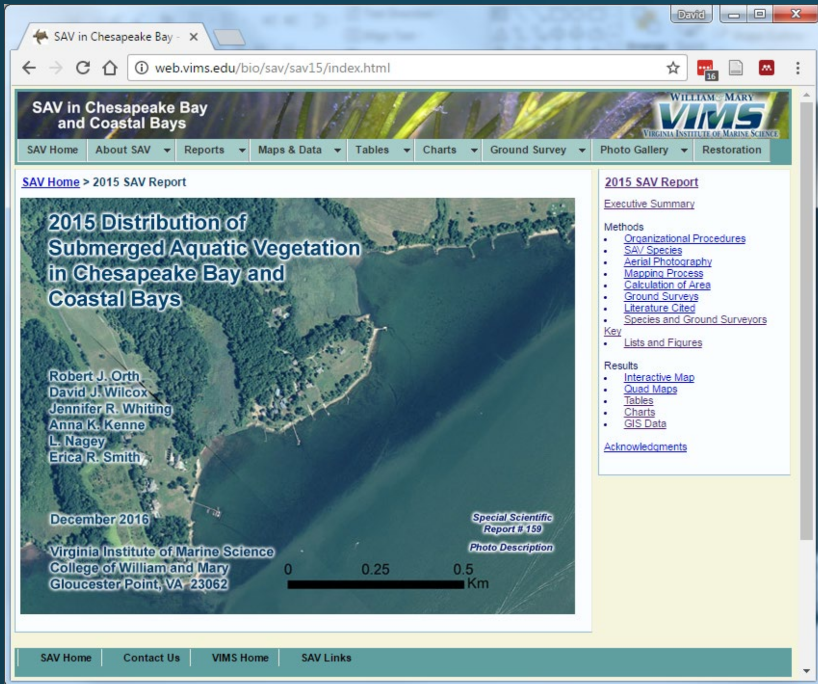
Major Changes in The Process

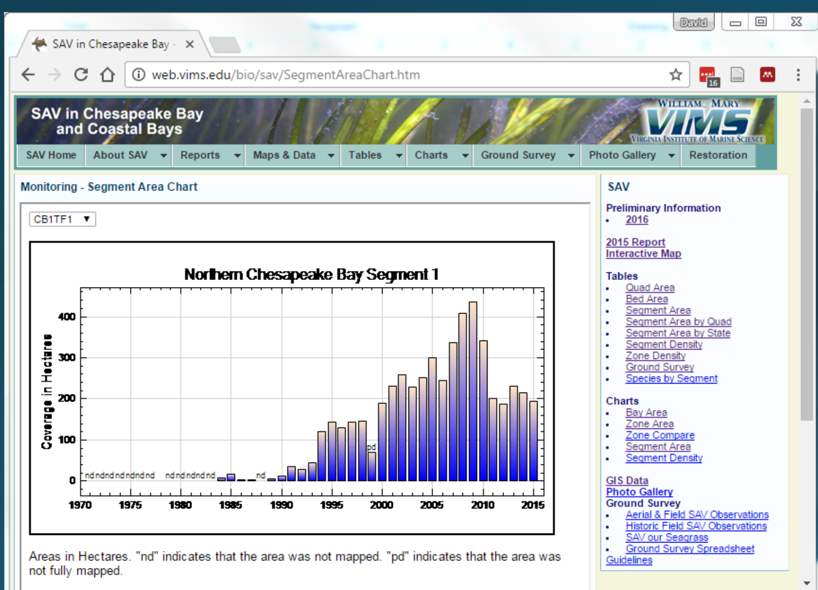
- The Web Revolution

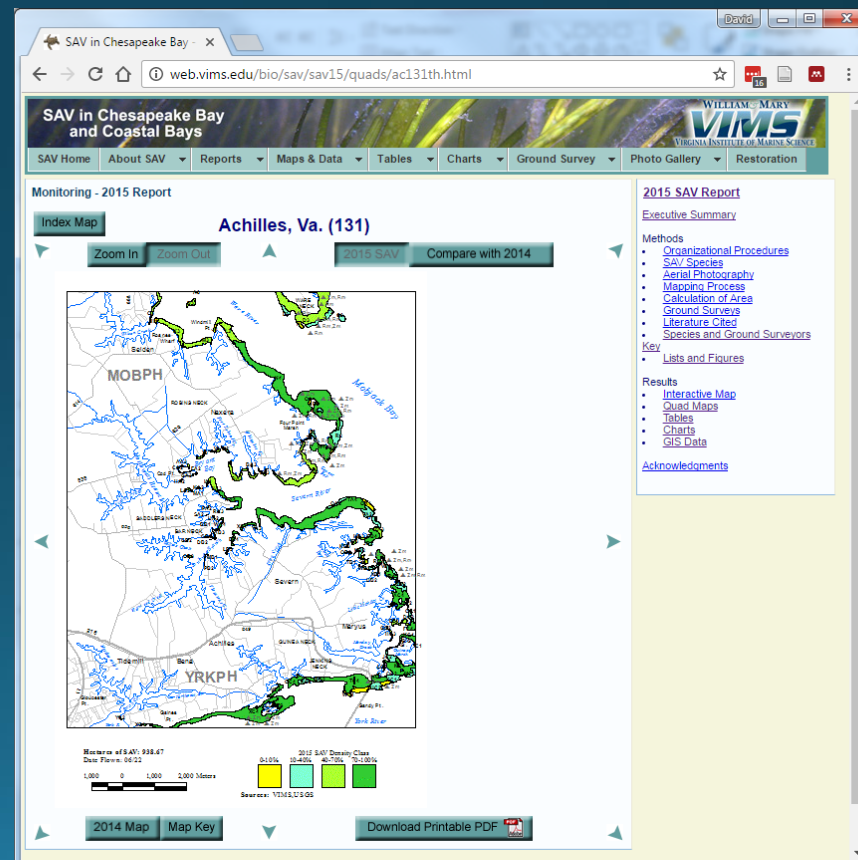
  Printed version of report to web-based report

The Old Days – Printed Reports – through 1998

Web Based reports 1999- present







Major Changes in The Process

- The Web Revolution
  - Printed version of report to web-based report
- The GIS revolution
  - Heads down (Manual) to on-screen Photo-interpretation
  - Add GPS/IMU to acquisition of imagery

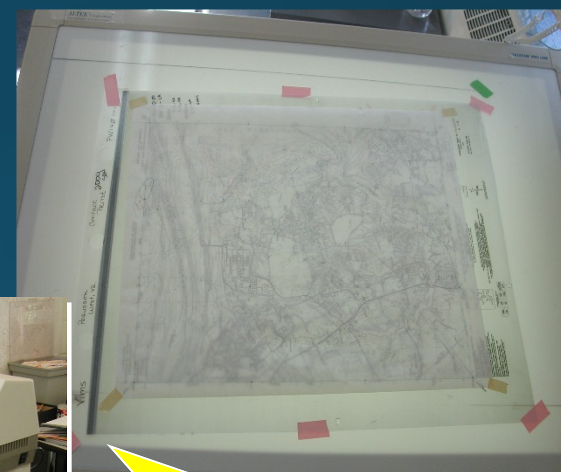
Old SAV Mapping Method

SAV Delineation

Mylar Overlay

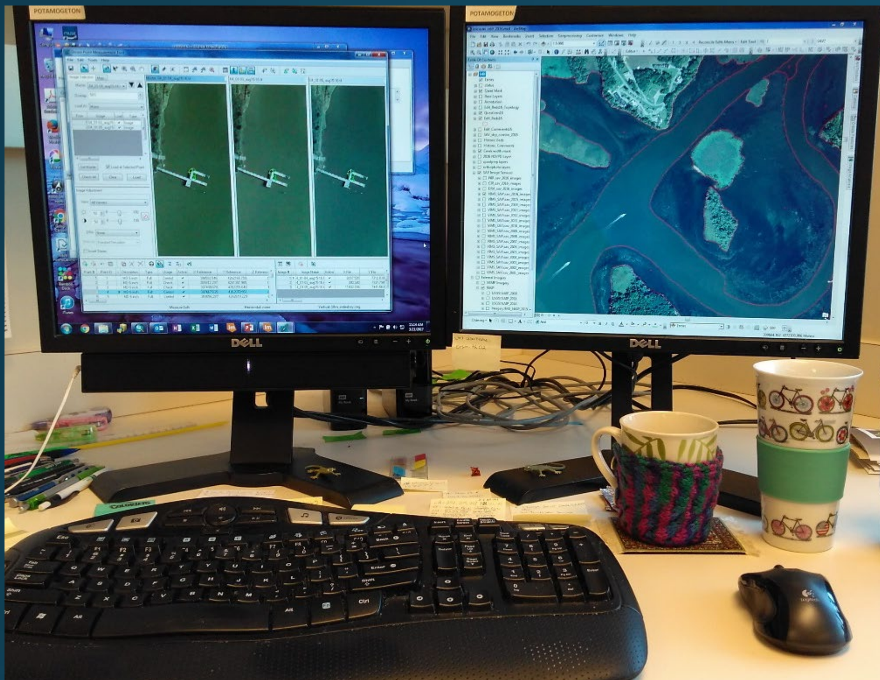
Old SAV Mapping Method

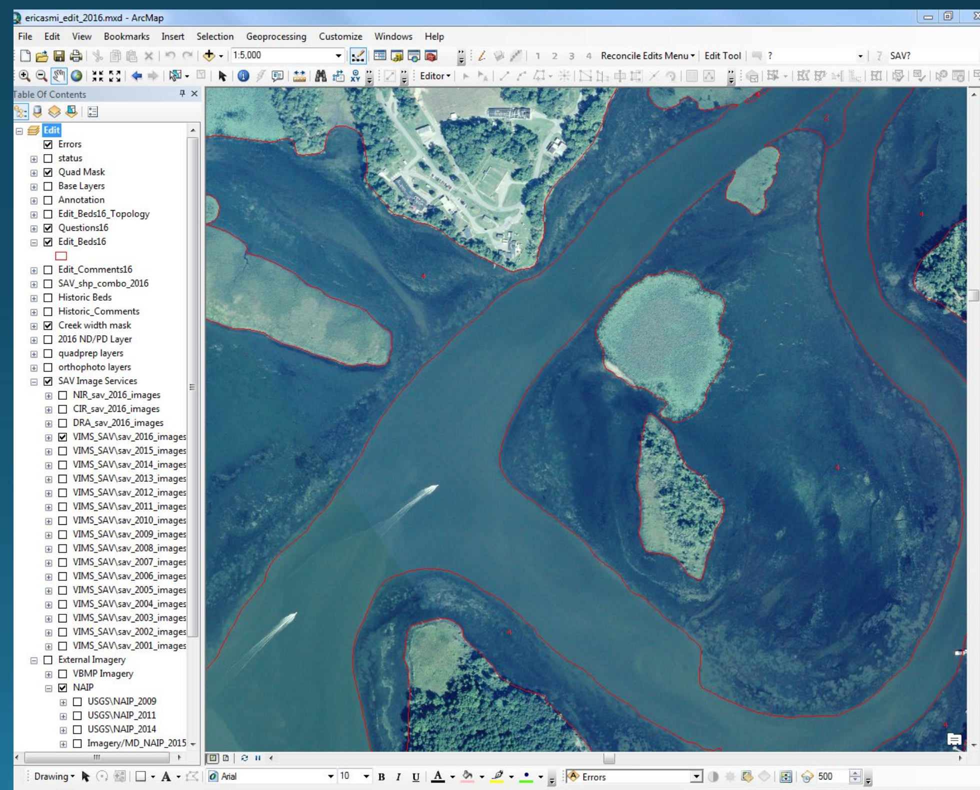
Digitize Beds



Plot and Proof

New SAV Mapping Method
Orthorectification, Mosaicking, Photo-interpretation

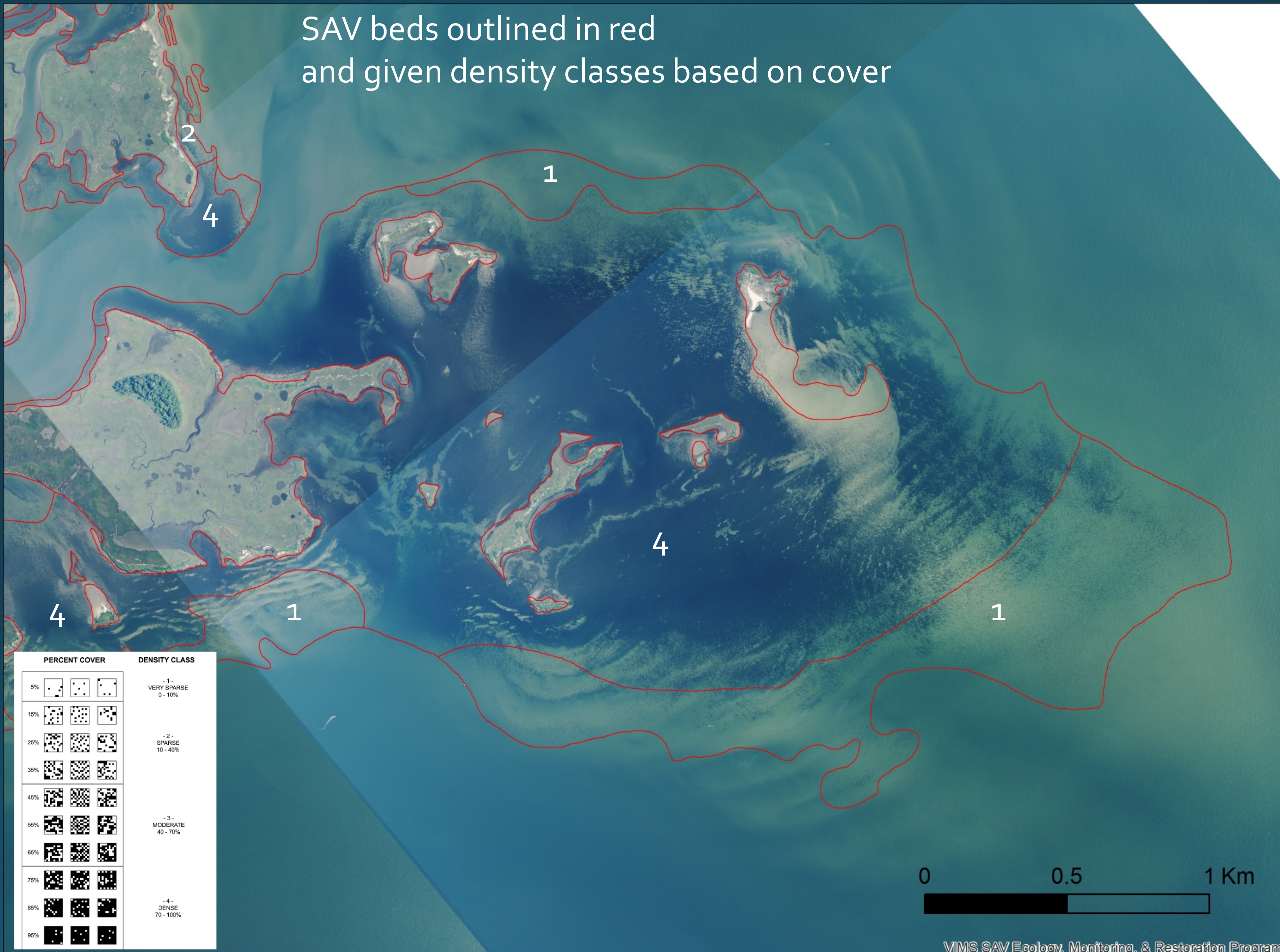




Requires knowledgeable and very dedicated staff

Photo Interpretation Guidelines

- Map only what you see
- Mapping scale is 1:2,500
- Minimum mapping unit is 0.1 hectare
  - SAV beds
  - Islands, bare areas, aquaculture, etc
- Use stream mode to create a smooth outer bed edge
  - Split into density classes
  - Be 'lumpers' instead of 'splitters’
- Compare with historic (composite) bed extent, historic imagery, and field data
- Document exceptions using comments


SAV beds outlined in red
and given density classes based on cover
2
4
1
4
4
1
1
PERCENT COVER
DENSITY CLASS
5%
15%
25%
35%
45%
55%
65%
75%
85%
95%
- 1 - VERY SPARSE 0 - 10%
- 2 - SPARSE 10 - 40%
- 3 - MODERATE 40 - 70%
- 4 - DENSE 70 - 100%
0
0.5
1 Km
VIMS SAV Ecology, Monitoring, & Restoration Program

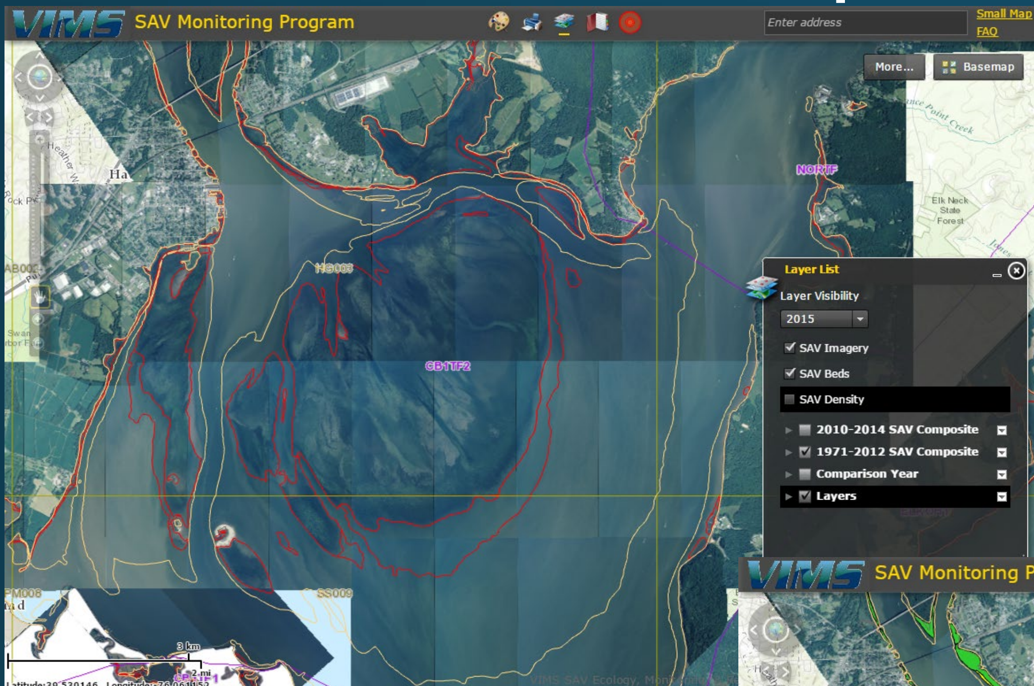
Major Changes in The Process

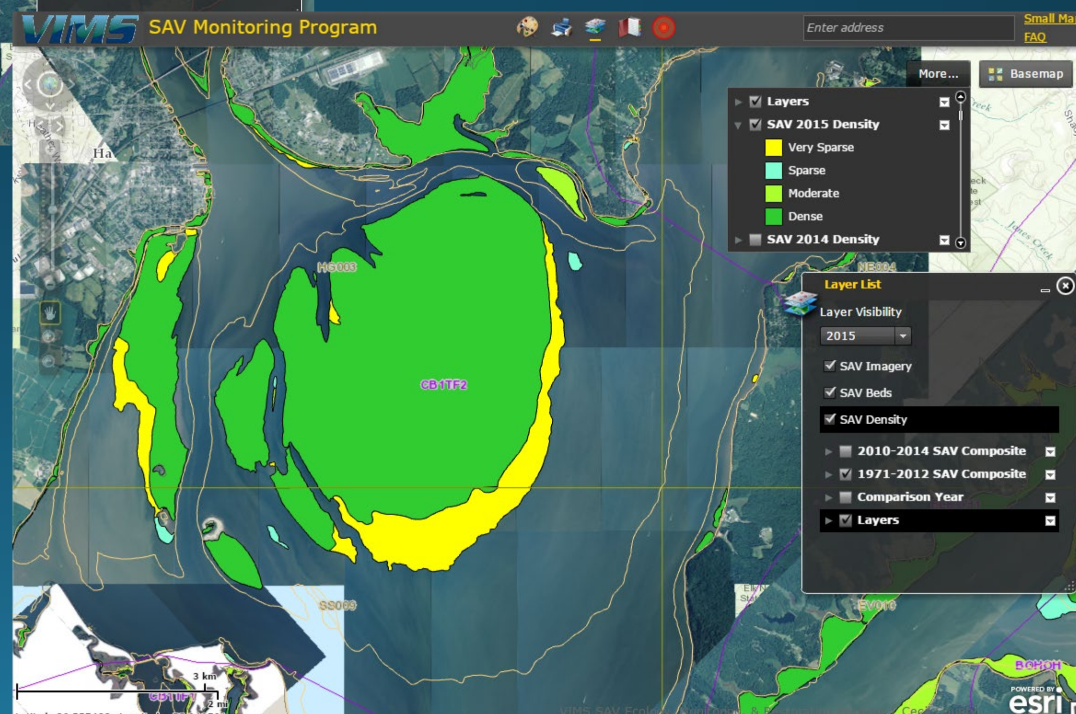
- The Web Revolution
  - Printed version of report to web-based report
- The GIS revolution
  - Heads down (Manual) to on-screen Photo-interpretation
  - Add GPS/IMU to acquisition of imagery

Major Changes in The Process

- The Web Revolution
  - Printed version of report to web-based report
- The GIS revolution
  - Heads down (Manual) to on-screen Photo-interpretation
  - Add GPS/IMU to acquisition of imagery
  - Interactive Map

Interactive Map





Major Changes in The Process

- The Web Revolution

  Printed version of report to web-based report

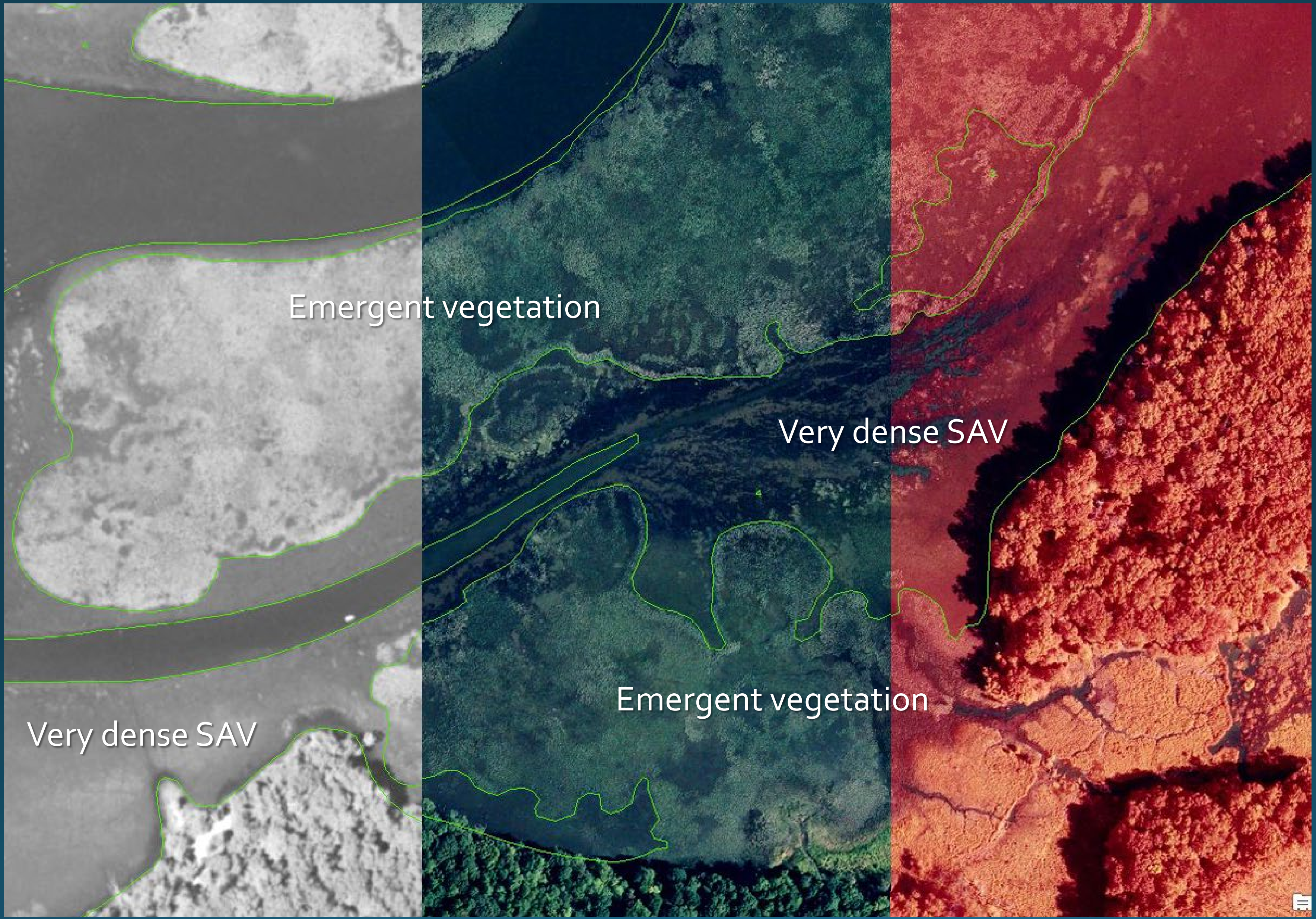
- The GIS revolution

  Heads down (Manual) to on-screen Photo-interpretation

  Add GPS/IMU to acquisition of imagery

  Interactive Map

- Switch from Film Prints to Digital Imagery. Ability to add imagery within days of obtaining it.



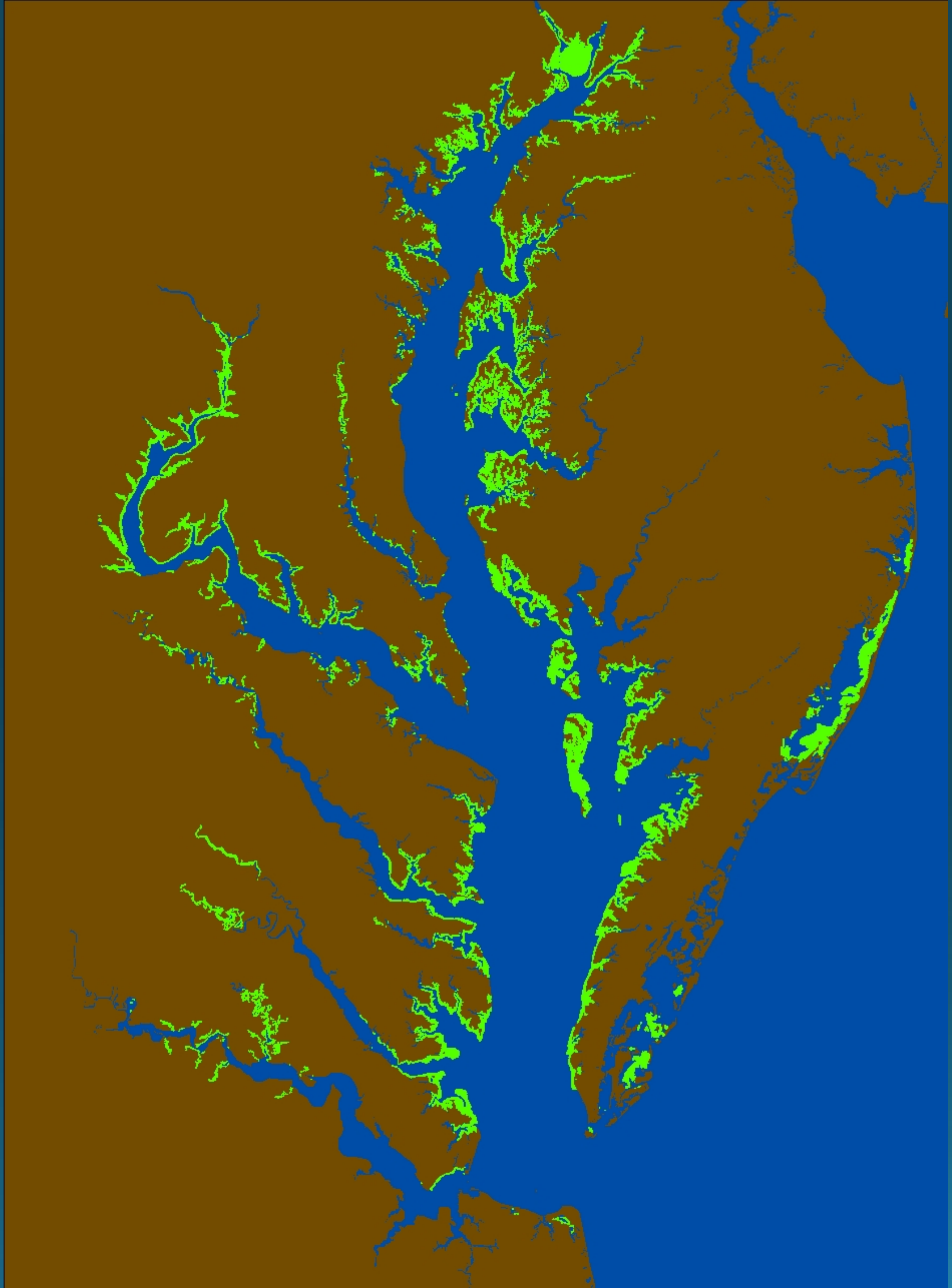
2014 Panchromatic

2015 Digital Imagery

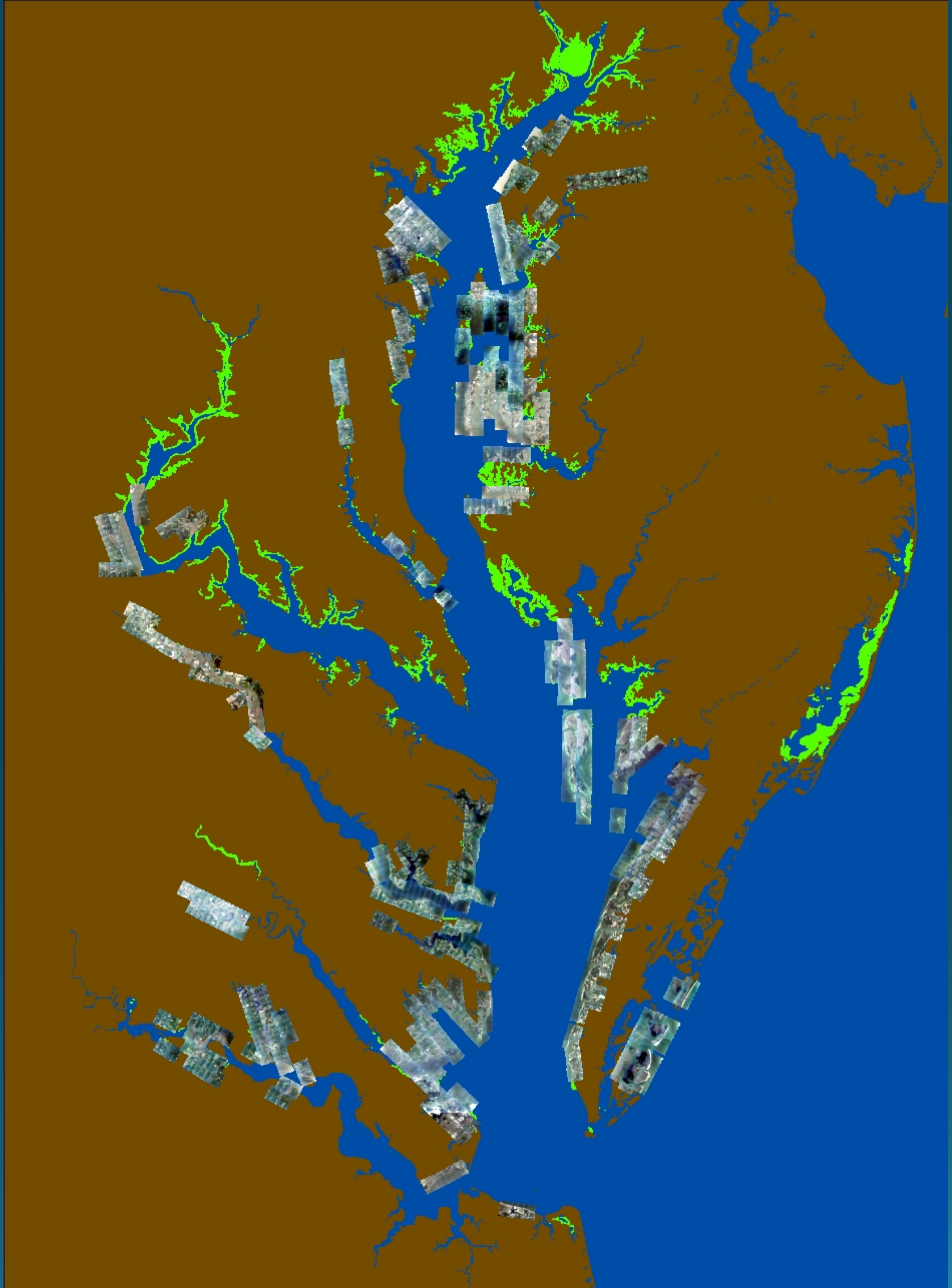
2015 Color Infrared

2018 Satellite Imagery – Lessons Learned

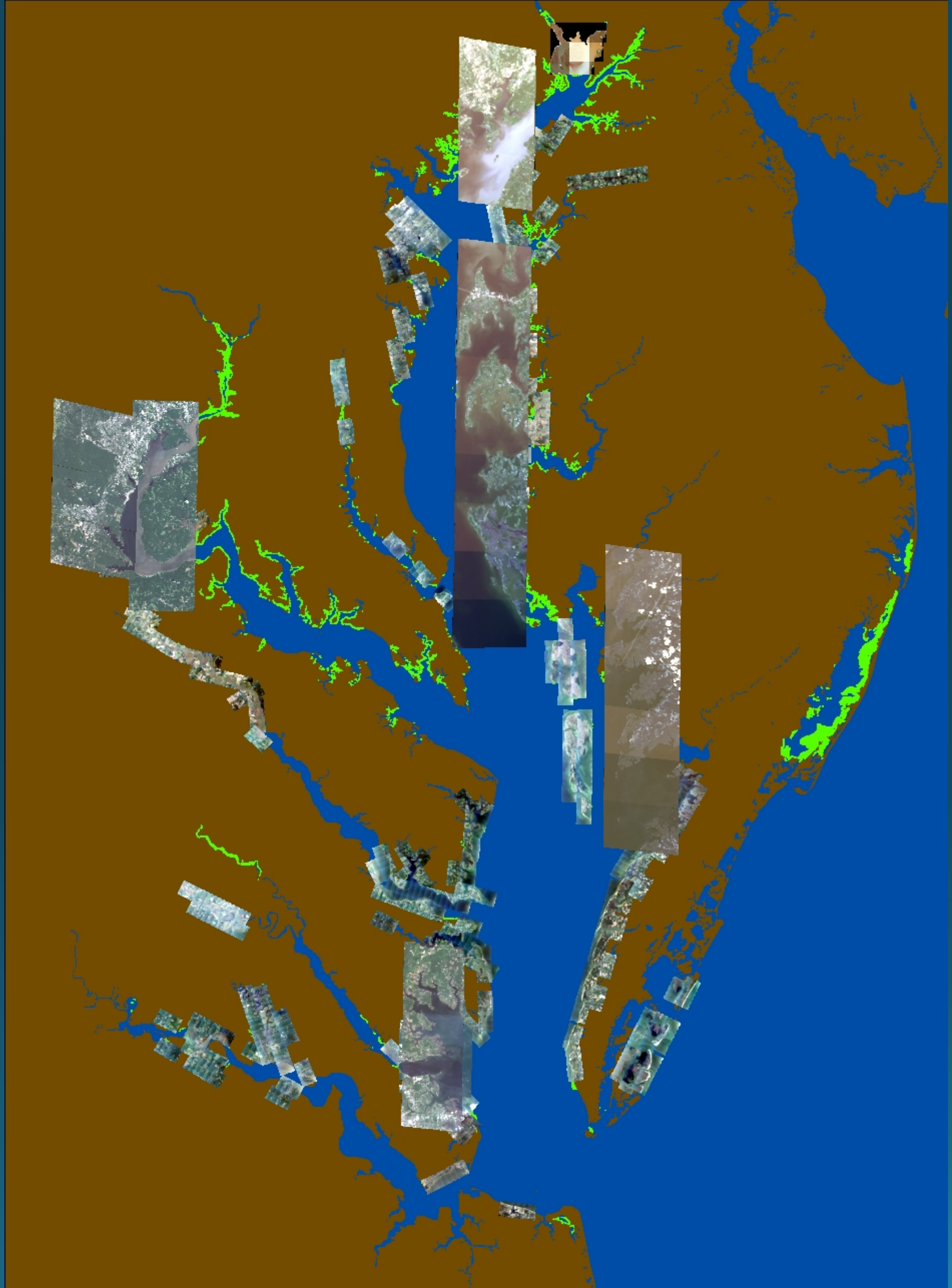
SAV in the Bay



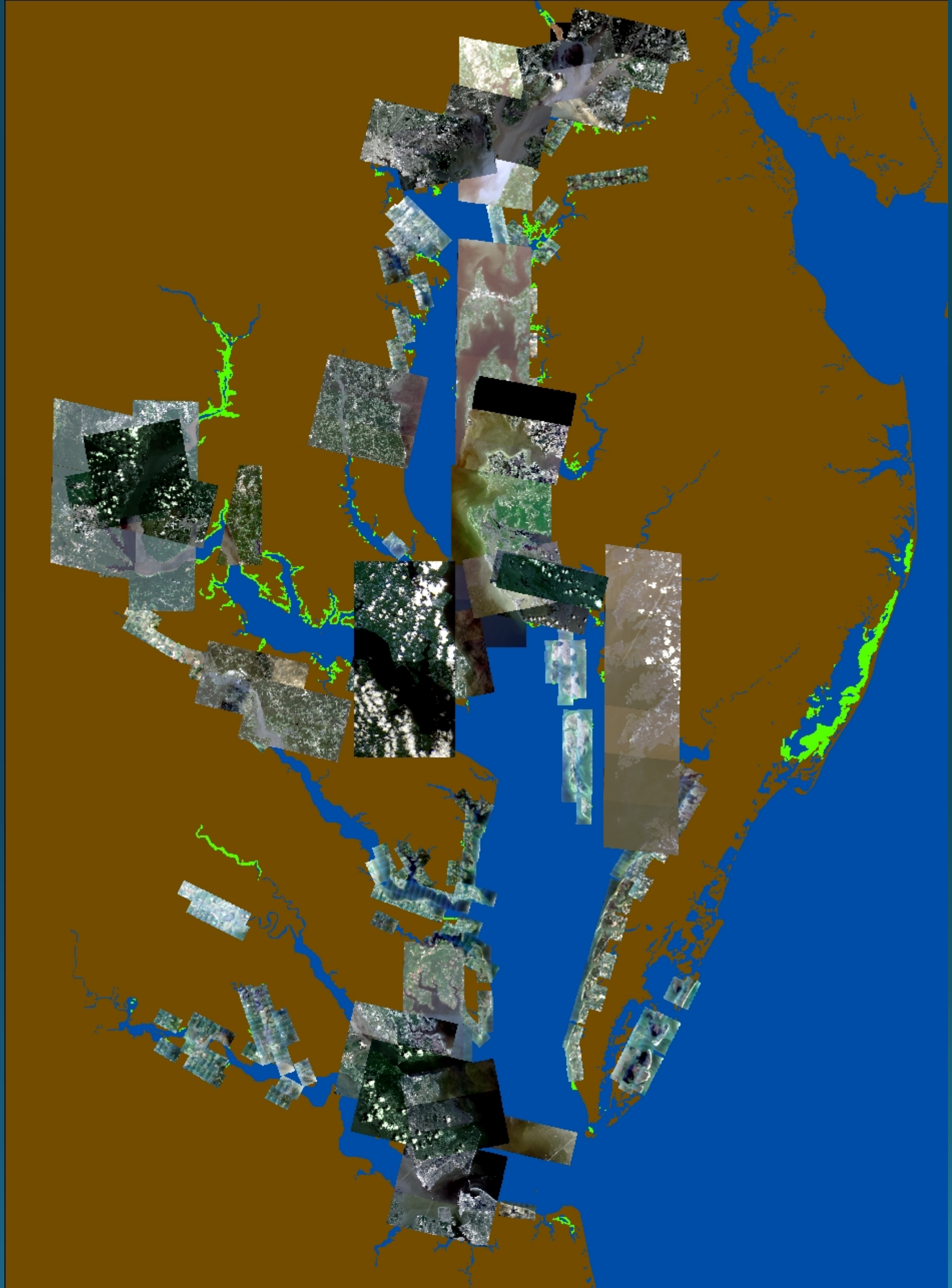
2018
Aerial
Coverage



2018 WorldView & GeoEye Coverage

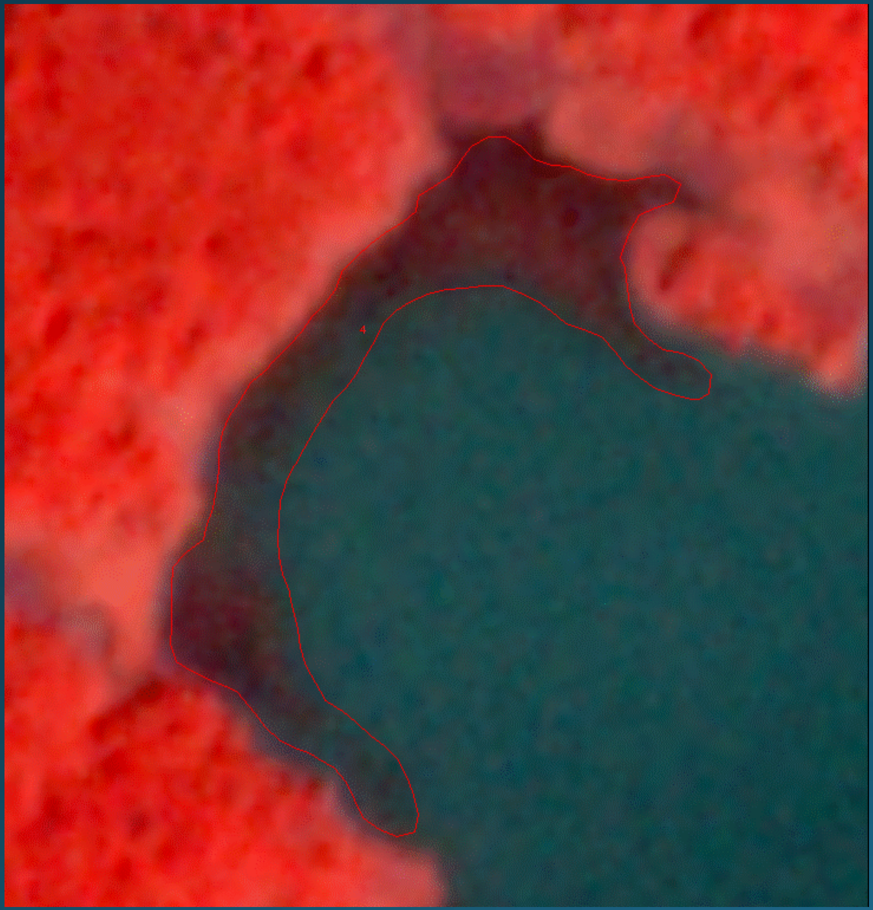


2018 Planet Coverage



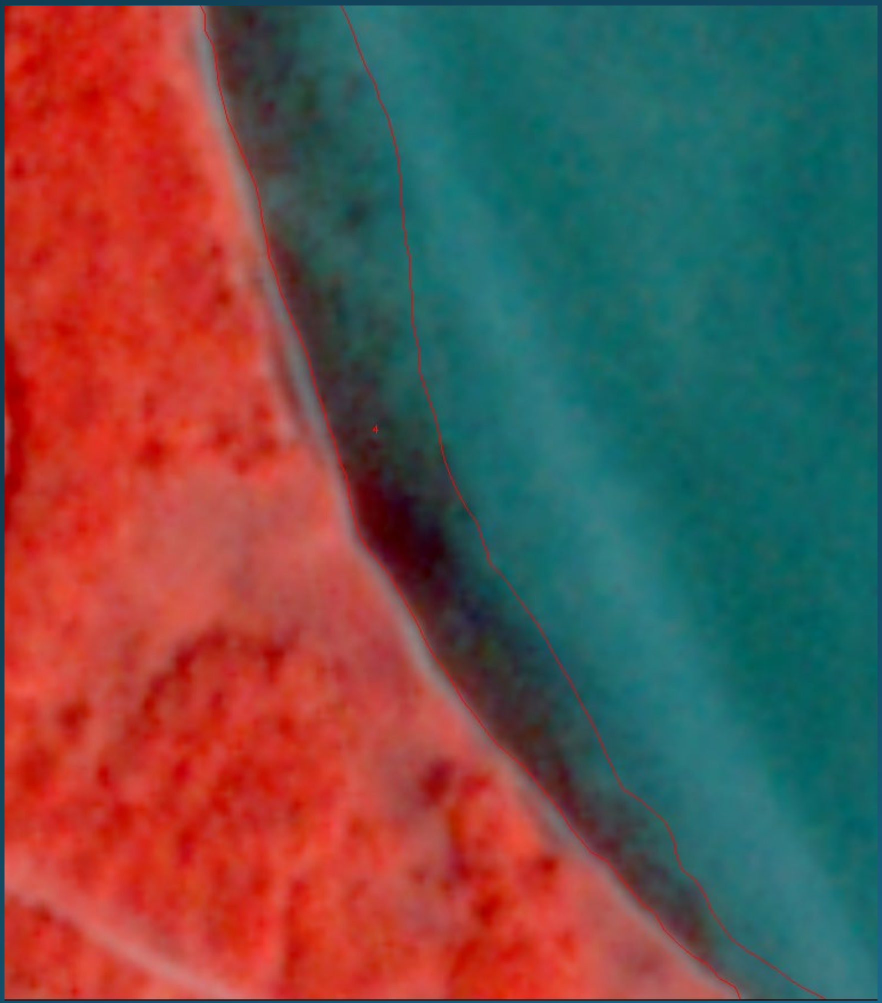
Areas Not Covered In 2018

Planet



GeoEye

Planet



GeoEye

Planet

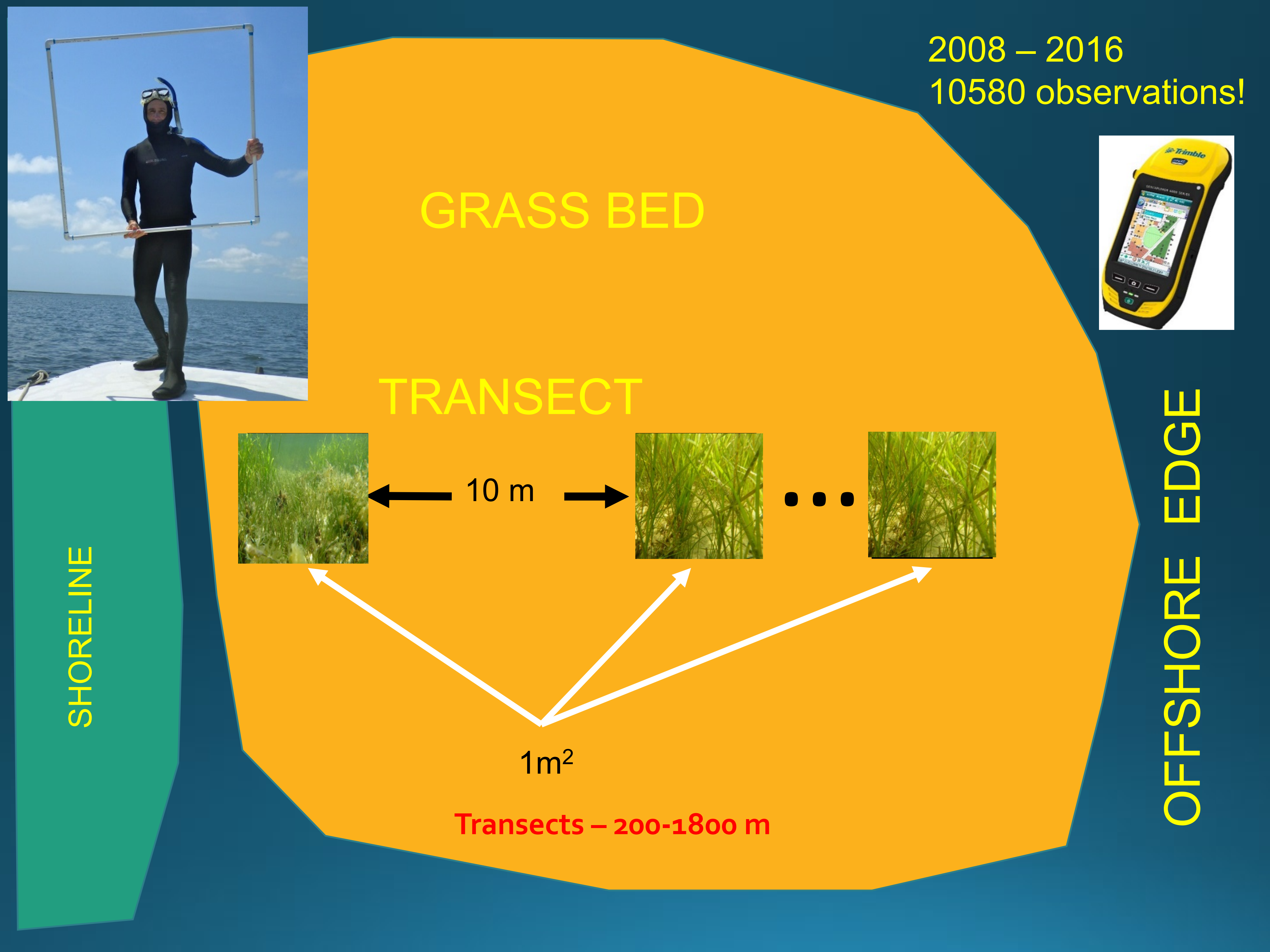
Aerial

2018 Satellite Imagery – Lessons Learned

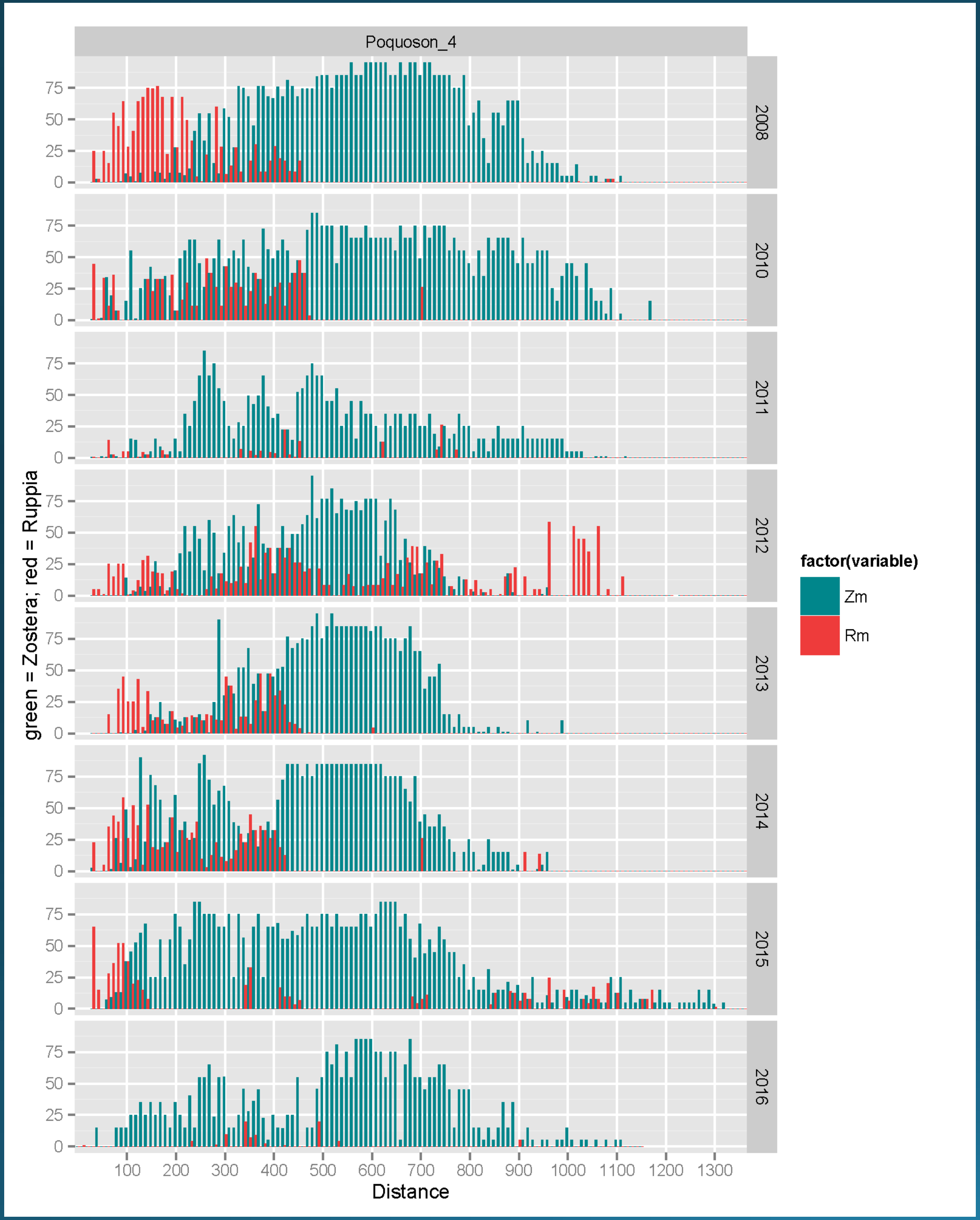
- WorldView and GeoEye did not provide full coverage of the Bay
- The process to orthorectify satellite imagery is different and includes pan sharpening
- More spectral bands provide more information that can take more time to process visually
- Planet could not be used as a primary source due to the low resolution (4m). It was helpful identifying the presence or absence of grass throughout the growing season
- Satellite overflight time often was midday, requiring off-nadir imagery
- The Digital Globe Agreement prevents the ability to share satellite imagery or retain imagery after the project period

SAV Ground Surveys

- Transect Surveys
- Ground Surveys
  - Citizens
  - Scientists


2008 – 2016
10580 observations!
GRASS BED
TRANSECT
10 m
1m²
Transects – 200-1800 m
SHORELINE
OFFSHORE EDGE
Trimble

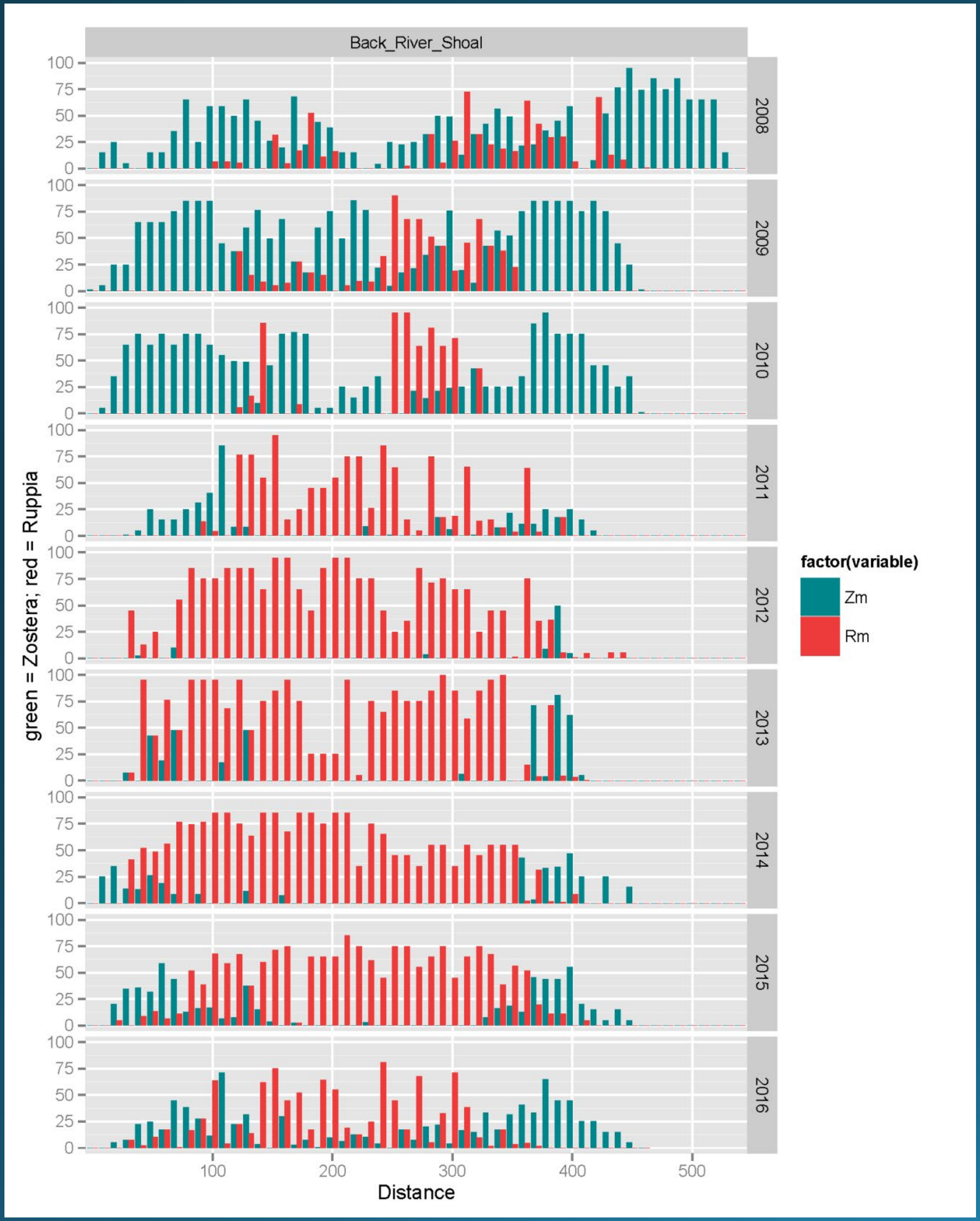
Poquoson Flats 2008-2016



Eelgrass

Widgeongrass

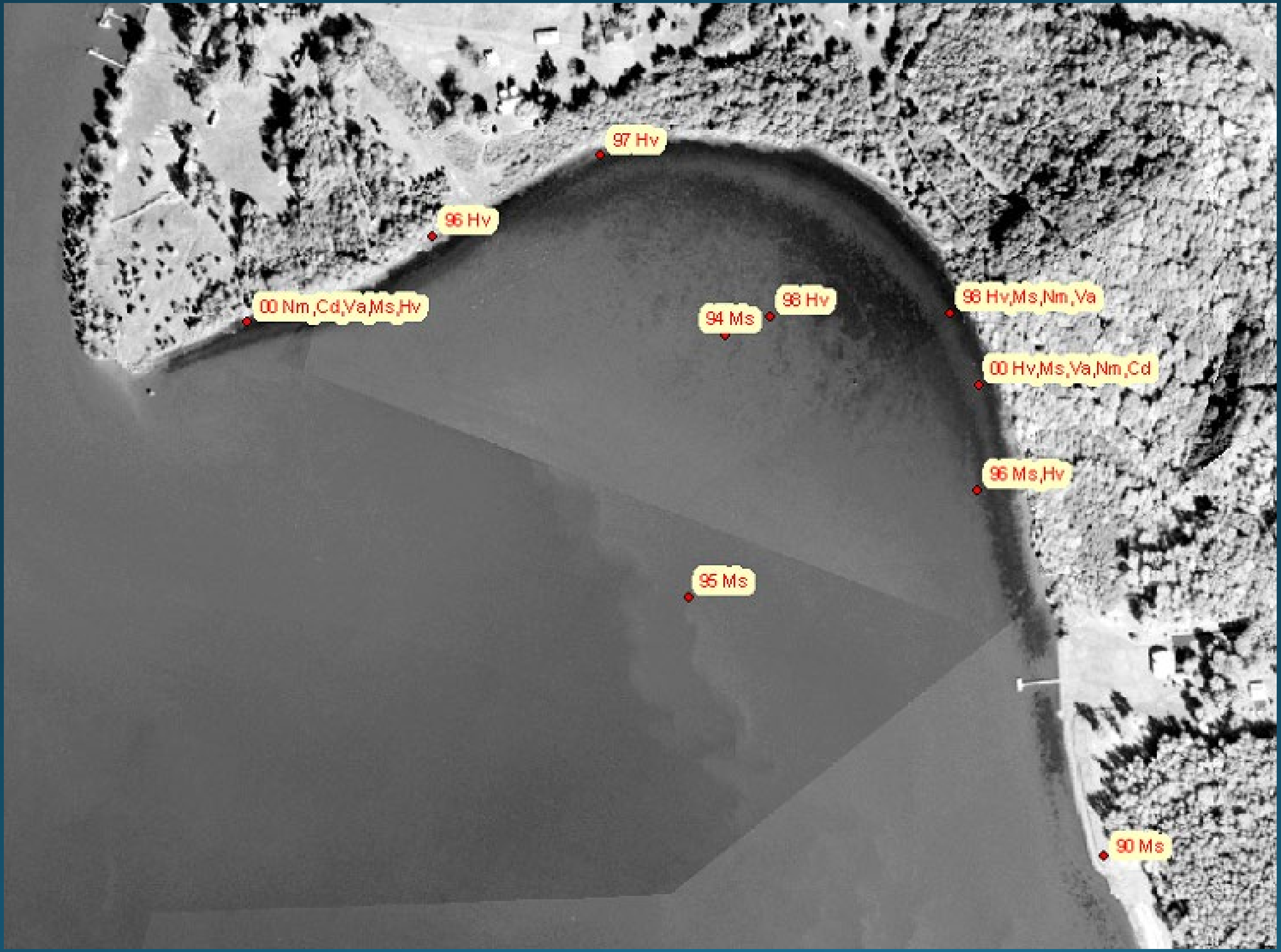
Back River Shoal 2008-2016



Eelgrass

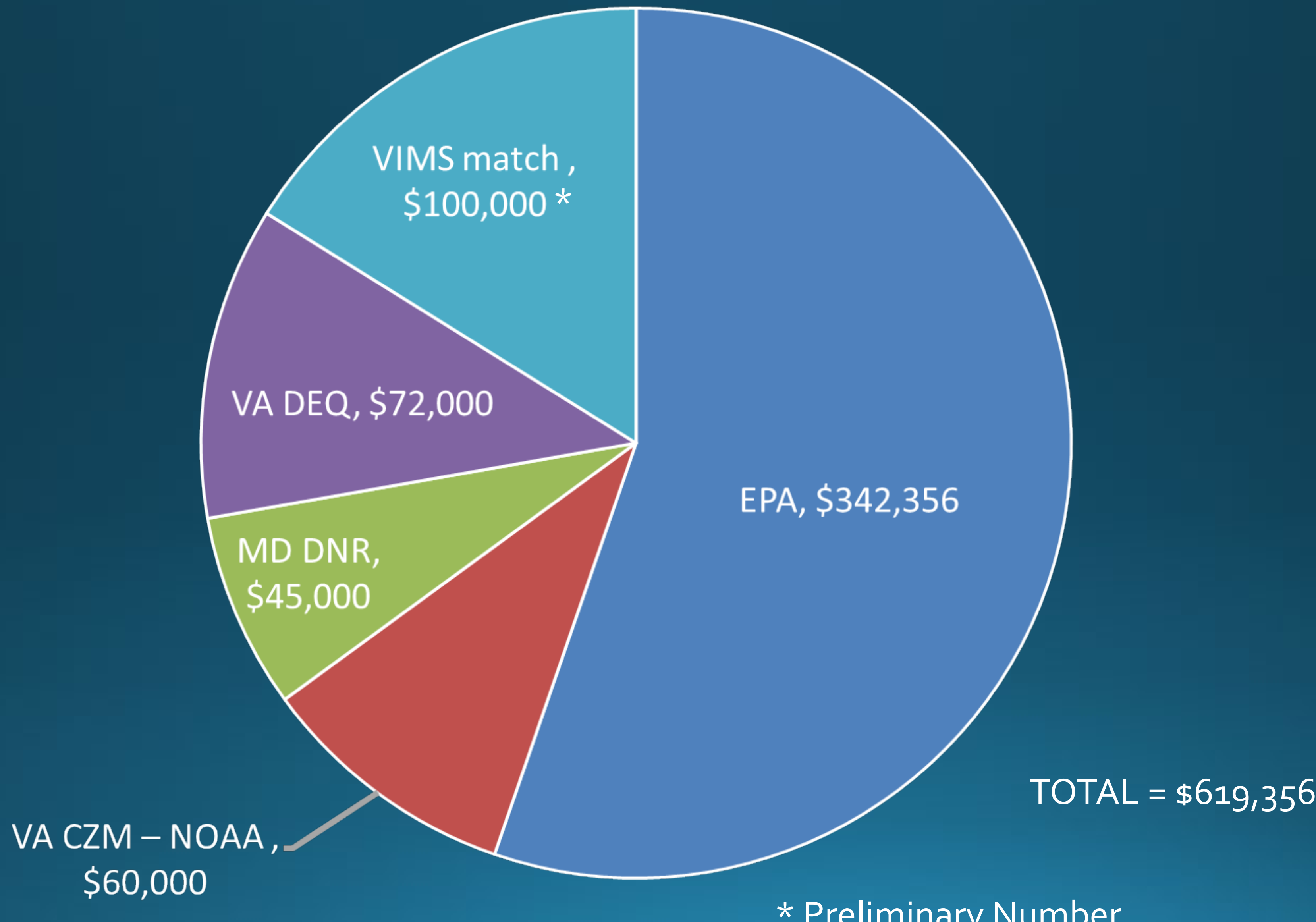
Widgeongrass

Ground Survey Point Data
Visual, Grab Samples

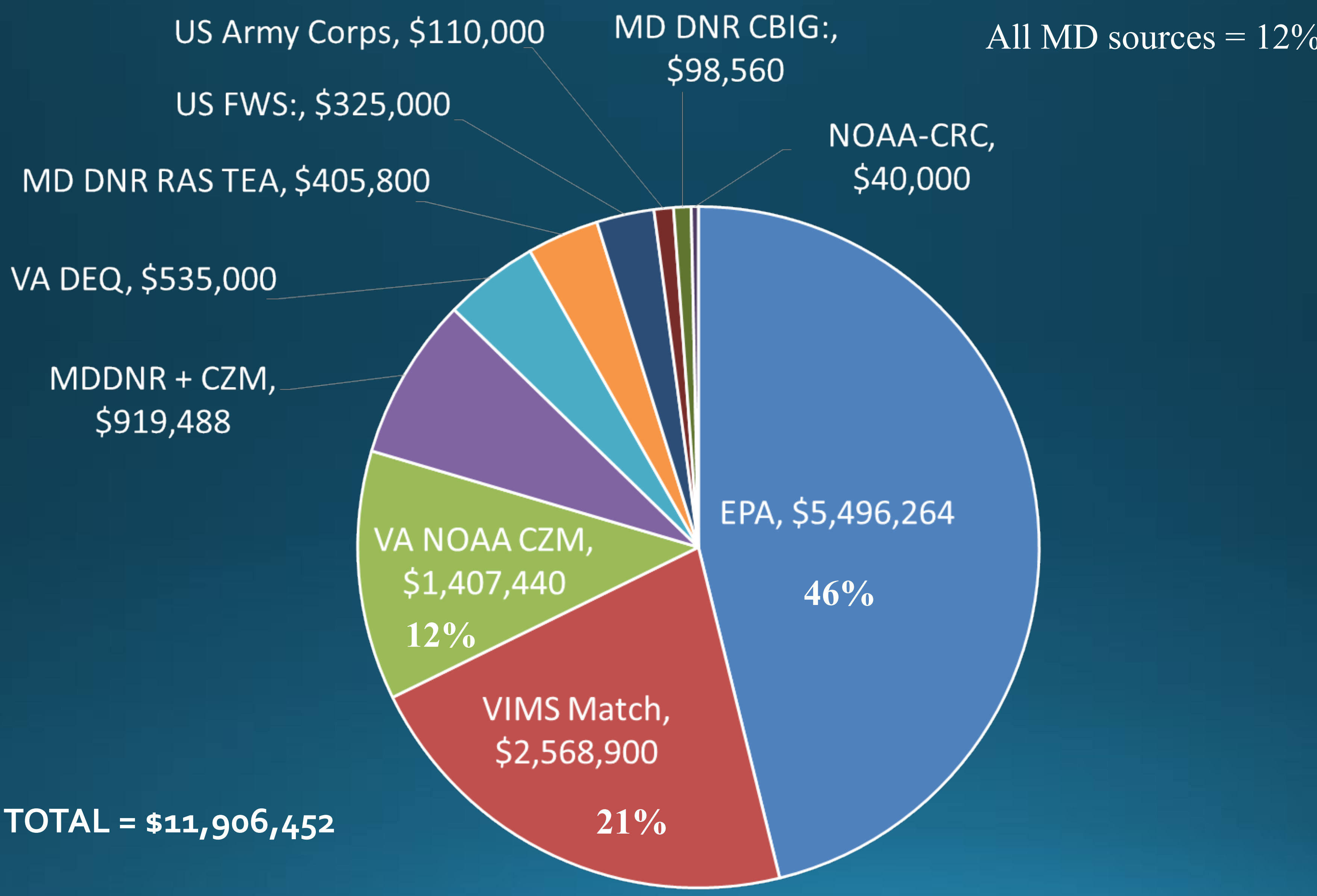

97 Hv
96 Hv
00 Nm,Cd,Va,Ms,Hv
94 Ms
98 Hv
98 Hv,Ms,Nm,Va
00 Hv,Ms,Va,Nm,Cd
96 Ms,Hv
95 Ms
90 Ms

The Budget Information

2016 SAV Survey Funding Sources

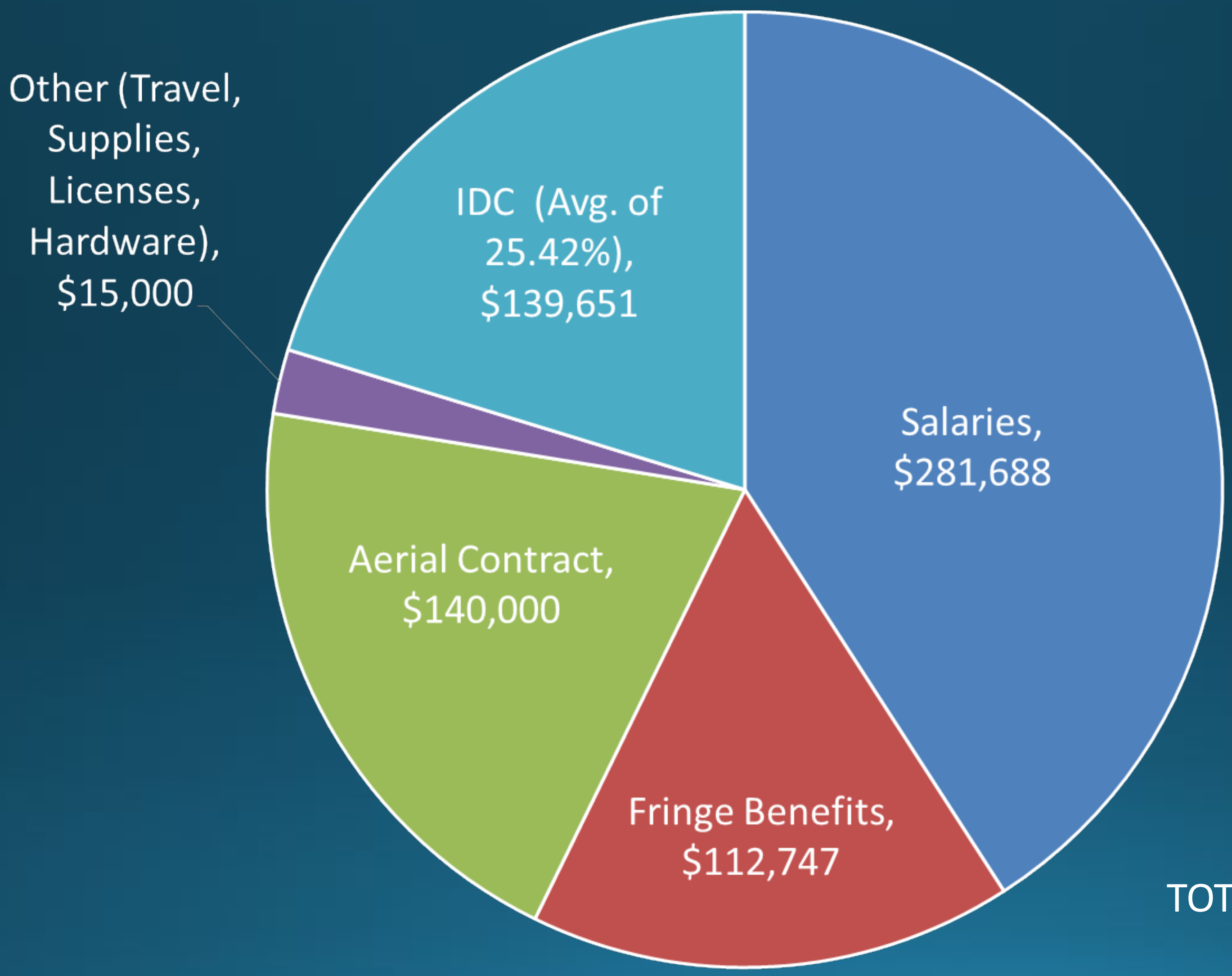


Grants Supporting the Survey 1989-2016



TOTAL = $11,906,452

2017 Budget



TOTAL = $689,086

Factors Influencing the Budget

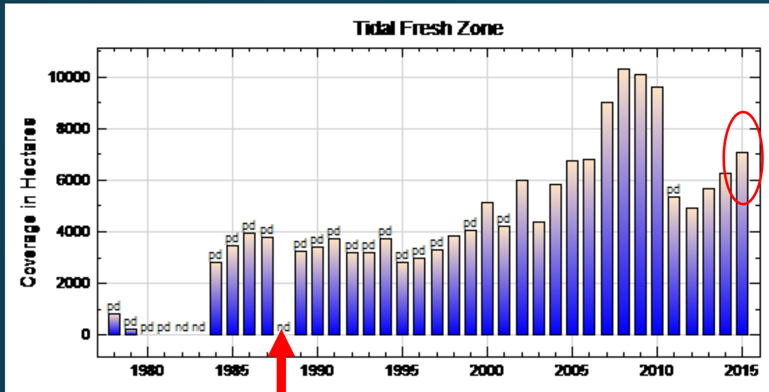
(+ = increases in budget; - = decreases in budget)

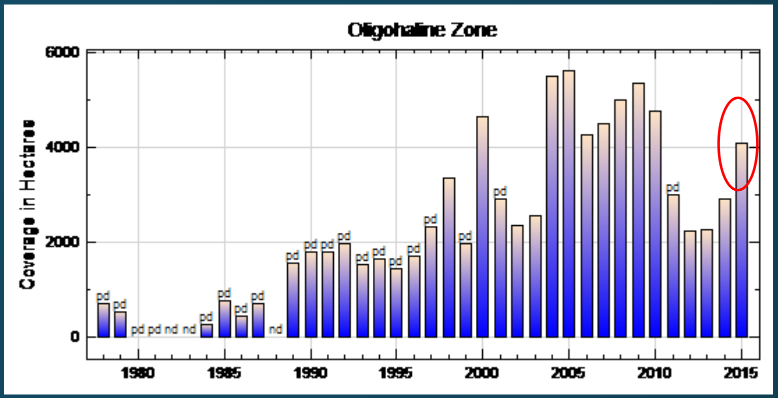
- Inflation ($100,000 in 1984 = $233,489 in 2016)
- Conversion of hourly staff to full time with benefits (+)
- Addition of flight lines in Virginia tributaries, 1999 (+)
- More SAV to map (+)
- Printed report to web based report (-)
- GPS/IMU added to imagery 2007 (+ $20-$30K)
- Added 4th full time person early 2000's (+)
- Eliminated 4th full time person 2017 (-)
- Digital Imagery requires more lines to cover SAV areas (+)
- Aerial contract increases, 1989 to 2016 (+)
- Personnel raises, reallocation of positions (+)

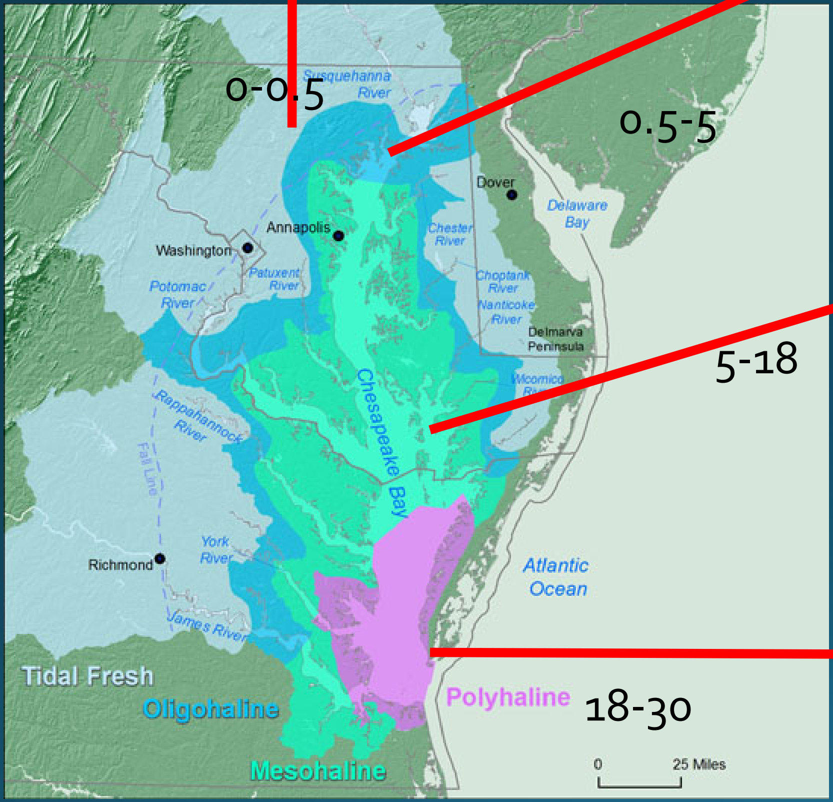
2019 Budget

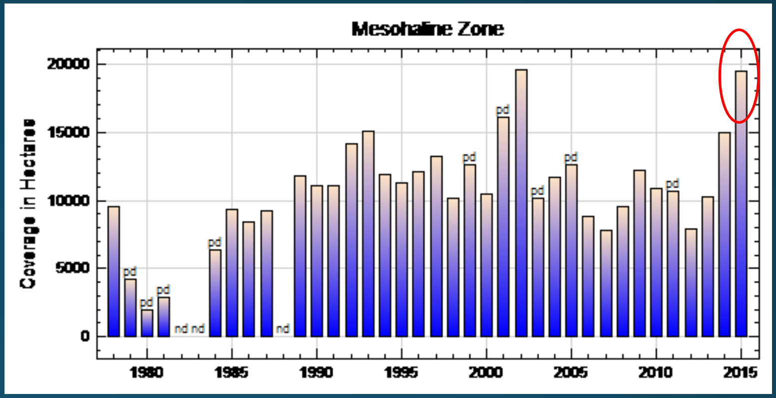
- EPA - $360,000
- VA CZM- $68,000
- MD DNR- $44,000 (tentative)
- MDE - $50,000 (tentative)
- Commonwealth of VA - $250,000 (NEW with caveat*)

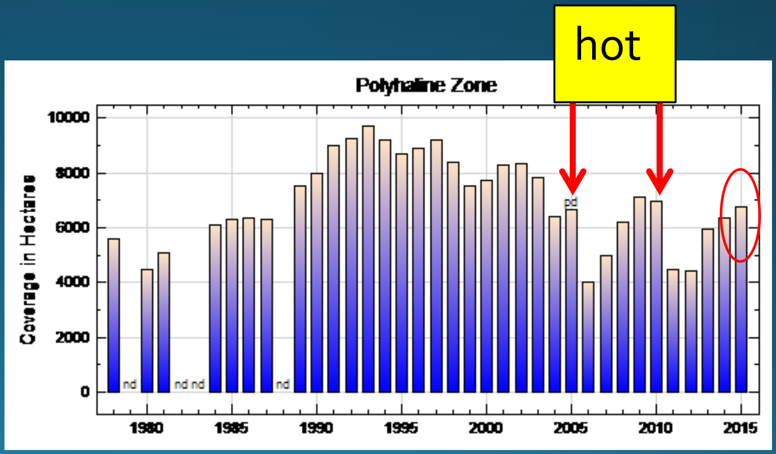
* Requires imagery that can be viewed by VA regulatory agencies (VMRC)







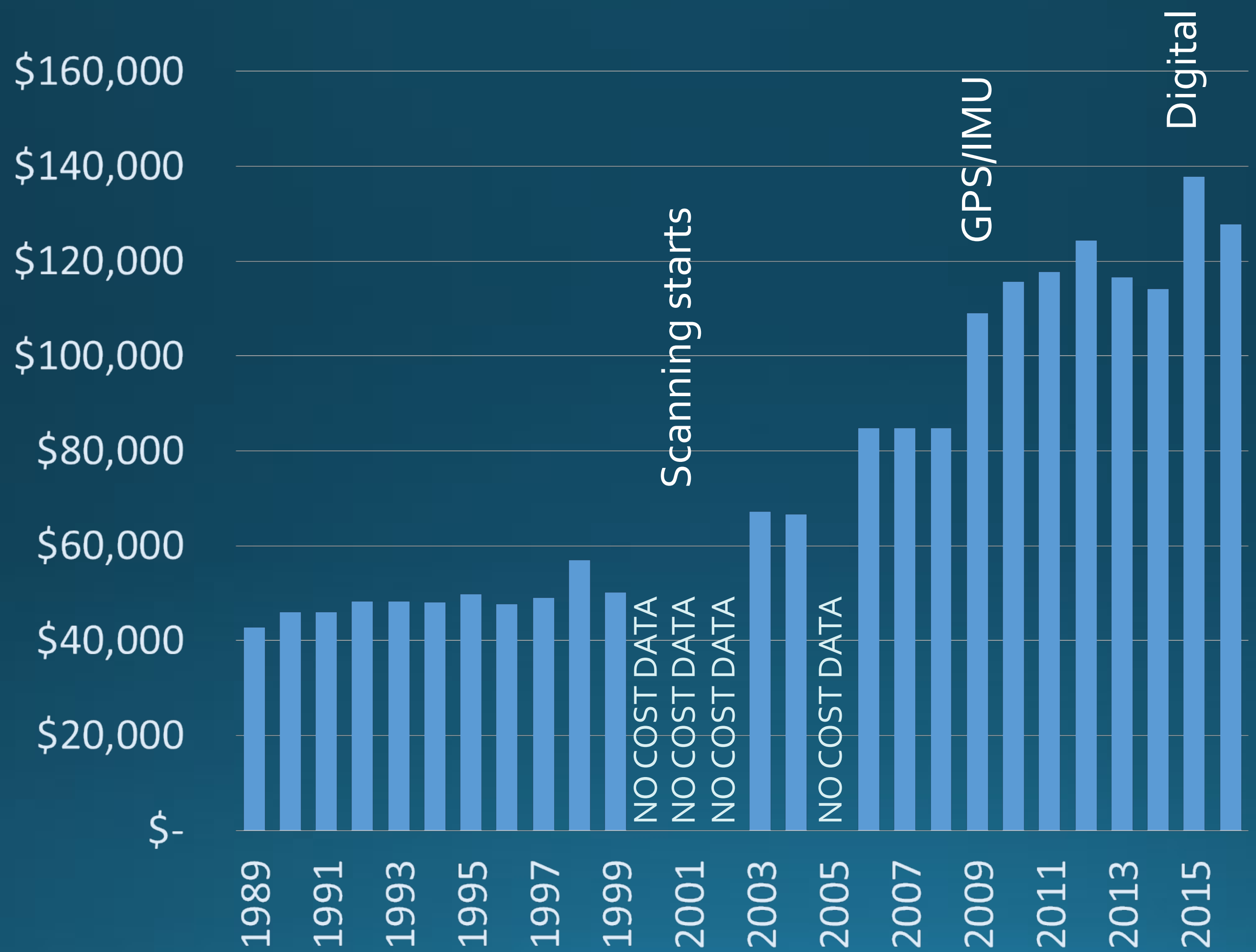




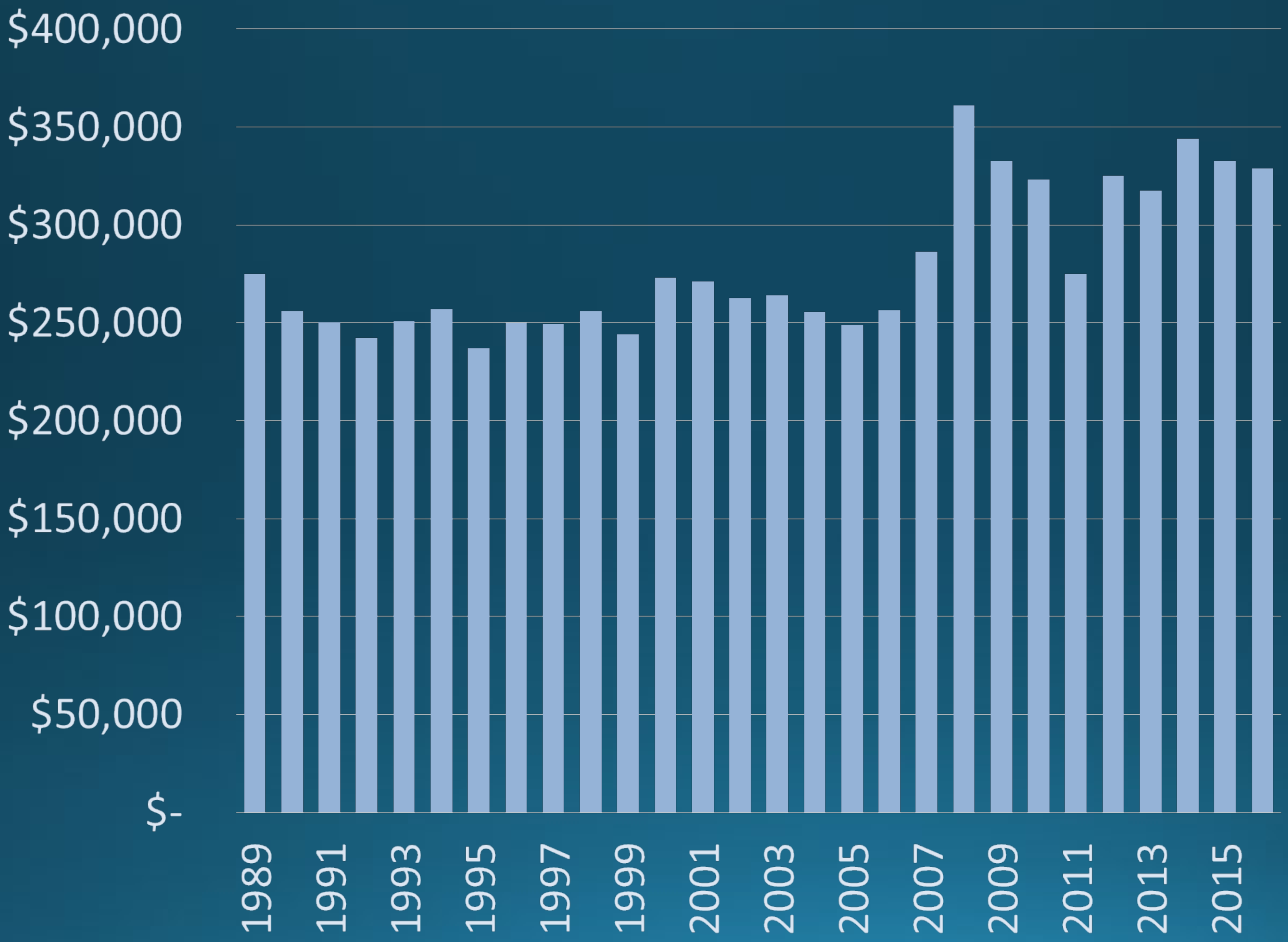
More SAV – more beds to map!

Aerial contract costs 1989-2016

Not adjusted for inflation



Survey Cost in 1989 Dollars



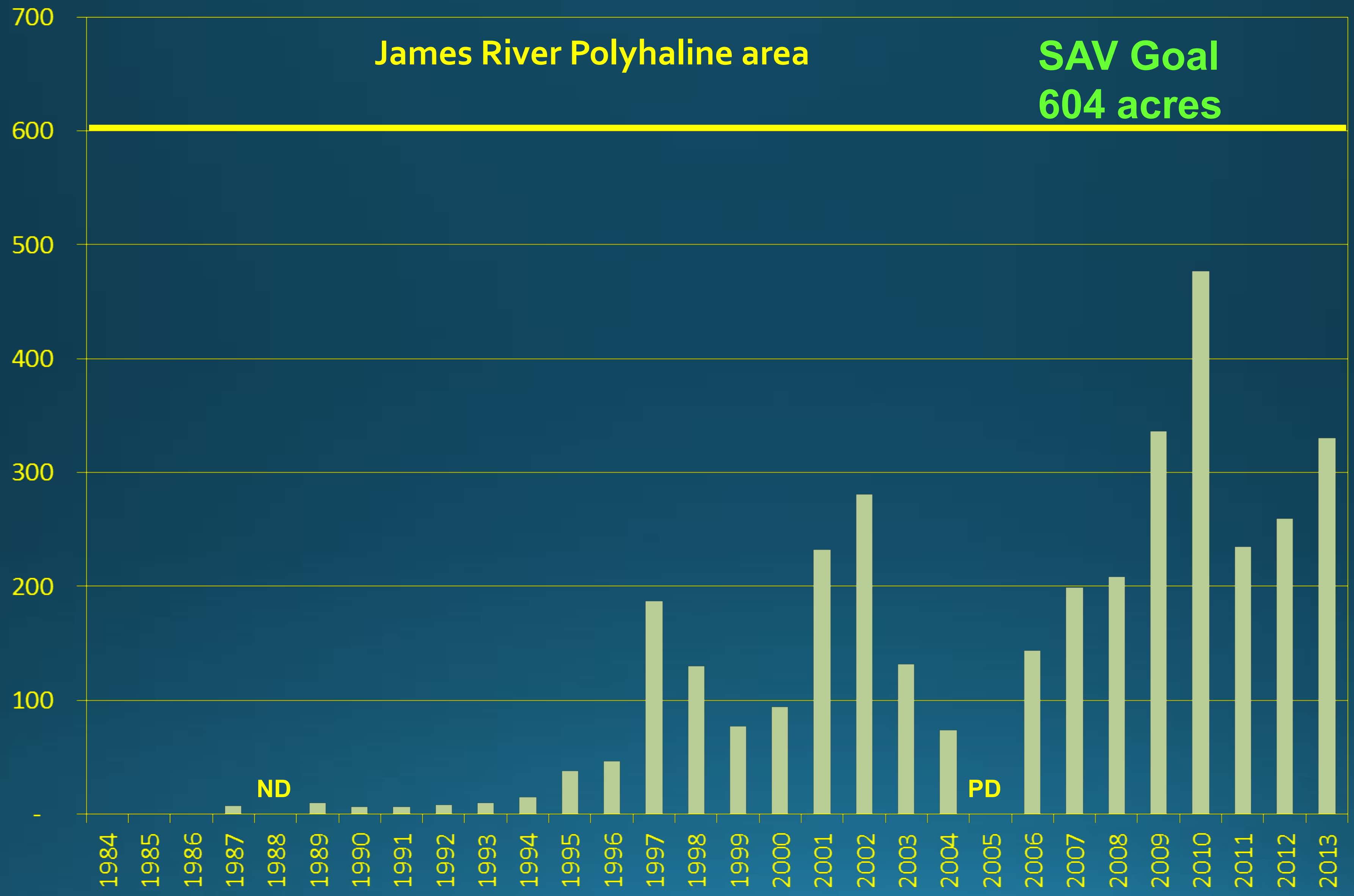
Significance of Annual Survey

- State Water Quality criteria – Restoration targets

Virginia and Maryland's Water Quality Standards (9 VAC 25-260 COMAR 26.08.02.03-3)

- SAV acreage now included in determining attainment of Chesapeake Bay water clarity standards
- EVERY ACRE COUNTS IN MEETING RESTORATION TARGETS!

Segment JMSPH



Significance of Annual Survey

- State Water Quality criteria – Restoration targets
- Necessary for Aquaculture Site Evaluations

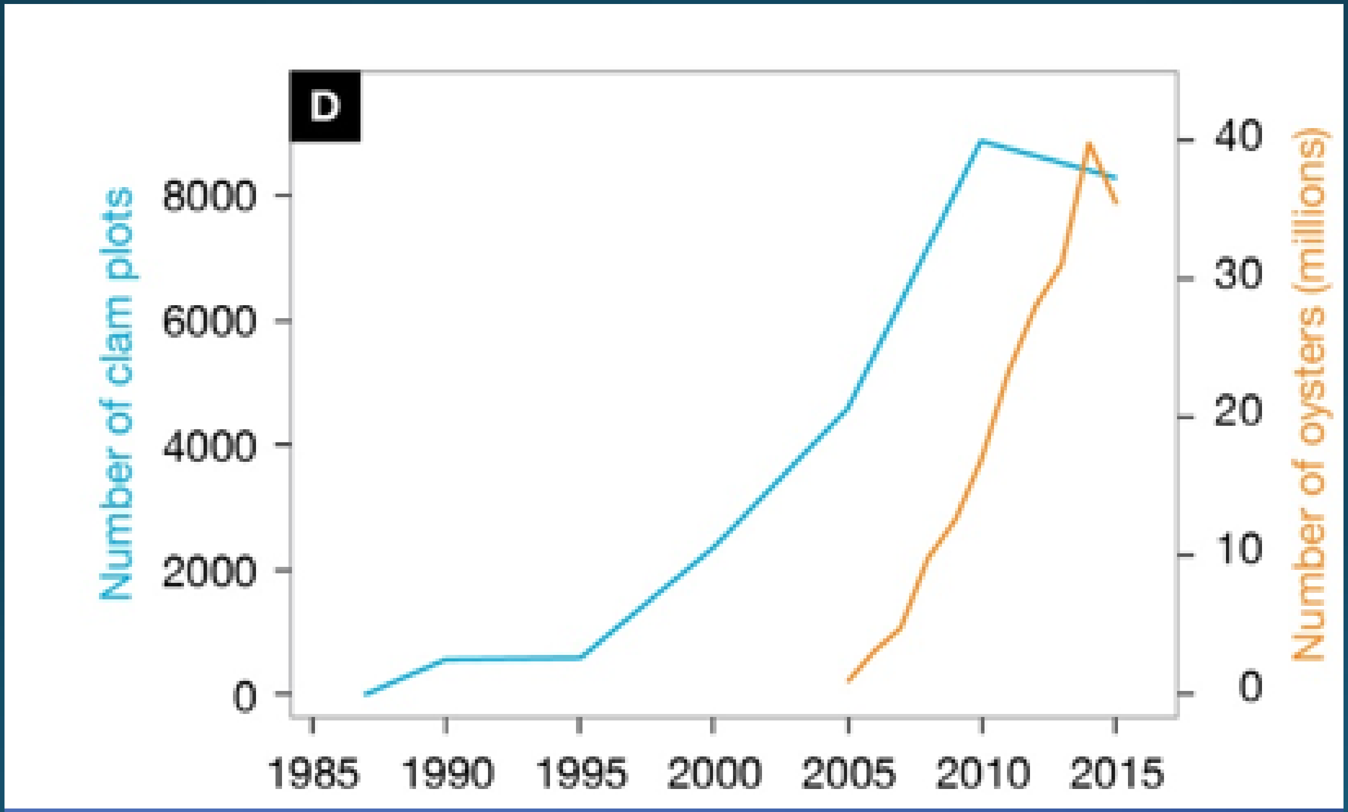
State Regs Governing Aquaculture

- **VMRC 4 VAC 20335-10** (Jan. 1998) – On-bottom shellfish aquaculture activities requiring structures are now prohibited from being placed on existing SAV

- **Md. NATURAL RESOURCES Code Ann. § 4-11A-01 (2015) - SAV Protection Zone. -- "SAV Protection Zone**" means an area of submerged aquatic vegetation as mapped in aerial surveys by the Virginia Institute of Marine Sciences in 1 or more of the 5 years preceding the designation of an Aquaculture Enterprise Zone or an application for a lease under this subtitle.

Oyster and Clam Aquaculture plots – The Gulf 2016

Aquaculture Expansion

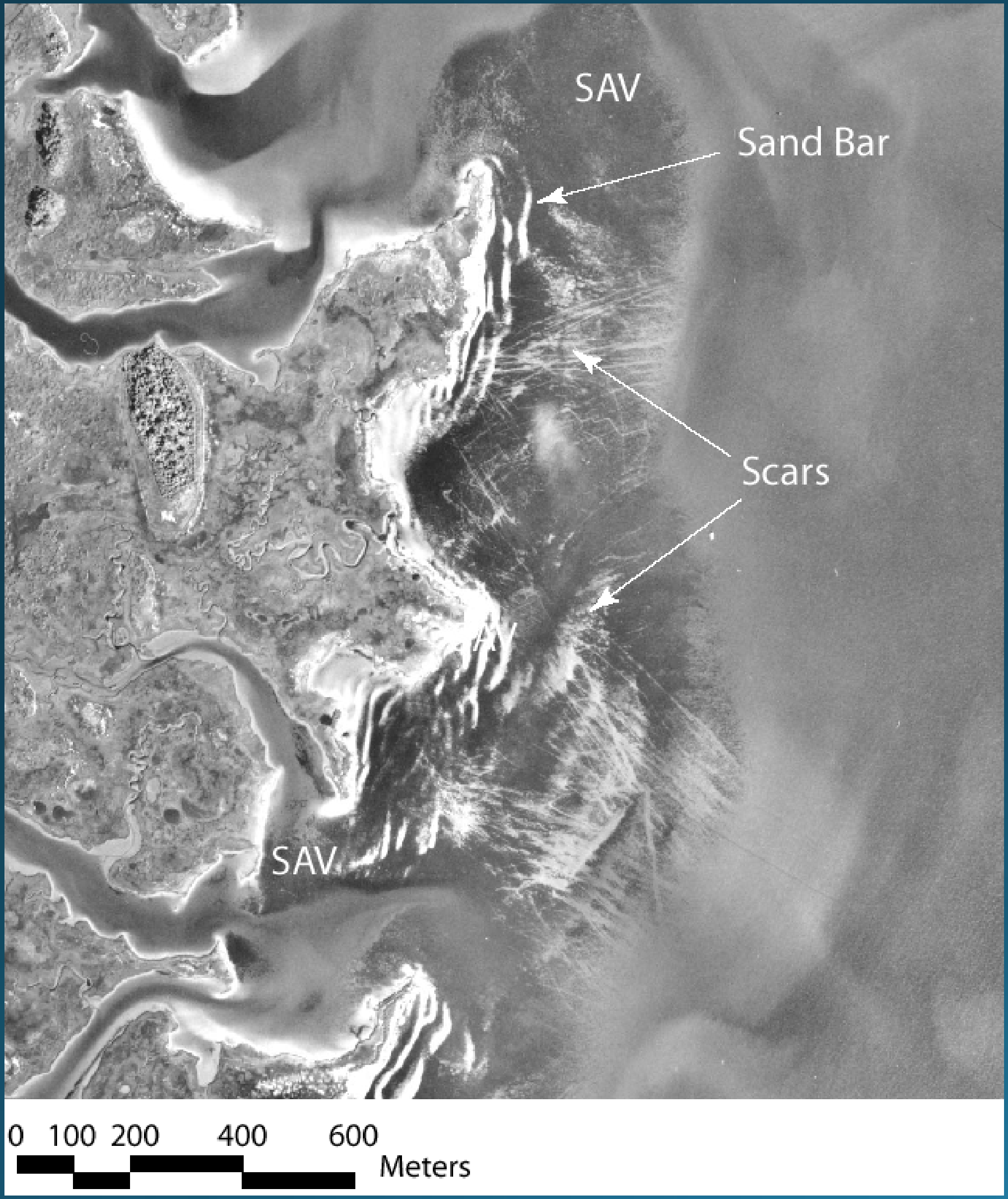


Orth et al. just accepted Bioscience

Significance of Annual Survey

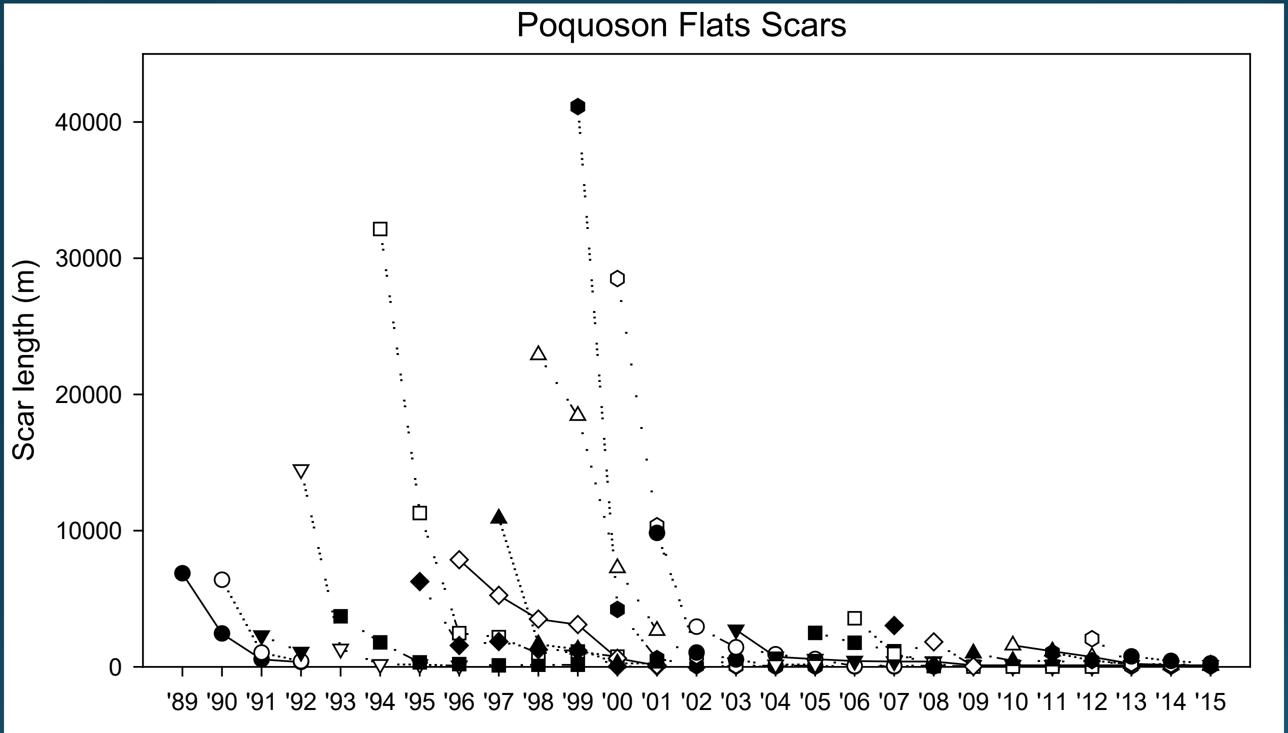
- State Water Quality criteria – Restoration targets
- Necessary for Aquaculture Site Evaluations
- Monitor Propeller Scarring in VA

Brown's Bay - 1997



Aerial photograph from VIMS monitoring showing extensive scarring in grassbed in Browns Bay located in the Mobjack Bay

Boat Scars



Each point represents how much propeller scaring we measured each year. Then we follow those scars in subsequent years.

Orth et al. In Press

Significance of Annual Survey

- State Water Quality criteria – Restoration targets
- Necessary for Aquaculture Site Evaluations
- Monitor Propeller Scarring in VA
- Supports Peer Reviewed Science Requiring Annual data

Scientific Analysis

Global Change Biology (2017), doi: 10.1111/gcb.13623

Multiple stressors threaten the imperiled coastal foundation species eelgrass (*Zostera marina*) in Chesapeake Bay, USA

JONATHAN S. LEFCHECK[1], DAVID J. WILCOX[1], REBECCA R. MURPHY[2], SCOTT R. MARION[3] and ROBERT J. ORTH[1]
[1]*Virginia Institute of Marine Science, The College of William & Mary, Gloucester Point, VA 23062, USA,* [2]*University of Maryland Center for Environmental Science, Chesapeake Bay Program, Annapolis, MD 21403, USA,* [3]*Oregon Department of Fish & Wildlife, Marine Resources Program, Newport, OR 97365, USA*

Vol. 537: 121–135, 2015
doi: 10.3354/meps11412
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser
Published October 14

Interannual variation in submerged aquatic vegetation and its relationship to water quality in subestuaries of Chesapeake Bay

Christopher J. Patrick*, Donald E. Weller
Smithsonian Environmental Research Center, PO Box 28, 647 Contees Wharf Rd., Edgewater, Maryland 21037, USA

Estuaries and Coasts (2010) 33:1144–1163
DOI 10.1007/s12237-010-9311-4

Long-Term Trends in Submersed Aquatic Vegetation (SAV) in Chesapeake Bay, USA, Related to Water Quality

Robert J. Orth · Michael R. Williams · Scott R. Marion · David J. Wilcox · Tim J. B. Carruthers · Kenneth A. Moore · W. Michael Kemp · William C. Dennison · Nancy Rybicki · Peter Bergstrom · Richard A. Batiuk

Estuaries and Coasts (2016) 39:158–170
DOI 10.1007/s12237-015-9970-2

The Relationship Between Shoreline Armoring and Adjacent Submerged Aquatic Vegetation in Chesapeake Bay and Nearby Atlantic Coastal Bays

Christopher J. Patrick[1] · Donald E. Weller[1] · Micah Ryder[1]

Estuaries and Coasts (2016) 39:951–966
DOI 10.1007/s12237-016-0074-4

Mechanisms of Storm-Related Loss and Resilience in a Large Submersed Plant Bed

Cassie Gurbisz[1] · W. Michael Kemp[1] · Lawrence P. Sanford[1] · Robert J. Orth[2]

Long-term reductions in anthropogenic nutrients link to improvements in Chesapeake Bay habitat

Henry A. Ruhl[a,1] and Nancy B. Rybicki[b,1,2]
[a]National Oceanography Centre, University of Southampton Waterfront Campus, Southampton SO14 3ZH, United Kingdom; and [b]US Geological Survey, Reston, VA 20192

Limnol. Oceanogr., 59(2), 2014, 482–494

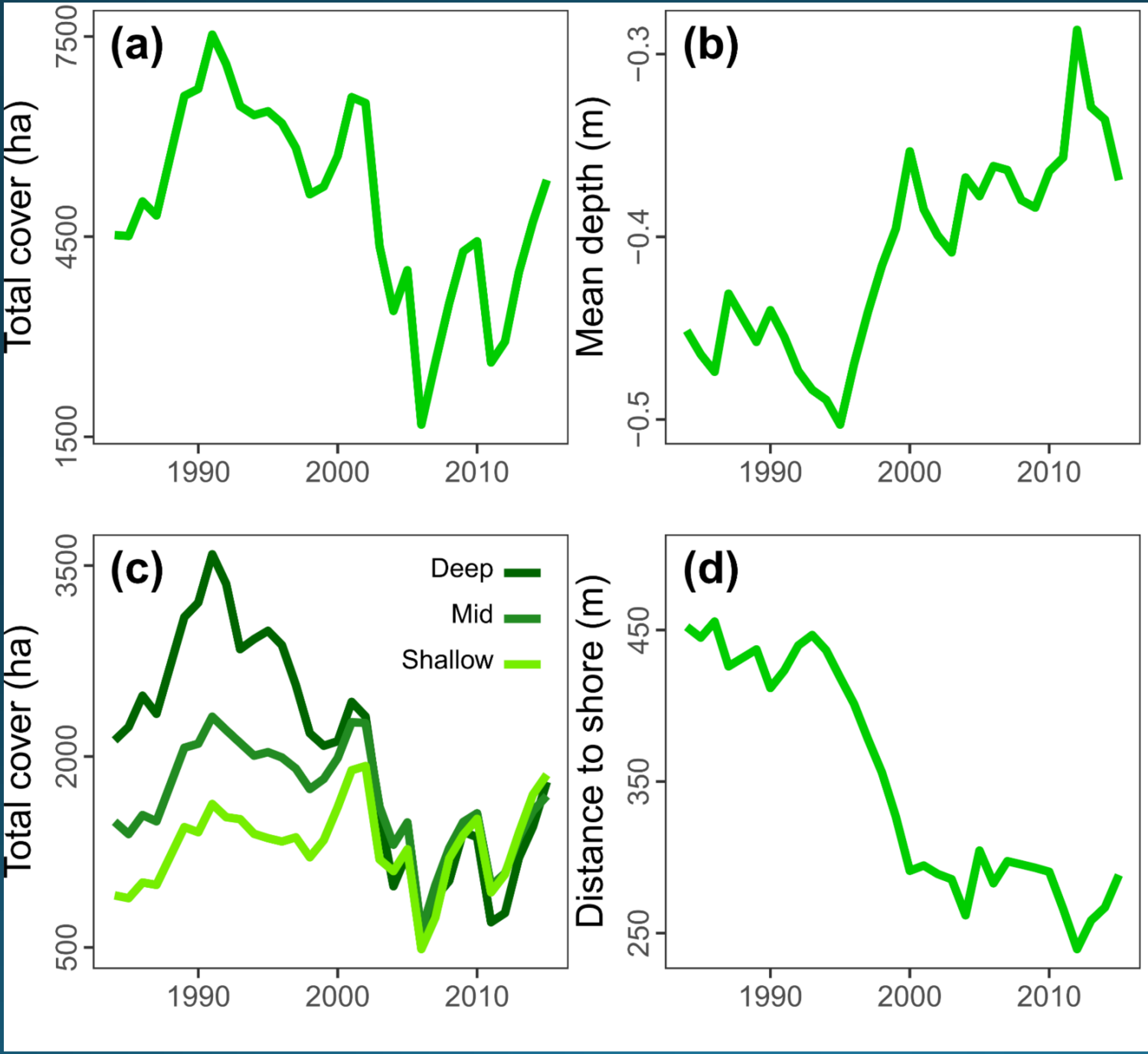
doi:10.4319/lo.2014.59.2.0482

Unexpected resurgence of a large submersed plant bed in Chesapeake Bay: Analysis of time series data

Cassie Gurbisz* and W. Michael Kemp
University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge, Maryland

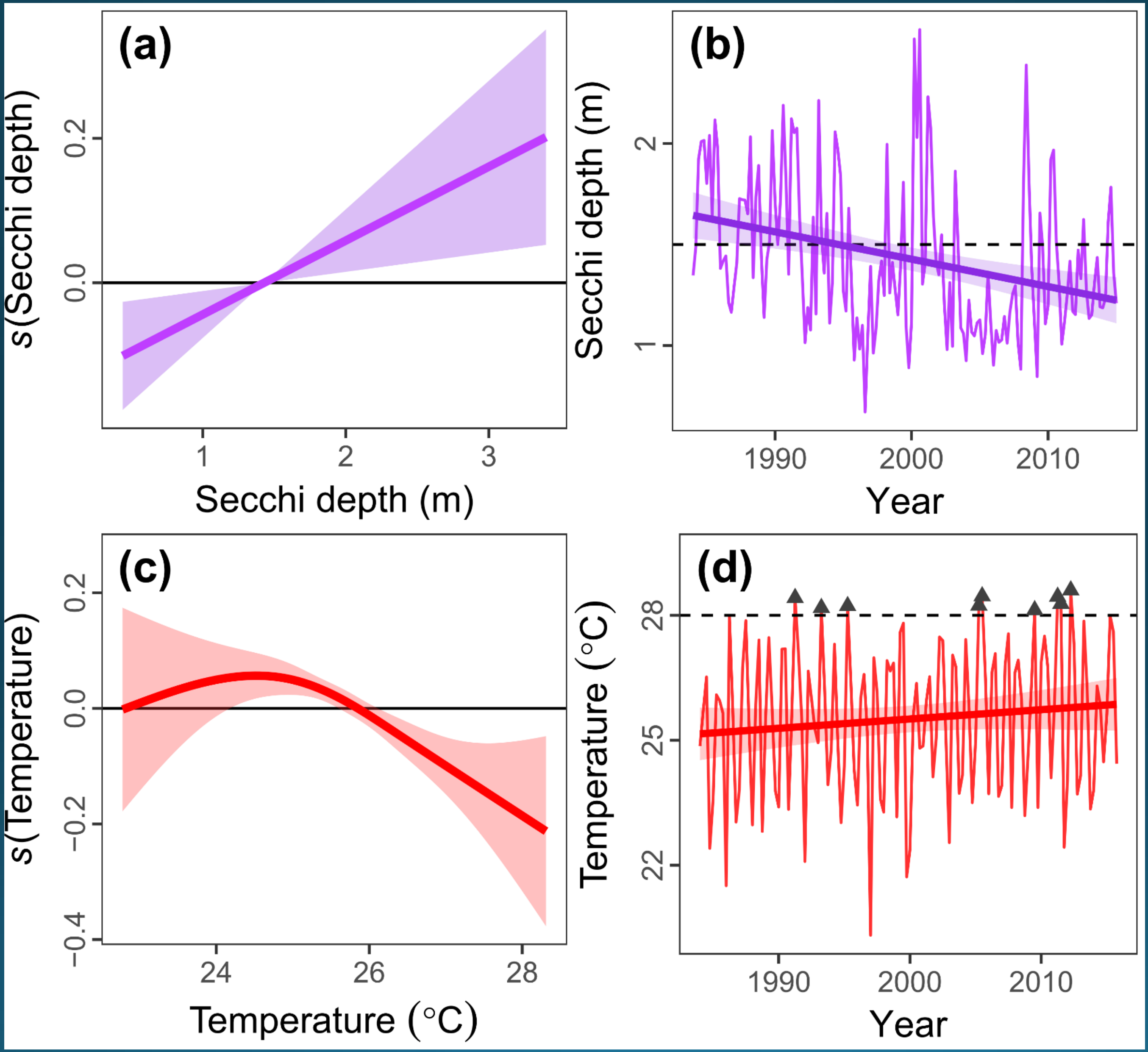
37 peer –reviewed papers in total

Eelgrass Changes 1984-2015



Lefcheck et al. 2017

Eelgrass Changes 1984-2015



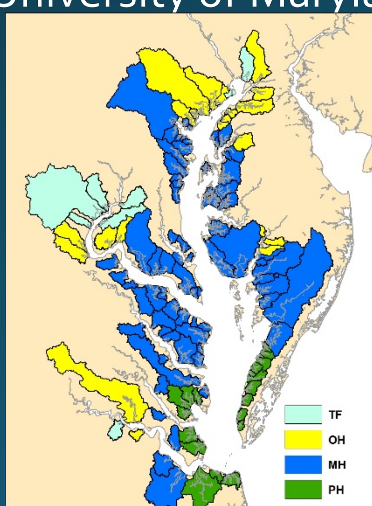
Lefcheck et al. 2017

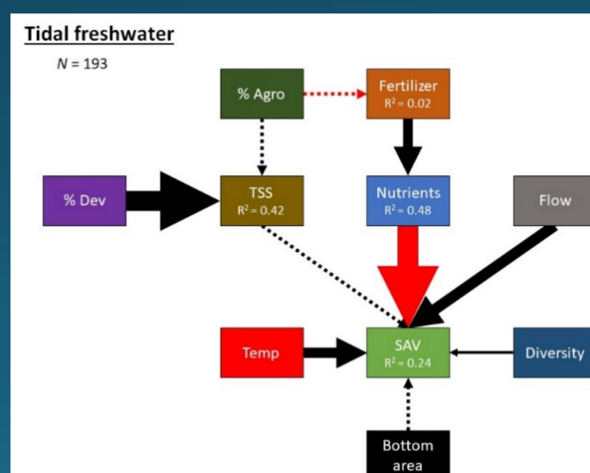
Conclusions

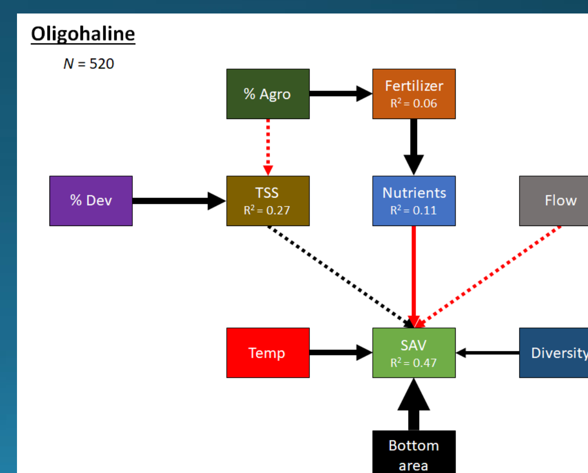
- Survey has been responsive to technological changes while maintaining continuity of data collection
- Survey has been responsive to management needs
- Funding has just kept up with inflation
- Annual Survey necessary for de-listing of Bay
- Annual Survey necessary for understanding processes influencing Bay SAV

Thanks – SAV SYN Team/EPA

University of Maryland CES, EPA, SERC, VIMS, USGS, MD DNR Texas A&M, SESYNC



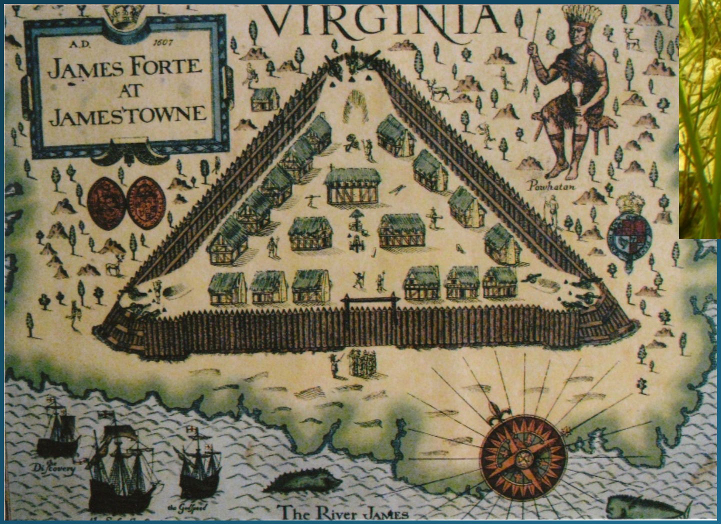




Submersed Aquatic Vegetation in Chesapeake Bay:

Sentinel Species in a Changing World

Just accepted to the journal BioScience!!



APPENDIX D:

Asking the right questions, getting the right answers

Questions and Answers
STAC Satellite SAV Monitoring Workshop

1. What is the relationship between the federal government and commercial satellite imagery (CSI)?

Acquiring high-resolution, commercial satellite imagery (CSI) at no cost is an option under the NextView License agreement between the National Geospatial-Intelligence Agency (NGA) and Maxar (previously DigitalGlobe, Inc). The NextView License was developed by the NGA to accommodate United States Government (USG) agencies, contractors, partners, and other entities that require CSI to support USG interests. The United States Geological Survey (USGS) assists with this arrangement by serving as the conduit to advance the CSI needs of the federal scientific community. The basic premise of the agreement is that any federal agency that *requires* satellite imagery from contracted commercial sources can request and obtain said imagery at no cost to the local agency. As 2017 updates to the Water Resource Development Act, which amends Section 117 of the Clean Water Act, called for an annual survey of Chesapeake Bay SAV, the U.S. Environmental Protection Agency (EPA) is required by statute to conduct an annual SAV survey. This makes it theoretically feasible for the EPA to now request and obtain the high-resolution CSI necessary for an annual SAV assessment in the Chesapeake Bay.

[From Neigh et al. 2013. High-Resolution Satellite Data Open for Government Research. Eos (94/13) 121-123: The National Geospatial Intelligence Agency (NGA), through commercial remote sensing space policy, has directed government acquisition of CI since 2003. These data are currently available to those who perform research that benefits U.S. government interests. In 2009, NGA began to use its online system to archive, retrieve, and distribute CI to federal civilian agencies through the Web-based Access and Retrieval Portal (WARP); data available through WARP are a subset of data archived by the commercial satellite operators. To be eligible for WARP access (https://warp.nga.mil), users are subject to verification and must have a federal .gov or .mil e-mail address. NASA is currently exploring options to support CI access for its funded scientists. Furthermore, the U.S. Geological Survey (USGS) has offered to serve as a conduit to assist with CI needs for the federal civilian scientific communities (NASA, Environmental Protection Agency, National Oceanic and Atmospheric Administration, USGS, etc.). CI requests can be submitted for archived imagery not available in WARP online via the USGS Commercial Remote Sensing Space Policy (CRSSP) Imagery Derived Requirements (CIDR) tool (https://cidr.cr.usgs.gov/). CIDR is a means of communicating and potentially tracking the status of federal civilian imagery needs. More information is available on the Web site.]

For the purposes of assessing SAV acreage in Chesapeake Bay, World View 3 CSI is the preferred resource. Maxar owns WorldView 3 and has an agreement with the federal government to provide requested data at no cost for federal scientific research purposes. As such, the following questions and answers are generally in reference to Maxar/WorldView and the process of obtaining CSI from that specific source rather than another satellite company.

2. Assuming CBP EPA will serve as NGA go-between, can we task Maxar to capture specific areas at specific times under specific conditions?

For the most part, yes. Once approved, any USG employee or entity working on behalf of USG interests can submit task orders through USGS. Specifications (e.g. % off nadir, preferred cloud cover, location of target area, date range, etc.) can be included in the task order. The WorldView constellation flies over the Chesapeake Bay region around solar noon, so time of day tasking is not an option.

3. How much advance notice is required for a task order?

A task order can be submitted up to 24 hours in advance, but the best strategy to collect a quality image for a target area is to offer multiple dates for acquisition pending suitable conditions. Filters (e.g. maximum cloud cover threshold) can be provided in the acquisition request with multiple dates so images of the target area won't be acquired if conditions are suboptimal. Once a suitable image is acquired, the additional date options provided can be cancelled, or multiple images could be collected on different days to provide multiple assessment images to support uncertainty estimates around the acreage in an area.

Turnaround time to view an image from the target date of acquisition is approximately 48 hours. Once received, the user can assess the quality of the imagery and make additional requests depending on the utility of the image for the given purpose. For example, if imagery of the upper Chesapeake Bay is requested on August 20th but the water quality that day isn't conducive to delineation of SAV beds (turbidity, algae bloom), the user is free to make additional requests/place additional task orders.

4. What is the exact process for submitting a task order, including contact information?

First, users must obtain authorization from NGA. To do so, a USG employee must authorize all temporary users, contractors, or volunteers. Carin Bisland served this role and submitted the request for VIMS access as an EPA employee. David Wilcox at VIMS requested access using the G-EGD online application. Bisland then received an email request for confirmation. Following confirmation, Wilcox received DigitalGlobe (now Maxar) credentials from rdoghelp@digitalglobe.com and access to https://evwhs.digitalglobe.com/myDigitalGlobe/.

Once authorized, targeting Maxar satellites is done through consultation with USGS staff and via the CIDR Tool (https://cidr.cr.usgs.gov/login). Detailed target regions for particular dates were created in consultation with Steven Hak at USGS and shared as KML files. Level 1B (radiometrically corrected) GeoTiff imagery with less than 50% cloud cover was requested.

Imagery from the Maxar commercial archive or imagery ordered from Maxar is then available using the https://evwhs.digitalglobe.com/myDigitalGlobe/ website with the above granted credentials OR through USGS and the EROS data center using the https://earthexplorer.usgs.gov/ website. To get access, complete the user registration at: https://ers.cr.usgs.gov/register/. See Appendix H and the email from Steven Hak at USGS for additional details. VIMS used Earth Explorer to download imagery used for the SAV project.

5. How many tasks can we submit each year?

There is no limit placed on tasking. Sufficient tasks can be requested to collect imagery across the entire Bay during the course of a year. That does not guarantee you will always get what you requested. Higher priority missions sometimes win out.

A good annual image acquisition strategy is to set up a calendar of acquisition targets and times according to SAV assessment needs. Multiple dates/times should be planned for each target in the event of poor conditions for any single date/time.

6. Can we get images over the entire bay or portions of the bay on a weekly basis? Monthly? Quarterly?

The data collection process is not limited by image requests. For the SAV monitoring program, we need a minimum of one good image of each region of the bay at appropriate times (ie. peak biomass) to support the SAV annual assessment. Multiple images of a region would be helpful to support uncertainty assessment. Seasonal imagery would be desirable for tracking species succession and species shifts.

Present limitations in the program are on assessment resources, however, and GIS analyst capacity. At this time, investments are made to complete hand delineation of one full set of images each year for the Bay. Development and application of AI algorithms for image interpretation are in the research phase but have shown plausibility for application in some systems. AI/Machine learning algorithms represent the future of improving efficiency with image interpretation.

7. What is the turnaround time on an image target time/location? (This is an issue of logistics in knowing how well an image meets program needs or if a better image needs to be collected.)

Rapid back-and-forth, same-day communications on satellite image collection is not possible like it is for aerial image acquisition from fixed-wing aircraft. Workshop participants that have some experience tasking for imagery suggested that Maxar can work with a range of view angles and a one-week window, which provides some flexibility for multiple dates being sampled for the same target pending image quality.

8. How are the data delivered? In what format? Is it encrypted?

WorldView 3 imagery is preferred. Acquisition and dissemination of the imagery and imagery products collected within the United States shall be restricted in accordance with law and regulation, therefore:

- Data would be accessed through an NGA license agreement, otherwise referred to as an End User License Agreement.
- Worldview 3 images are delivered as unprocessed sensor data.
- Data are zipped.
- Data are not encrypted but the acquisition and sharing of data requires the license agreement with the details evaluated on a case-by-case basis.
- Data are downloaded as basic geotiff images.
- Data needs to be pushed to an FTP site to avoid corruption. There are options to download data from Maxar and/or the US Geological Survey.
- CBP has a cloud account for modelling outputs, so the monitoring program could potentially be supported by using the same account for managing the satellite data. Considerations for this approach include the account is CBP owned, not EPA, so there

might be restrictions on its use. Another alternative is to have an Amazon bucket account. (cloud account, https://aws.amazon.com/s3/).
    - Important note on data management: Radiometric image correction requires 2x storage of original images – you maintain the original and the corrected version.
- Details for working with the Worldview-3 sensor data are available here: https://dg-cms-uploads-production.s3.amazonaws.com/uploads/document/file/95/DG2017_WorldView-3_DS.pdf

9. Is imagery/data delivered in usable state, or does it require additional processing prior to use, such as atmospheric correction and orthorectification?

Worldview 3 images are delivered as unprocessed (Level 1B) sensor data. Atmospheric correction, orthorectification, mosaicking, radiometric calibration (if necessary for automation) etc. are processed by the user.

- Geotiff images (Level 1B) are downloaded for research, not derived products.
- Additional processing workflow will need to be worked out, e.g., automating steps. Local experts are working mainly in Python such that targeting Python for automating work is a good target.

10. Would VIMS or CBP need improved/enhanced storage capacity? Would VIMS or CBP need to enhance computer security on access to the stored images?

Password protected *access* to geotiff images with guidelines for use is necessary. A password protected FTP site is recommended. USGS archives images requested for USG projects as a back-up data set on EROS (Level 1B imagery, not maps or other derivative products).
Note – The program should avoid getting the images in NITF format. NASA has noted this image format generates database issues resulting in added costs for the software necessary to work with NITF format imagery. This should not be a problem as long as the program does not use a DOD channel for the images.

11. Can we publish jpgs of satellite imagery on any public server? Can we publish portions of the photographs or land-masked versions of the images? Is there a format that is publishable? What is the process for getting permission to do so?

Currently, VIMS publishes both the aerial photograph and the derived map product on their SAV monitoring website. This provides transparency for regulatory agencies that approve or deny lease applications based on the presence or absence of SAV (e.g. for aquaculture). Consequently, funding from said agencies is contingent on the publication of both the aerial image and the derived map. If a transition to CSI-based SAV assessment is recommended, approval for CSI publication is necessary.

All data and imagery obtained either directly from Maxar (purchased) or through the NextView license agreement are subject to publication restrictions associated with the specific End User License Terms for each license type. Each image must be individually approved by NGA prior to publication, and approval is not guaranteed.
https://www.maxar.com/legal/product-terms-and-conditions
https://www.maxar.com/legal

The aforementioned licensing restrictions do not apply to derived products, however, so the hand delineated maps of SAV derived from the original satellite data are not subject to restriction for any reason.

Requests to publish an original true color image are coordinated with NGA through a data use approval request that includes the who, what, when, where, why and how and specifications of image use. All requests and uses are deemed negotiable. However, any consideration for publication and distribution of true color images that are obtained through a no-cost agreement will have to be addressed with NGA. Publication may be possible if criteria are satisfied that publication supports a government need. At this time, expect the public release of any true color image to be decided on a *case-by-case* basis. Recognize that the U.S. Government shall do its reasonable best effort to minimize effects on commercial image sales and uses. See Appendices E, F, and G for additional information.

12. What are possible options if we can't publish the imagery? (Could we overlay the maps derived from Worldview with another publicly available layer like Planet?)

This is a complicated question. To track progress towards restoration goals, the Chesapeake Bay Program only requires the derived product and acreage totals for each segment. It is the regulatory agencies (and possibly others) that make use of the aerial imagery itself.

If the imagery cannot be published, the program must either maintain its current protocol of aerial image acquisition, lose funding, or adapt other publicly available aerial (e.g. NAIP) or satellite imagery to the purpose. The resolution of alternatives may not be as high, but they may suffice for SAV bed verification at the least.

13. What are the repercussions associated with not being able to publish the imagery (and only publish the mapped SAV bed)? What agencies and missions would be affected?

There is a priority need for imagery to corroborate maps of SAV especially with respect to aquaculture siting. In Virginia, funding allocated to the survey is contingent upon availability of imagery (the funds recently allocated by the Virginia General Assembly goes straight to VIMS).

Concerns over any raw image availability, derived products, and impact to data needs of agencies and institutions were summarized in the 2017 Workshop Survey.

14. How much more work is needed before AI is ready for Chesapeake Bay SAV mapping? What is the level of accuracy now? What are the conditions that AI is tuned for now? Can we define where it is geographically viable and where it needs more work?

Workshop presentations provided the state of the science and highlighted the plausibility of the machine learning process in coastal waters. Significant tuning of the SAV detection algorithms for Chesapeake Bay is still required, but do-able within the next 3-5 years if funding is allocated. Sooner if significant funding is allocated.

Although the topic of AI was discussed at length during the first session, AI/algorithm development and consensus was set aside as an objective that could not be realized during this workshop. Regardless, the steering committee recommends that progress towards AI/machine learning/algorithm development for Chesapeake Bay SAV assessment continues on a parallel track as the tasking and calibration studies. It was observed during this workshop that the algorithms that have been developed for specific areas of the Chesapeake Bay work well when used in the same area during different times (95-99% accuracy). Those same algorithms do not work well, unfortunately, on different areas or regions of the Bay. The Chesapeake Bay is a very complex ecosystem with four salinity regimes, as many SAV community types, and a diverse physical environment, so a great deal more field data will be necessary to train algorithms for the unique environments all over the Bay.

One avenue for collecting this data would be to employ the SAV Sentinel Site Program. The SAV Workgroup developed an SAV Sentinel Site Program for Chesapeake Bay that will collect long-term SAV, habitat, and physical data at twenty locations throughout the Bay – five sites in each salinity regime. The SAV Sentinel Site Program was developed to require very little funding, so taking physical samples – core samples – may require additional funding for collection and processing. It also may be necessary for additional sites to be established, if the 20 Bay-wide sites are not adequate. There is a possibility that data needs could also be met through the Chesapeake Bay SAV Watchers Program – the CBP's volunteer SAV monitoring program. The data collected by SAV Watchers is more superficial than that planned at SAV Sentinel Sites, but it should be considered regardless.

15. What is the advantage to using AI/machine learning over hand-mapping?

When using AI to interpret images, a pixel is given a single classification value, which is why image resolution is important. AI is based on machine learning and SAV detection algorithms that are "trained" with patches of known habitat. Field data and aerial images can be used to train SAV detection algorithms. Once trained, AI can automate the SAV bed delineation process, decreasing the time and resources necessary to get from image to mapped product.

Though not necessarily of value for the SAV monitoring program because of the discontinuity in trends that it would create, AI is also more precise than hand delineation of SAV beds. AI works on a pixel by pixel interpretation basis, yielding more precise density and acreage values. AI eliminates the space between patches whereas hand delineation includes the space and just assigns a lower density classification to the overall bed. Both approaches have merit. And of course, while AI is more precise, boundary classification methods could be developed to more closely mimic hand delineation results.

In addition to precise density and cover estimates, more detailed data is possible from AI. With the addition of core sample/biomass data to further train SAV detection algorithms, carbon storage capacity and leaf area index can also be measured from radiometrically calibrated satellite imagery.

16. What are the logistical/scientific advantages of hand-mapping?

Logistically speaking, VIMS GIS analysts have perfected the art of hand delineating SAV beds, with decades of data and interpretation results to show for their efforts. Continuity of protocols and interpretation methodology is important for any monitoring program, so there is value in maintaining the status quo. Trained staff understand the nuances of image interpretation, and hand delineation provides instant information about the Bay – someone is looking at and interpreting the aerial imagery for every single tributary. If ground data is necessary to fully interpret an image, someone knows to request it.

Under any approach, human-based image review is necessary to detect change that may not be quantified by AI.

17. Can we train AI to map SAV beds using hand-delineation techniques to ensure continuity of data (ie. so that the numbers don't drop dramatically when each individual patch is mapped rather than the larger bed as a whole)?

Theoretically, yes, although boundary classification methods still need to be developed to more closely mimic hand delineation results.

18. What sort of comparison study would be necessary for CBP to move forward transitioning to satellite, or at least incorporating it?

VIMS GIS analysts stated during the first session of this workshop that good CSI was a comparable product to aerial photography, despite the slightly lower resolution. Hand-delineation using either source was the same and yielded the same results. Regardless, a calibration study comparing the hand-delineation of SAV beds from CSI and aerial photos is necessary. This study should include newly acquired data – not historical data – because newly acquired CSI will have been specifically tasked to capture SAV beds whereas archived data may not have been acquired under ideal conditions and therefore underestimate the value of CSI. For the study, fix or six sites should be selected from the satellite imagery that was acquired under sufficiently comparable conditions to aerial imagery. Each site should be interpreted from the satellite imagery by one VIMS analyst and from the aerial imagery by another VIMS analyst. After mapping the scene from one imagery source, the analyst should save the results for comparison and review the other imagery source, noting where changes would be made based on the additional information.

Once sufficient algorithms are developed to map areas throughout the Bay with AI, additional calibration studies should be conducted to determine the difference in results.

19. Will additional funding be needed for a comparison study? If so, how much?

Yes, based on the estimated time it would take to complete full Bay tasking and a calibration study, approximately $30,000 in additional funding would be necessary.

20. With regard to the fixed-wing aircraft image acquisition, how much will the new contractors (Midwest, based in Ohio) charge once their current contract is up in 2021? How much would other flight contractors charge?

The initial estimate is that costs of image acquisition could increase to 1.7X the current $150K if VIMS maintains their relationship with AirPhotgraphics/Midwest Aerial Photography. Estimates from other flight contractor are closer to 2X the current $150K. This will be important in justifying either incorporating (or not incorporating) satellite imagery into our CB SAV Monitoring Program.

21. Is there a place for drone imagery in the CB SAV Monitoring Program? Should it be an official part of the program, or used to spot check and ground truth as periodically available?

Drone imagery is already being used to spot check and ground truth aerial survey data and are commonly used by Riverkeepers and other watershed groups to conduct site specific SAV surveys (as well as for other reasons). However, strict laws are getting stricter by the day with flying drones for almost any reason. Presently, the application of drones is not envisioned as an official part of the SAV monitoring program.

22. What financial benefit will transitioning to satellite imagery provide, if any?

The CB SAV monitoring program has been under financial strain for decades and keeping the program solvent and active has been a herculean effort by the VIMS monitoring program director and individuals at the Chesapeake Bay Program. As such, several studies have been conducted recently to assess options in hopes of decreasing the program budget and ensuring its long-term sustainability. To date, incorporating or transitioning to a satellite-based approach is the most promising financially and scientifically. By taking advantage of the NextView license agreement (no cost CSI), the SAV monitoring program could potentially decrease budget needs for aerial photo acquisition, although the steering committee does not anticipate a full transition immediately; there are still several kinks to work out. In the long run, however, as satellite resolution continues to improve, access and tasking continues to improve, and AI continues to improve, there will be financial benefits associated with both the image acquisition and the processing.

23. What logistical benefit will a transition to satellite-based imagery provide, if any (ie. will it reduce the time spent coordinating flights, or will tasking be just as cumbersome?) for the annual baywide SAV assessment?

Although there appear to be long-term benefits to incorporating or transitioning to CSI for SAV assessment related to the potential for automation, logistical benefits at this time are still in question. Coordinating aerial photo acquisition is a cumbersome process, but it is a known process and the team at VIMS is comfortable with it. Tasking satellite image acquisition will be more cumbersome initially as the process is worked out, but eventually may be on par with flight coordination. With that said, contingency planning is always necessary in either case. Commercial satellite companies go bankrupt and satellites get decommissioned in short order, just as aerial flight contractors go out of business. A model that incorporates both is probably the best.

24. Does the steering committee, as a whole, recommend incorporation of satellite imagery into the CB SAV Monitoring Program?

At this time, rather than whole-heartedly endorsing the incorporation of CSI into the SAV monitoring program, the steering committee is recommending that additional steps be taken to answer lingering questions that will determine whether incorporating or transitioning to CSI is realistic and feasible for SAV acreage assessment and the Chesapeake Bay SAV monitoring program.

Based on the 2018 SAV survey when it was necessary to fill data gaps with multiple sources of imagery, we know that CSI can be used for SAV assessment if it is available. VIMS analysts stated that there was no difference between aerial photography and CSI when using their standard hand-delineation techniques. Extensive searches of the archived data, however, indicated that it would be impossible to map SAV throughout the Bay without a coordinated targeting and tasking operation. Issues such as glint, cloud cover, timing (not taken during peak biomass), and turbidity rendered many of the archived images inadequate for mapping SAV. Fortunately many of those issues may be alleviated with targeted acquisition. When ordering imagery, you can request off-nadir capture, adjust the view angle, and task specific days to accommodate the tide and biomass. It is uncertain at this time how many requests will be acquired.

To determine the exact steps and contacts necessary to begin tasking and data acquisition, the steering committee recommends that VIMS analysts conduct two primary exercises: test tasking of the whole Bay and a calibration/match-up exercise. It was the steering committee's original intent that much of this information would be determined or obtained during and between sessions, but once the complexity of the tasking became clear, we realized that it would require additional, funded time and effort beyond the capacity of this workshop. Fortunately, funding has already been allocated and the work has been initiated by VIMS analysts.

The recommended whole-Bay ***tasking exercise*** began in spring 2020 and continued throughout the summer SAV growing season. Tasking for the whole Bay at this time is important for several reasons: 1. It will establish acquisition zones based on tides and peak biomass. 2. It will provide an estimation of the time needed for assembling task orders. 3. It will promote familiarity with the steps involved. 4. It will allow calculation of a failure rate – the percentage of the Bay that was not able to be captured with CSI for various reasons. 5. It will facilitate the opportunity to conduct the calibration exercise because 2020 SAV data was also obtained via aerial photography.

The recommended ***calibration study*** will take place during winter 2020/2021 using CSI from the tasking exercise and the aerial photography from the 2020 aerial survey. Up to six test sites for comparison will be selected from the satellite imagery that was acquired under sufficiently comparable conditions. Each site will be interpreted from the satellite imagery by one VIMS analyst and from the aerial imagery by another VIMS analyst. After mapping the scene from one imagery source, the analyst will save the results for comparison and review the other imagery source, noting where changes would be made based on the additional information.

The steering committee recommended the Chester River, the York River, the Susquehanna Flats, Tangier Sound/Smith Island, and a tributary along the southern Eastern Shore for the calibration exercise, but recognizes that it will depend on what CSI acquired during the 2020 test tasking are adequate for SAV assessment. We know, again based on the 2018 SAV survey that the two source do provide comparable imagery that can be mapped with the same techniques but the subtle differences are important to note in a formalized study. If a transition to CSI does occur, all potential differences in photo interpretation must be accounted for. This calibration exercise will allow analysts to determine if tasking with specific requirements (ie. off nadir) improves the quality of the CSI and produces a closer match to the aerial photography.

The steering committee recommended that this work begin as soon as funding could be allocated through the CBP grants office, and fortunately that occurred in time for the summer 2020 SAV growing season. Working under that time frame and depending on the duration of the calibration study, the steering committee then recommends that the committee and principle participants reconvene in 2021 to assess progress and, based on that progress, make more definitive recommendations for the long-term evolution of the SAV monitoring program. After completing the recommended exercises, if it is discovered that any barriers that currently exist can be alleviated or at least accommodated, the steering committee and workshop co-chairs will recommend incorporating CSI into the monitoring program first as a hybrid effort and eventually to a full Bay effort, with aerial photography potentially reserved as back-up.

25. What support from the Chesapeake Bay Program (Office or Partnership or both?) will be necessary to transition to partial or complete use of satellite imagery?

As mentioned previously, funding will need to be allocated to run tasking and calibration exercises. The time it will take to work out the kinks will be significant. Aside from that, significant funding will be necessary for AI/algorithm development to eventually automate the process. Funding will be necessary both for the computer development aspect and the field data collection component. Until the delineation process can be automated, the full benefits of satellite won't be realized. The following outline defines a multi-year path towards integrating satellite imagery into the CBP SAV monitoring program with support from the CBP partnership.

2018: Use(d) Satellite data to fill gaps in aerial imagery (VIMS)

- Used existing imagery – it was not tasked for the purpose of SAV acreage assessment
- Hand delineated; same methods as with aerial imagery
- Issues with satellite included glint, cloud cover, lack of peak biomass data, turbidity
- Future satellite fixes: request off nadir, adjust viewing angle, task specific days for tide
- Overall where data were good, CSI was a completely comparable product

2019-2020: Conduct STAC Workshop and Complete Workshop Report (CBP/STAC)

- In 2019 and 2020, the entire Bay was mapped with aerial imagery through flight contractor.

2020: Aerial acquisition with complimentary CSI tasking exercise to determine flexibility and calibration study (VIMS)

- Write Federal Agency scope of work/requirements
- Task for FULL BAY as back-up and mimic.*
- Conduct a calibration exercise to determine if imagery produces similar results using 2020 CSI and aerial imagery.*
- Determine steps to obtain approval for CSI retention and publication.
- Continue conversations with NGA/EPA/DOD
  ***This work was funded following this STAC workshop and VIMS has been working through the steps since spring 2020.**

2021: Reconvene steering committee in 2021

- Review progress and make final recommendations

2022-2032: If recommended, incorporate CSI into SAV monitoring program, continue working to perfect AI for eventual automated mapping. Incorporation may be best as a gradual shift from aerial imagery with CSI as back up to CSI with aerial imagery as back up, gradually reducing the budget necessary for aerial imagery acquisition.

- Map using CSI and, once available, incorporate use of AI
- Hand delineate SAV beds where necessary

APPENDIX D:

Quantification of Blue Carbon Burial in Seagrass Ecosystems from High Resolution Commercial Imagery

Presented by Drs. Richard Orth and Jiang Li
Co-authors: Dr. Victoria Hill, Dr. Blake Schaeffer, and Megan Coffer

NextView License Information Paper

NextView License – NGA does not own the imagery; it is licensed to use the imagery under the terms of the NextView License

Commonly referred to as the NextView License, the End User License Agreement (EULA) of the EnhancedView Contract establishes the terms of use (*how data may be used*) for commercial imagery. The entire language of the license is captured on the back side of this sheet.

The NextView License applies to all data, imagery, imagery services, and imagery derived products. The license rights for use by the U.S. Government (USG) are established under the EnhancedView Contract and apply in perpetuity. Any derived product may be generated.

Subject to:	Copyright	NextView License
Imagery *	√	√
Imagery Derived Products (e.g. image city maps, reduced resolution images)	√	√
Derived Products (e.g. maps, line drawings)	**N/A**	**N/A**

*** Still subject to other laws and policies (e.g. EO 12333)**

Licensed Users

Members of the United States Federal Government including all branches, departments, agencies, and offices are licensed to use the imagery under the terms of the NextView License.

The U.S. Government (USG) may share the imagery with the following organizations, as temporary licensed users:

- USG Contractors & University Researchers supporting USG contracts
- State & Local Governments
- Foreign Governments & Intergovernmental Agencies
- Non-Governmental Organizations (NGO) & Non-profit Organizations

Rules for Use

USG Purpose

Imagery shared with organizations beyond the USG must support a USG purpose, with a direct benefit to the USG.

Educate

- USG must educate anyone who receives the data on the terms of the NextView License.
- Communicate restrictions for proper use, to ensure compliance with the license.

Product Creation

Licensed users may generate an unlimited number of hardcopies and softcopies for their use, as well as any derived product.

Marking - Copyright & License

Any new imagery or imagery derived products obtained through NGA must contain copyright and NextView License notice.

Marking

© 2010 DigitalGlobe
NextView License

Access & Sharing

- A USG employee or person authorized by the USG must authorize all temporary users, contractors, and volunteers.
- Control access to imagery by implementing access controls (e.g. password protection).
- Sponsoring Federal Agencies must maintain USG oversight of imagery distribution, end users, and downstream use.
- Take local action, if aware of any improper use.

Business Impact

- USG shall use its reasonable best efforts to minimize the effects on commercial sales.
- Do not share imagery with anyone planning to sell it or use it for commercial gain.

Restrictions (DO NOT):

- Publish imagery in printed reports without direct USG benefit.
- Transfer imagery to commercial entities for commercial use.
- Release imagery to third parties for non-US Government use.
- Host reports on websites containing NextView imagery without copyright or license.

Seek Additional Guidance, when considering:

- Sharing imagery with non-licensed users, foreign governments, or for crowdsourcing.
- Authorizing the release of imagery to media (local, state, or national) or public.
- Posting imagery on NGO or USG systems.
  - Hosting imagery or products on web sites by NGOs or non-profit organizations.
  - Sharing imagery on websites to generate derived products for public release.
  - Posting to sites where imagery and products can be further disseminated.

NextView Imagery End User License Agreement (EULA)

a. **General Terms**

1. This **clause applies to all unprocessed sensor data and requirements-compliant processed imagery, imagery services, imagery-derived products** and imagery support data licensed under this Contract. No other clauses related to intellectual property or data rights of any sort shall have any effect related to the unprocessed sensor data and requirements-compliant processed imagery, imagery services, imagery-derived products and imagery support data delivered under this Contract.

2. All license rights for use of the unprocessed sensor data and requirements-compliant processed imagery, imagery services, imagery-derived products and imagery support data provided to the U.S. Government purchased under this NGA contract are in perpetuity.

3. **Licensed users may generate an unlimited number of hardcopies and softcopies** of the unprocessed sensor data and requirements-compliant processed imagery, imagery services, imagery-derived products and imagery support data for their use.

4. (i) **Licensed users may generate any derived product** from the licensed unprocessed sensor data; and requirements-compliant processed imagery, imagery services, imagery-derived products and imagery support data.

(ii) Unprocessed sensor data and requirements-compliant processed imagery, imagery services, imagery-derived products and imagery support data licensed under this NGA contract have **no restrictions on use and distribution, but shall contain the copyright markings**.

b. Licensed Users

1. The imagery **may be used by the U.S. Government (including, all branches, departments, agencies, and offices)**.

2. The **U.S. Government may provide the imagery to the following organizations:**

State Governments
Local Governments
Foreign Governments and inter-governmental organizations
Non-Governmental Organizations (NGO) and other non-profit organizations

3. In consideration for the flexibility afforded to the U.S. Government by allowing unprocessed sensor data and requirements-compliant processed imagery, imagery services, imagery-derived products and imagery support data to be shared, the **United States Government shall use its reasonable best efforts to minimize the effects on commercial sales**. Acquisition and dissemination of imagery and imagery products collected within the United States shall be restricted in accordance with law and regulation.

APPENDIX F:

NextView License Sharing and Release Guidance

NextView License Sharing and Release Guidance

NextView License Requests for Sharing and Release – NGA reviews requests to share and release commercial imagery on a case by case basis to maintain license compliance

Under the NextView License, members of the United States Federal Government (USG) and NGA gather information and clarify the scope of initiatives / projects using commercial imagery.

Key Factors to Capture Project Scope

USG personnel initiate requests to share and release NextView licensed imagery beyond the USG, with potential for public release, by providing the following information for NGA to review.

Urgency and timeframe – provide release dates with rationale to help prioritize all requests

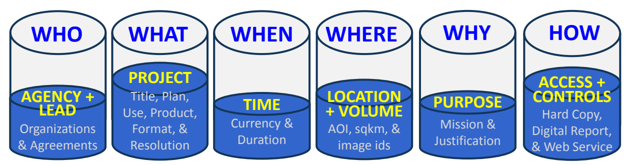
WHO (USG lead/official; USG agency/office; contract/agreement; receiving organizations)

WHAT (Project title; description; use; imagery/product type; format; resolution)

WHEN (Time of imagery collections; date and duration of sharing or web posting)

WHERE (Geographic coverage of areas of interest (AOIs); sqkm; and image ids)

Capturing Project Scope



WHY (USG purpose/mission; justification capturing USG purpose and direct USG benefit of sharing and/or release of commercial imagery or imagery derived products)

HOW (Method of sharing/release: hard copy, digital reports, briefs, website URL, web service; access controls: password protection, IP limits, user account restrictions, bounding boxes)

Levels of Release

	Description	Scope	Coordination	Marking
NextView License	Use by USG (all offices, agencies, departments, and branches); share in support of USG purpose	USG uses its reasonable best efforts to minimize effects on commercial sales	End User License of EnhancedView Contract	*© 2017 DigitalGlobe, NextView License*
Limited Public Release	Public distribution for emergencies, disasters, and humanitarian efforts; limited to 30 days per request	30 day exception to NextView License; after 30 days remove from public access and handle in accordance with NextView License	NGA contractually required to notify vendor within 24 hours after releasing imagery	*© 2017 DigitalGlobe, NextView License*
Coordinated Public Release	Public release coordinated for use in reports, briefs, websites, and other methods	Typically for 1-2 images	NGA coordinates with vendor for business impact input	*© 2017 DigitalGlobe*
License Uplift	Full public dissemination by USG without restrictions	No product type or format restrictions; annual volumetric limit	NGA communicates decisions to vendor by project title, image ids, and sqkm	*Imagery courtesy of DigitalGlobe*

NOTE: Same day requests for public release require USG agency, project title, use, time, date, AOIs, image ids, sqkm, method of release, and sample products to expedite response.

Assessing Business Impact

USG missions drive a broad range of sharing under the NextView License. The NextView License states that the USG shall use its reasonable best efforts to minimize the effects on commercial sales. NGA EnhancedView Program Management Office developed a framework for public release to assess the business impact of requests to share and release commercial imagery in order to maintain license compliance.

Key Elements

NGA EnhancedView Program assesses business impact with these elements:

Value
- *Competitive Environment*
- *Commercial Interest (target, geography, & time)*

Extent of Exposure
- *Volume*
- *Duration*
- *Access Control*

Geospatial Scope
- *Location*
- *Currency*

Image Differentiation
- *Resolution*
- *Format*
- *Metadata*

The dynamic and fluctuating operating environment for this framework necessitates review of the case by case circumstances of each request.

The inherent value of commercial imagery is the visual information captured in the image

The NextView License applies to imagery and imagery derived products which contain an image or look like an image. These definitions differentiate the line of demarcation for the license.

Imagery Derived Product - product created from imagery with characteristics of the imagery, regardless of file format (e.g. image city maps, reduced resolution images)

Derived Product - product derived from imagery that no longer looks like an image or retains image characteristics (e.g. maps, line drawings)

Seek Additional Guidance from the following parties, when considering:

License Compliance - NGA EnhancedView Program Management Office for scope and impact [NextView_License@coe.ic.gov; NGANextView_License@nga.mil]
Legal Interpretation - NGA Office of the General Counsel for legal opinions [GCP@coe.ic.gov]
Intelligence Issues - NGA Analysis Foreign Disclosure [ForeignDisclosure@coe.ic.gov]

Limited Public Release for Emergencies, Disasters, & Humanitarian Effort

30 Day Exceptions to the NextView License

In support of emergencies, disasters, and humanitarian efforts, the **NGA may disseminate and/or post on open web sites imagery** licensed under this contract regardless of whether the recipients are within the NextView license user groups. **The imagery will contain copyright notice and NextView license notice.** After 30 days, the imagery will be handled in accordance with the NextView license.

License Uplift for Full Public Disclosure

A limited amount of NextView imagery uplifted to permit full public dissemination by the U.S. Government without restrictions. There are no restrictions on product type or format. All uplifted rights granted herein for use of the unprocessed sensor data and requirements compliant processed imagery and imagery derived products provided to the U.S. Government purchased under this NGA contract are in perpetuity.

For additional details on license compliance refer to NextView License Information Paper

APPENDIX G:

NGA Framework for Public Release: Reviewing requests to release NextView licensed imagery into the Public Domain

NGA NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

Framework for Public Release:

Reviewing requests to release NextView licensed imagery into the Public Domain

The release of NextView licensed imagery and imagery derived products into the public domain has grown dramatically over the last few years and prompted NGA to take action to mitigate risk

NGA establishes this framework to review public release requests

As EnhancedView Contract holder, NGA bears primary responsibility for ensuring end user license compliance and associated license interpretation risk

NGA works with USG entities to gather information to:

- clarify the scope of initiatives and projects
- evaluate exposure against a common set of factors (who, what, when, where, why, how)
- assess potential business impact and if necessary work with the vendor for input
- render a decision on license compliance

NGA offers to meet with all parties once a quarter or more often as needed to review initiatives and discuss options to maintain license compliance

A goal of this framework is to assess business impact of public release [a license requirement] and alleviate potential conflict prior to escalation

Releasing any USG licensed information into the public domain requires review

Effective June 2017, releasing or posting NextView licensed imagery and imagery derived products in the public domain without prior NGA review is not in compliance with the NextView License and may result in loss of access to imagery

USG personnel initiate public release requests for NextView licensed imagery and imagery derived products by sending an email to the following NGA distribution lists:

NGANextView_License@nga.mil
NextView_License@coe.ic.gov

NGA is ultimately responsible for demonstrating USG due diligence in meeting the contractual requirements of the NextView License; the USG shall use its reasonable best efforts to minimize the effects on commercial sales

NOTE: This framework provides guidance to maintain NextView License compliance. Additional reviews may be required by NGA or the requesting organization depending on justification of the public release.

6/6/2017 2:00 PM

APPENDIX H:

Summary of steps and sample text necessary to obtain authorization from NGA, target Maxar satellites, and access imagery

Accessing Maxar Commercial Imagery through the NextView License

The NextView License provides a method for the U.S. Government to access Maxar commercial satellite data. This document shares the steps that were taken to obtain authorization from NGA, who manages the license; target acquisition of Chesapeake Bay areas, and access the resulting imagery. Please review the attached set of documents that cover the NextView program, Maxar's satellite products, and associated restrictions in more detail. **Note that use and sharing of imagery acquired through the NextView License is tightly controlled**.

1. Obtaining Authorization from the National Geospatial-Intelligence Agency (NGA)

A U.S. Government employee must authorize all temporary users, contractors or volunteers. Carin Bisland served in this role and submitted the request for VIMS access as an EPA employee. David Wilcox (SAV Monitoring Program Manager at VIMS) requested access using the G-EGD online application. Carin Bisland received the following request for her confirmation.

> Attn: Government POC,
>
> Please confirm that the User Cc:'d above (David Wilcox) REQUIRES access to these services.
>
> In addition, you must provide/approve the following information provided by the user:
>
> - Current Period of Performance/Option Year CONTRACT/ Delivery Order (or FEDERAL GRANT) NUMBER (CB 96343701)
> - EXPIRATION DATE (2022-05-16 UTC)
> - AREA OF INTEREST (Chesapeake Bay)
> - JUSTIFICATION (I work on a contract for the EPA Chesapeake Bay Program Office. EPA is required, under Section 117(1)(3) as amended to conduct an annual survey of SAV in the Chesapeake Bay (exact language is "ANNUAL SURVEY.—The Administrator shall carry out an annual survey of sea grasses in the Chesapeake Bay"). We have been doing this annual survey since the 1970s using fixed wing aerial photography and are researching the use of satellite imagery to enhance or replace this technology. To do this research, a data acquisition request was submitted in early March (DAR ID 556).)
>
> We will decline non-responsive User account requests approximately 03 days from the initial request.
>
> Your understanding and cooperation with our procedures is appreciated.
>
> Thank You,
>
> NGA, G-EGD Admin

Carin Bisland responded with this confirmation.

> All,
>
> See my responses provided below. Also, see attached email that I sent earlier today and on Friday.
>
> David Wilcox REQUIRES access to these services to do a comparative analysis of fixed wing aerial surveys with satellite imagery. EPA is required to monitor SAV extent annually as described in Section 117 (1)(3) of the Clean Water Act as amended by WRDA "ANNUAL SURVEY.—The Administrator shall carry out an annual survey of sea grasses in the Chesapeake Bay." Virginia Institute of Marine Sciences (VIMS) has been doing these surveys since the 1970s and is the current recipient of the EPA grant CB 96343701 ending 5/24/2022. This access is required so that the grantee (David Wilcox) can compare the two technologies so that EPA can evaluate using satellite imagery to enhance or replace fixed wing aerial photography. EPA will be looking at the feasibility, the potential cost savings to the federal government, and consistency/availability of data across the Chesapeake Bay and its tributaries. Without this access, it puts EPA in jeopardy of not being able to comply with Section 117(1)(3) of the Clean Water Act as amended.
>
> Carin Bisland, Chief
> Partnerships and Accountability Branch
> EPA Chesapeake Bay Program Office

David Wilcox then received DigitalGlobe credentials from rdoghelp@digitalglobe.com and access to https://evwhs.digitalglobe.com/myDigitalGlobe/.

2. Accessing Maxar Commercial Imagery

Imagery from the Maxar commercial archive can be downloaded directly from Maxar using the https://evwhs.digitalglobe.com/myDigitalGlobe/ website using the granted credentials or through USGS and the EROS data center using the https://earthexplorer.usgs.gov/ website. To get access, complete the user registration at: https://ers.cr.usgs.gov/register/. See the email below from Steven Hak at USGS for additional details. VIMS used Earth Explorer to download imagery used for the SAV project.

> Good afternoon David, please follow these steps to access commercial imagery. Virginia Institute of Marine Sciences (VIMS) has been granted access to DigitalGlobe NextView commercial imagery to task/acquire new collects and archived imagery on behalf of the Environmental Protection Agency (EPA).
>
> *Special note image sharing must support a U.S Government purpose with a direct benefit for the EPA.

ACQUIRING NEW/ARCHIVED COMMERCIAL SATELLITE IMAGERY

Discover Archived DigitalGlobe Data

You can view existing coverage of your area of interest at: https://discover.digitalglobe.com/ .

DG's Discover tool allows you to draw a shape on a map, enter a location name, or upload coordinates or a shape file to search for imagery of your area of interest. You will see a list of image scenes that cover some or all of your AOI, if coverage is available. You can also view browse images for any results listed. The Discover tool can only be used to check for data availability – it cannot be used to order DG data. It is recommended you make a list of image IDs you may want to order through either of the methods described below.

Search for & Order Archive & New DG Data at the U.S. Geological Survey

The USGS houses many types of data and products at its Earth Resources Observation and Science Center. For more details, visit: https://eros.usgs.gov/find-data. To establish an account allowing you to search for and order DG data, please do the following:

1) Complete User Registration at: https://ers.cr.usgs.gov/register/ (confirmation sent by email).
2) Search USGS holdings and order archive DG data at: https://earthexplorer.usgs.gov/.

If USGS doesn't have specific archive DG data you find during a Discover search or if no data at all is available for your AOI, you may order specific data or request new DG data collection with the USGS CRSSP Imagery Derived Requirements Tool at: https://cidr.cr.usgs.gov/login.

For questions about Earth Explorer, the CIDR Tool, or USGS data holdings, contact the EROS Center at cidr@usgs.gov.

In addition I attached within this email the NextView License (limitations on using/sharing DG data, and DigitalGlobe base product FAQ .

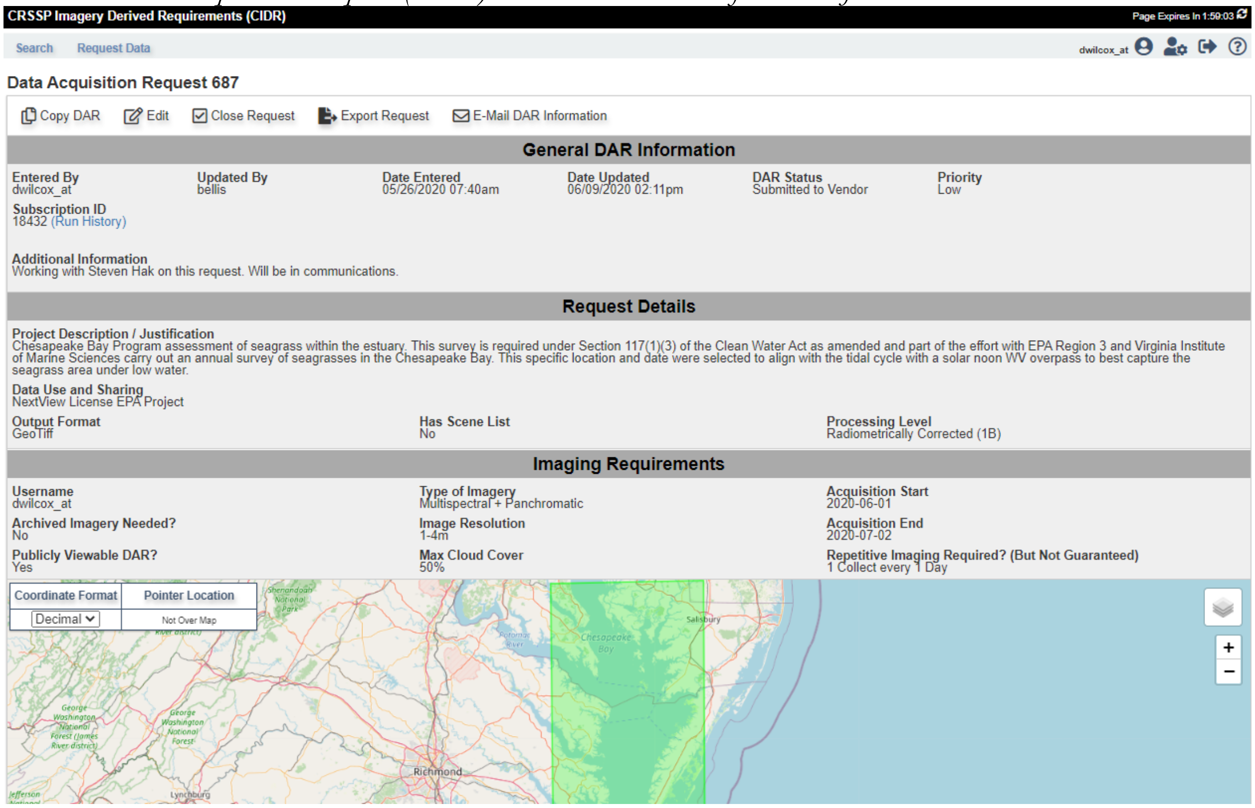
R/S, Steven

J. Steven Hak
Source Operations and Management
U.S Geological Survey
jhak@usgs.gov
james.s.hak@nga.mil

3. Targeting Maxar Satellites

It is possible to request that areas be specifically targeted by Maxar satellites. This is done through consultation with USGS staff and via the CIDR Tool (https://cidr.cr.usgs.gov/login).

The First Data Acquisition Request (DAR) Submitted via CIDR for the Project


CRSSP Imagery Derived Requirements (CIDR) — Page Expires In 1:59:03

Search | Request Data — dwilcox_at

Data Acquisition Request 687

Copy DAR | Edit | Close Request | Export Request | E-Mail DAR Information

General DAR Information

Entered By	Updated By	Date Entered	Date Updated	DAR Status	Priority
dwilcox_at	bellis	05/26/2020 07:40am	06/09/2020 02:11pm	Submitted to Vendor	Low

Subscription ID
18432 (Run History)

Additional Information
Working with Steven Hak on this request. Will be in communications.

Request Details

Project Description / Justification
Chesapeake Bay Program assessment of seagrass within the estuary. This survey is required under Section 117(1)(3) of the Clean Water Act as amended and part of the effort with EPA Region 3 and Virginia Institute of Marine Sciences carry out an annual survey of seagrasses in the Chesapeake Bay. This specific location and date were selected to align with the tidal cycle with a solar noon WV overpass to best capture the seagrass area under low water.

Data Use and Sharing
NextView License EPA Project

Output Format	Has Scene List	Processing Level
GeoTiff	No	Radiometrically Corrected (1B)

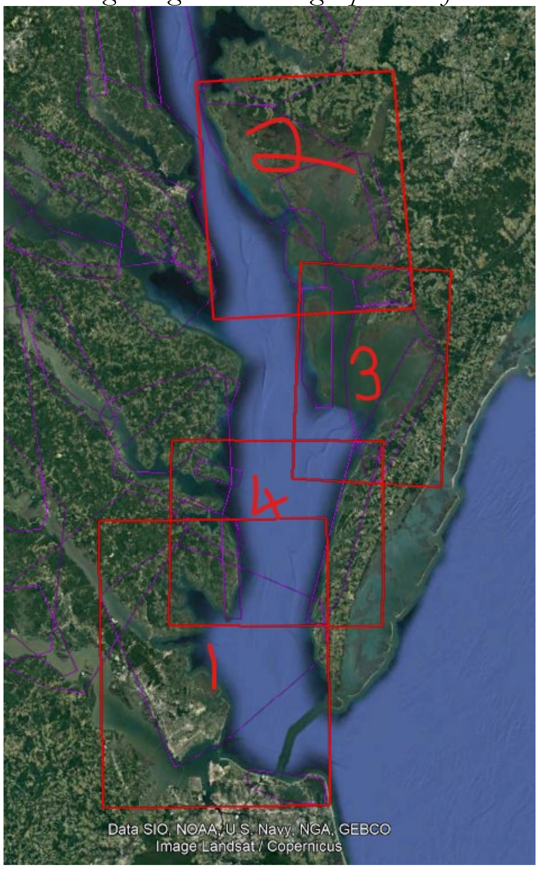
Imaging Requirements

Username: dwilcox_at	Type of Imagery: Multispectral + Panchromatic	Acquisition Start: 2020-06-01
Archived Imagery Needed?: No	Image Resolution: 1-4m	Acquisition End: 2020-07-02
Publicly Viewable DAR?: Yes	Max Cloud Cover: 50%	Repetitive Imaging Required? (But Not Guaranteed): 1 Collect every 1 Day

The request covers a full month and a large area. Detailed target regions for particular dates were created in consultation with Steven Hak at USGS and shared with him as KML files. Note that processing level 1B (radiometrically corrected) GeoTiff imagery with less than 50% cloudcover is requested.

For SAV coverage tide stage is critical. The Maxar WorldView satellites seem to capture the Chesapeake Bay close to solar noon and cover a swath approximately 10 nautical miles in width. Therefore, a set of rectangular targets were created to cover the SAV in the Bay.

Four Target Regions Covering a portion of the lower Bay.



These areas were then targeted to coincide with low tide, developing a schedule (below) for the first month of acquisition. Since the images were being acquired near solar noon, off-nadir imagery is important to avoid sun glint.

Target	Dates
Target 1	6/1, 6/2
Target 2	6/8, 6/9, 6/10
Target 3	6/11, 6/12
Target 4	6/13, 6/14
Target 1	6/15, 6/16
Target 2	6/23, 6/24, 6/25
Target 3	6/26, 6/27
Target 4	6/28, 6/29
Target 1	6/30, 7/1

Many factors control whether an area will be acquired. Commercial and emergency response targets are given higher priority. Cloud-free days are relatively rare. For example, there were approximately eight relatively cloud-free days in June. Targets and dates were configured for one month at a time. USGS would like at least one week notice of any requested changes in the schedule.