Wetland Classification Study: Phase 2
Cooper River, South Carolina
Final Report to the U.S. Army Corps of Engineers, Charleston District

September 20, 2017

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Preface

This study was performed by the Environmental Laboratory (EL) of the U.S. Army Engineer Research and Development Center (ERDC) and was funded by the U.S. Army Corps of Engineers. The report was prepared by Molly Reif, Environmental Systems Branch, ERDC-EL, Vicksburg, MS. The work described in the report was performed by Molly Reif under the general supervision of Mark Messersmith, Planning and Environmental Branch, USACE-Charleston District, Charleston, SC.

Executive Summary

This work follows on a previous study (Reif, 2013), "Wetland Classification Study Cooper River, South Carolina Final Report to the U.S. Army Corps of Engineers, Charleston District" that was completed for the Charleston Harbor Post 45 Feasibility Study in which dominant wetland plant communities were mapped using WorldView-2 satellite imagery from 2010 and 2011 to assist with potential impact assessment and used to delineate vegetative transition zones corresponding to salinity regime. This new report provides an updated wetland plant community map using WorldView-3 satellite imagery from January 2017 as well as a change detection assessment between the two maps. The data are intended to track potential shifts in wetland plant communities, especially between freshwater and saltwater species, as well as provide a benchmark for change prior to construction. In addition, this mapping effort used the same classification approach and schema as in the previous study to minimize errors and to assist with long-term monitoring needs. A classical change detection algorithm was used to difference the classification maps, and a fuzzy logic approach was used to help minimize issues with overlapping classes or imprecise community designations. More specifically, the fuzzy logic approach was used to illustrate degrees of change or the likelihood for class changes between the two dates. In summary, a little over 50% of the area experienced no change, while 40% experienced very unlikely and unlikely changes due to class overlap, and approximately 6% of the area experienced possible or somewhat likely class changes. Detailed class changes are as follows:

- A decrease in ITEM Freshwater Mix area - 11.51% to 8.88%; class changes were mostly to ITEM Freshwater Mix w/Big Cordgrass or Cattail and ITEM Big Cordgrass Mix
- A decrease in ITEM Freshwater Mix w/Big Cordgrass or Cattail area – 14.05% to 11.10%; class changes were mostly ITEM Freshwater Mix and ITEM Big Cordgrass Mix
- An increase in Floating Leaf Vegetation area – 0.08% to 0.19%; class changes were mostly to ITEM Freshwater Mix and ITEM Freshwater Mix w/Big Cordgrass or Cattail
- A decrease in ITEM Big Cordgrass Dominant area – 2.29% to 1.70%; class changes were mostly to ITEM Big Cordgrass Mix, ITEM Black Needlerush Dominant, ITEM Black Needlerush Mix, and ITEM Smooth Cordgrass Dominant
- An increase in ITEM Big Cordgrass Mix area – 5.23% to 10.76%; class changes were mostly to ITEM Black Needlerush Mix and ITEM Smooth Cordgrass Dominant
- An increase in ITEM Black Needlerush Dominant area – 32.24% to 32.89%; class changes were mostly to ITEM Black Needlerush Mix
- An increase in ITEM Black Needlerush Mix area – 17.50% to 21.30%; class changes were mostly to ITEM Black Needlerush Dominant
- A decrease in ITEM Smooth Cordgrass Dominant area - 14.77% to 1305%; class changes were mostly to ITEM Black Needlerush Dominant
- A decrease in ITEM Smooth Cordgrass Mix area – 2.34% to 0.14%; class changes were mostly to ITEM Black Needlerush Dominant and ITEM Black Needlerush Mix

While most of the class changes were between overlapping classes, evidence of some class confusion or changes exists between such classes as ITEM Big Cordgrass Dominant and Mix classes which experienced interplay with ITEM Black Needlerush Mix, ITEM Black Needlerush Dominant, and ITEM Smooth

Cordgrass Mix classes. Some of this change was observed along the edge of the marsh along the Cooper River channel itself. Regardless of some confusion between classes, the overall change trends are stable, especially in the extreme northern and southern ends of the area of interest. Block statistics were calculated to illustrate this, showing the mean degree of possible change values in longitudinal blocks along the area of interest. While the northern and southern ends of the study area showed mean change likelihood values close to 0, the middle section, which corresponds to the transition from brackish to fresh zones, shows higher mean change likelihood values. Thus, that part of the study area may be more dynamic and apt to exchanges between certain vegetation classes depending on seasonal and annual cycles. It has been acknowledged that the area of interest along the Cooper River has remained stable in terms of habitat changes in recent history, and the period between 2010/2011 to 2017 reflects this trend. Yet, it also highlights where changes may tend to occur such as along channel edges and the central part of the study area in the transition zone from brackish to fresh, which may prove useful for assessing future impacts.

Introduction

This work follows on a previous study (Reif, 2013), "Wetland Classification Study Cooper River, South Carolina Final Report to the U.S. Army Corps of Engineers, Charleston District" that was completed for the Charleston Harbor Post 45 Feasibility Study. That report discusses methods used to identify dominant wetland plant communities along the Cooper River, SC using satellite image analysis in conjunction with seasonal field work. Please see that report for information on mapping methods and findings which are duplicated for this mapping effort. In summary, the previous mapping effort identified the following data sources: Digital Globe WorldView-2 (WV-2) 8-band imagery (2010-2011), National Agriculture Imagery Program (NAIP) orthoimagery (2011), U.S. Geological Survey orthoimagery (2011-2012), light detection and ranging (LiDAR) elevation data (2011), The Citadel Rice Field Study data (1989-2006), and the South Carolina Department of Health & Environmental Control's Ocean & Coastal Resource Management Study data (2006). The USACE Army Engineer Research and Development Center's Environmental Laboratory (ERDC-EL) evaluated the datasets and determined that they were suitable to identify and map dominant wetland plant communities. Two field surveys of the study area were conducted, December 3-6, 2012 and June 4-6, 2013, to collect site data for training (supervised classification) and validation to correspond with the seasonal timeframes of the historic WV-2 imagery (December 9, 2010 and May 25, 2011). The maximum likelihood classification technique was used to identify 14 classes, 12 of which are wetland classes, ranging from freshwater (northern study area) to brackish (central study area) to saltwater (southern study area) communities (Figure 1). A total of 54,801.77 acres were mapped (excluding Woody Mix, which includes both low-lying and non-wetland forest).

The purpose of the new study, conducted in 2016-2017, is to once again determine wetland extent and composition in order to compare changes along a specified area of interest of the Cooper River, SC between the two dates. Since it has been documented that the area of interest may experience potential salinity changes due to channel modification proposed in the Charleston Harbor Post 45 Project, the District contacted the ERDC-EL to assist with monitoring potential project impacts. As such, wetlands mapping has been proposed for pre-construction, post-construction +1 year, post +3 years, and post +5 years. The same mapping methods were employed to classify imagery for the identification of dominant wetland plant communities in salt, brackish, and freshwater marshes as performed during the feasibility phase. The data will be used to track potential shifts in wetland plant communities, especially between freshwater and saltwater species, as well as provide a benchmark for change prior to construction. This report compares the two map classifications and presents change detection results prior to construction.

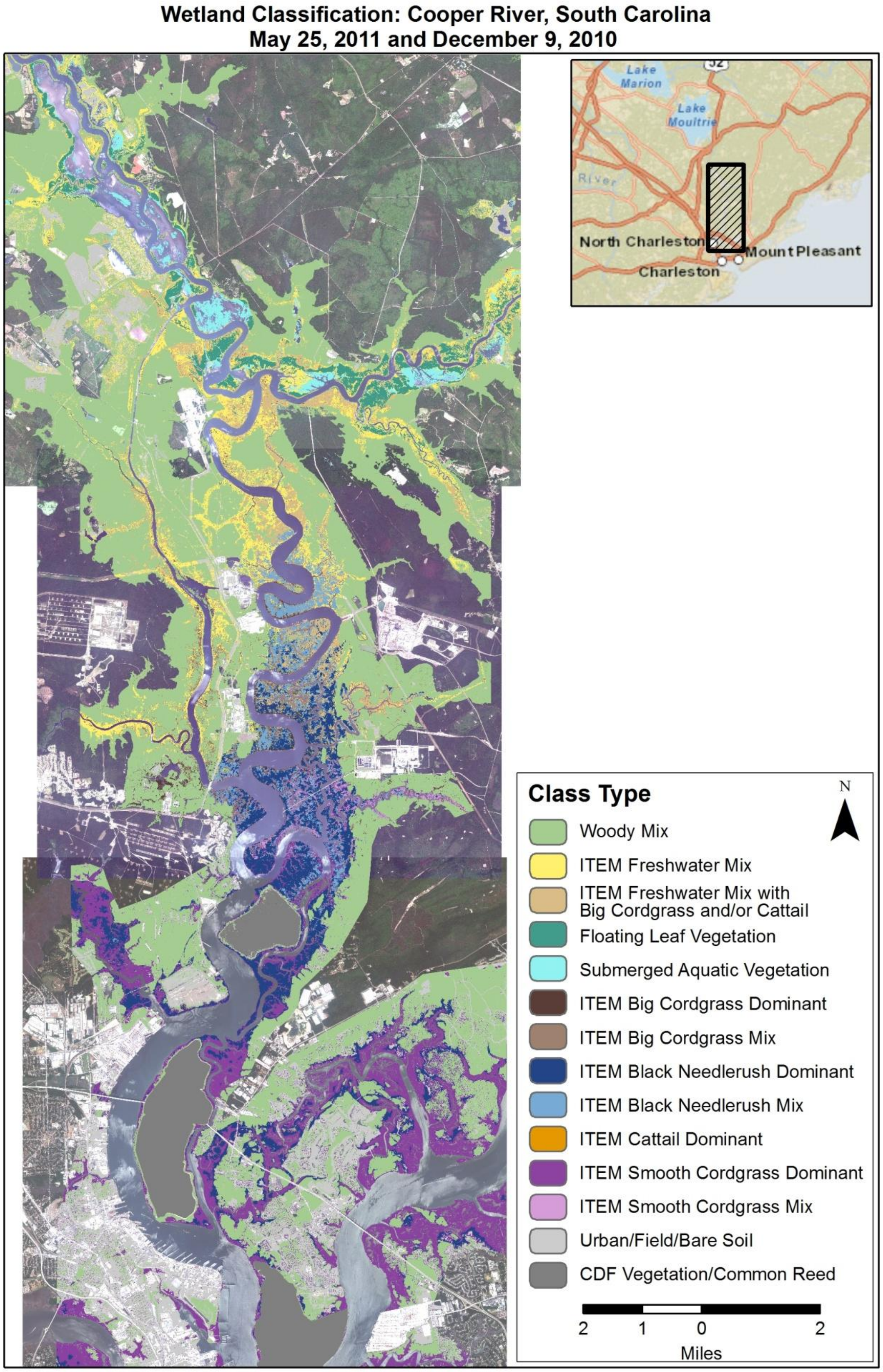


Figure 1. Classification map using the May 2011 and December 2010 WV-2 imagery

Methods

Data and Pre-processing

WorldView-2, 8-ft image scenes (May 25 and June 14 2016) and WorldView-3, 6-ft image scenes (Jan 24 2017) were delivered in geocorrected format in which individual scenes were geometrically corrected (orthorectified) to control points using the WorldView RPC geometric model in ERDAS Imagine software using the U.S. Geological Survey's National Elevation Dataset for the elevation information. Image scenes were provided in the projection, NAD 1983 State Plane South Carolina FIPS 3900 Feet International, with 6-foot spatial resolution and processed by the USACE Wilmington District (POC: Spencer Roylance). Since the May and June 2016 imagery had pop up clouds and cloud shadows over the area of interest, the January 2017 imagery was used as the primary data source for the classification. As in the previous mapping effort, image scenes required radiometric calibration and atmospheric processing prior to analysis. This is because in order to analyze surface reflectance in an image, the influence of the atmosphere collected during image acquisition must be minimized or removed. Steps were conducted in Harris Geospatial ENVI 5.3 software as follows:

1. The ERDAS file format was converted to ENVI file format;
2. The ENVI header file was edited to include band names and wavelengths (units to micrometers and band centers for each: 0.4274, 0.4819, 0.5471, 0.6043, 0.6601, 0.7227, 0.8240, 0.9136);
3. In order to calculate gains and offsets needed for radiometric calibration, Digital Globe recommends using the values outlined in the following document (Table 1: WV-3 https://dg-cms-uploads-production.s3.amazonaws.com/uploads/document/file/209/ABSRADCAL_FLEET_2016v0_Rel20170606.pdf). These values are also manually entered into the ENVI header file in the attributes tab for Gain and Offsets by band. In the past, a calculation was applied using he AbsCal factor/Bandwidth using the numbers provided in the .IMD file; however, this is no longer the practice. Once values are entered into the header file, the Radiometric Calibration tool is run to convert to radiance values (using the FLAASH settings). From there, the QUAC tool was used to convert to reflectance values.

The image area was reduced to the area of interest provided by the District in shapefile format. This file was converted to NAD 1983 State Plane South Carolina FIPS 3900 Feet International to match the projection of the imagery. It was converted to grid format using the spatial extent, snap raster, and cell size of each of the p001 and p002 January 2017 scenes (e.g. processed individually with Environment settings set to each image, respectively). The mask files were converted to ENVI format, used to build mask files, and applied to the respective reflectance images for masking (Figures 2 and 3).

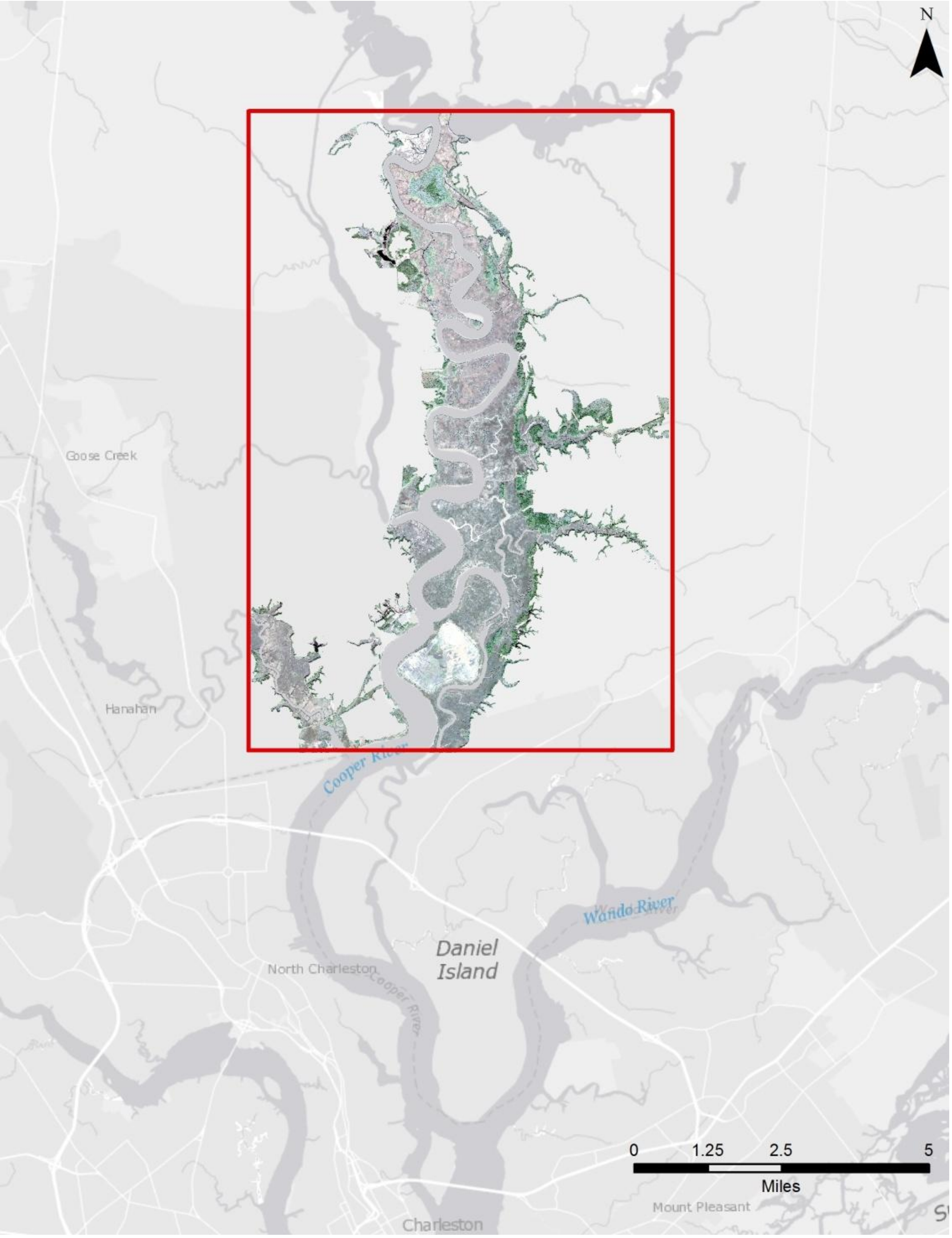


Figure 2. Masked WV-3 scenes for the area of interest along the Cooper River, SC

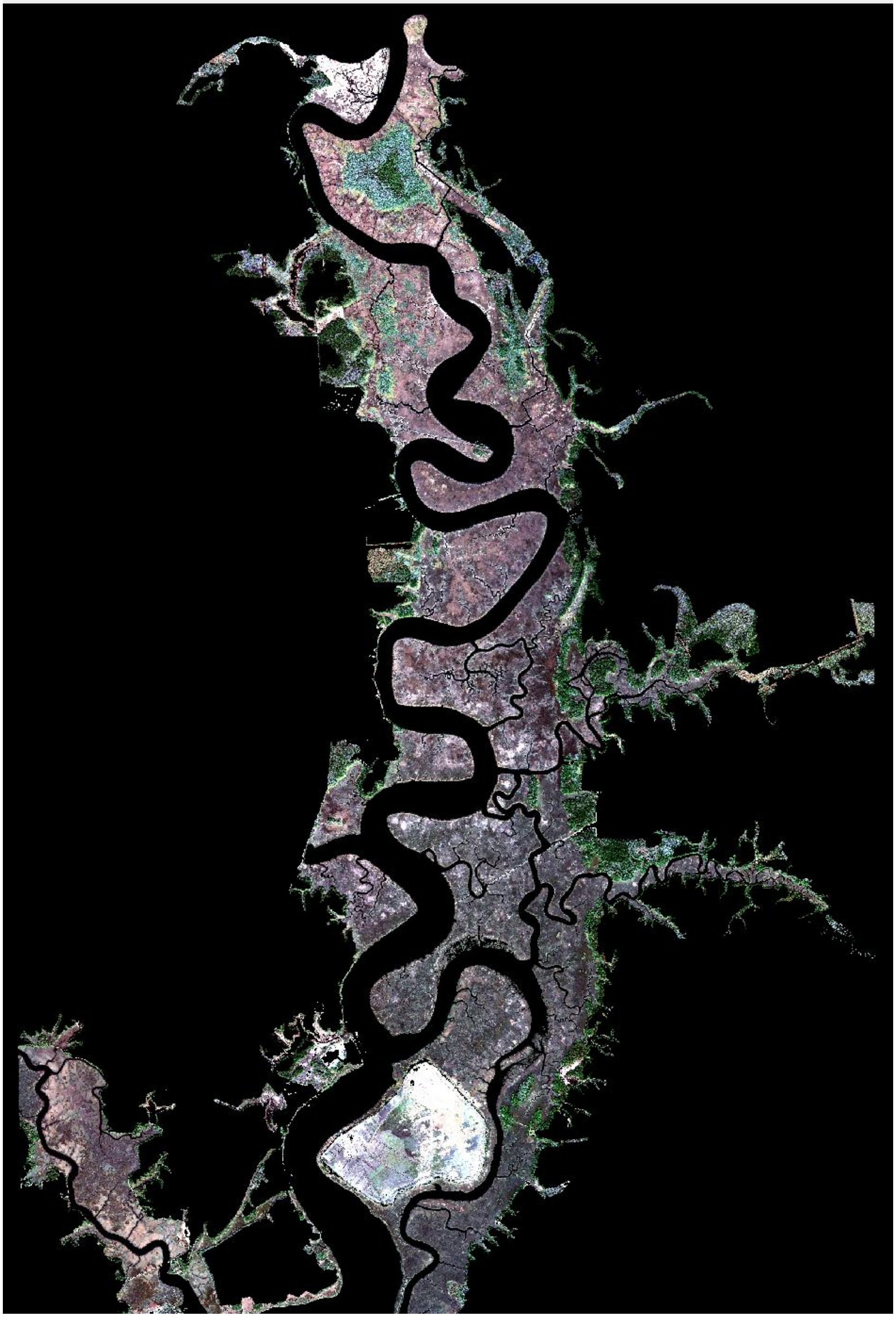


Figure 3. Masked WV-3 scenes for the area of interest along the Cooper River, SC (view from ENVI 5.3)

Classification

Field data, including spectral samples, were collected from 54 sites in June 2016 and 100 sites in January 2017 near the time of image acquisition using the same methods described in Reif, 2013 (Figure 4).

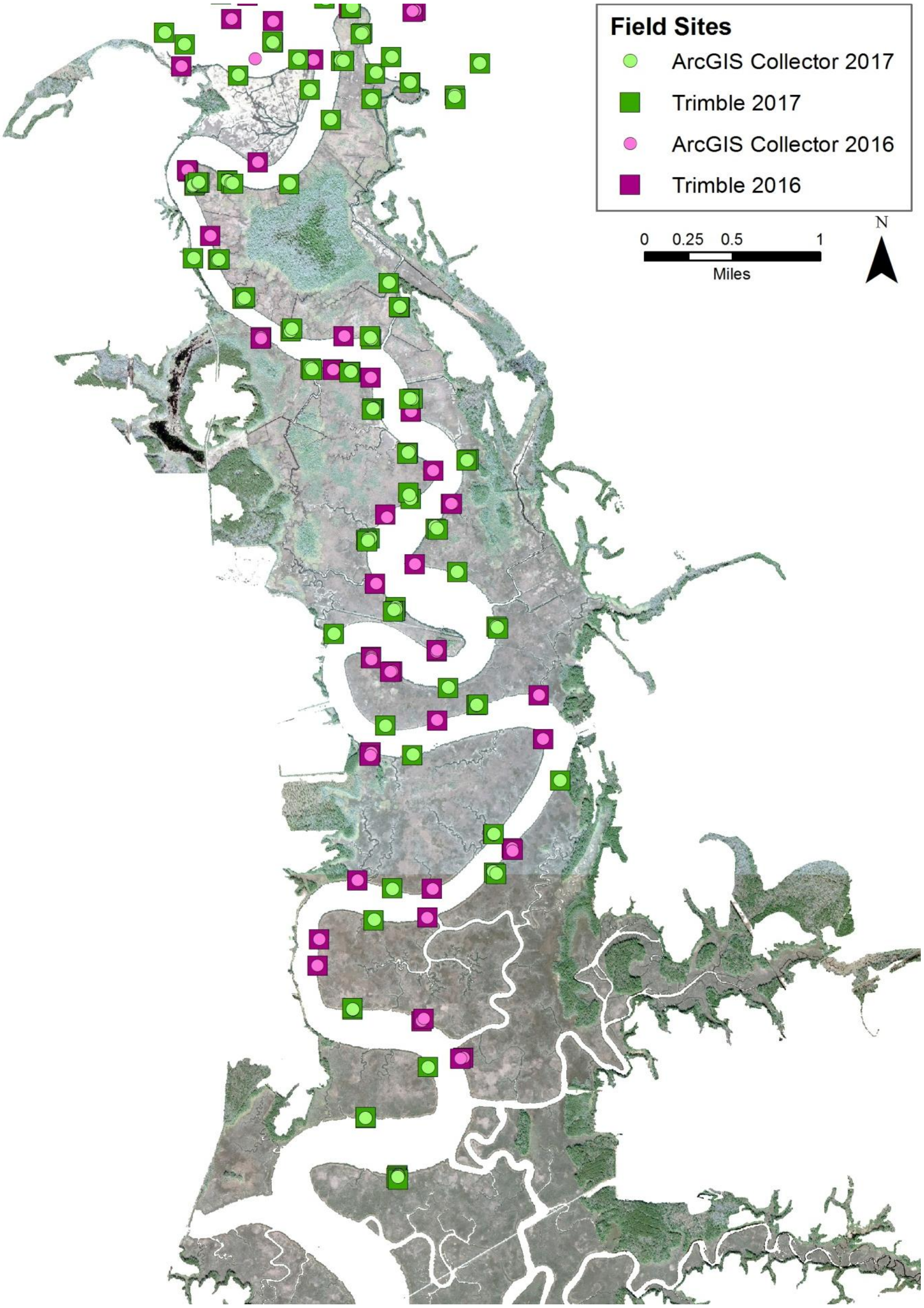


Figure 4. Field sites visiting in June 2016 (pink) and January 2017 (green)

The purpose of a supervised classification is to identify different materials or habitat types in an image over a large area based on training sites (field data) as the basis for the classification. Specified pixels in a training site are evaluated, while remaining pixels are then assigned to a matching or corresponding class based on statistics. In the ENVI 5.3 software, a spectral library was created of all the representative target canopy spectra to compare with the WV-3 image scene spectra. More specifically, the Endmember Collection Tool was used to import .REF files (ASD spectral files collected in the field) by which the reflectance image is first selected and then the Import ASD Binary File option is selected to simultaneously import and resample field spectra to match the band and wavelength settings of the reflectance image to facilitate comparison. Direct comparison of the two spectra is useful for determining appropriate pixels or "regions of interest" (ROIs) to help train the image classifier and identify similar pixels (Appendix A).

Field and image spectra were compared for field sites from the January 2017 field campaign and used to help select ROIs. In total, 240 ROIs were selected for the image classification using ENVI's Image Classification Workflow tool. More specifically, the Maximum Likelihood classifier approach was used which is the same process as in the 2010/2011 image classification. The Maximum Likelihood classification technique was selected for use as it is the most commonly used classification method in remote sensing image analysis (Foody, 1992). It assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a particular class (Lillesand, 2008). Therefore, the distribution of a class response pattern is described by a mean vector and thus, given those parameters a statistical probability can be computed for each pixel to determine the most suitable class with the highest probability value. Once the classification process was complete, post-processing was performed to "smooth" the result. Due to the high amount of spectral variability in an image scene, classification results often display a salt and pepper appearance and are post-processed. Therefore, a majority filter was applied to remove isolated pixels and show the dominant class. In this approach, a 3x3 moving window (3x3 pixels) is passed over the classification result, and in each 3x3 neighborhood, the majority class is determined; when the central pixel is not the majority class, its value is changed to that class value. In addition to the majority filter, an aggregation function was also conducted in the post-processing step of the Classification Workflow tool.

Results

In 2017, four classes were not mapped either due to insufficient field observations or the class was not a primary class of interest (numbers 3 and 4): 1) Submerged Aquatic Vegetation, 2) ITEM Cattail Dominant, 3) Urban/Field/Bare Soil, and 4) CDF Vegetation/Common Reed. For the purposes of comparison, these classes were omitted from the 2010/11 classification result and the area of interest was further refined to include pixel areas common to both map results along the area of interest of the Cooper River corridor. Figure 5 shows the 2017 image classification result, and Figure 6 shows a side-by-side comparison with the 2010/11 results. Table 1 shows the class area statistics for both dates. Woody mix was omitted from the table summary in order to focus on dominant wetland classes.

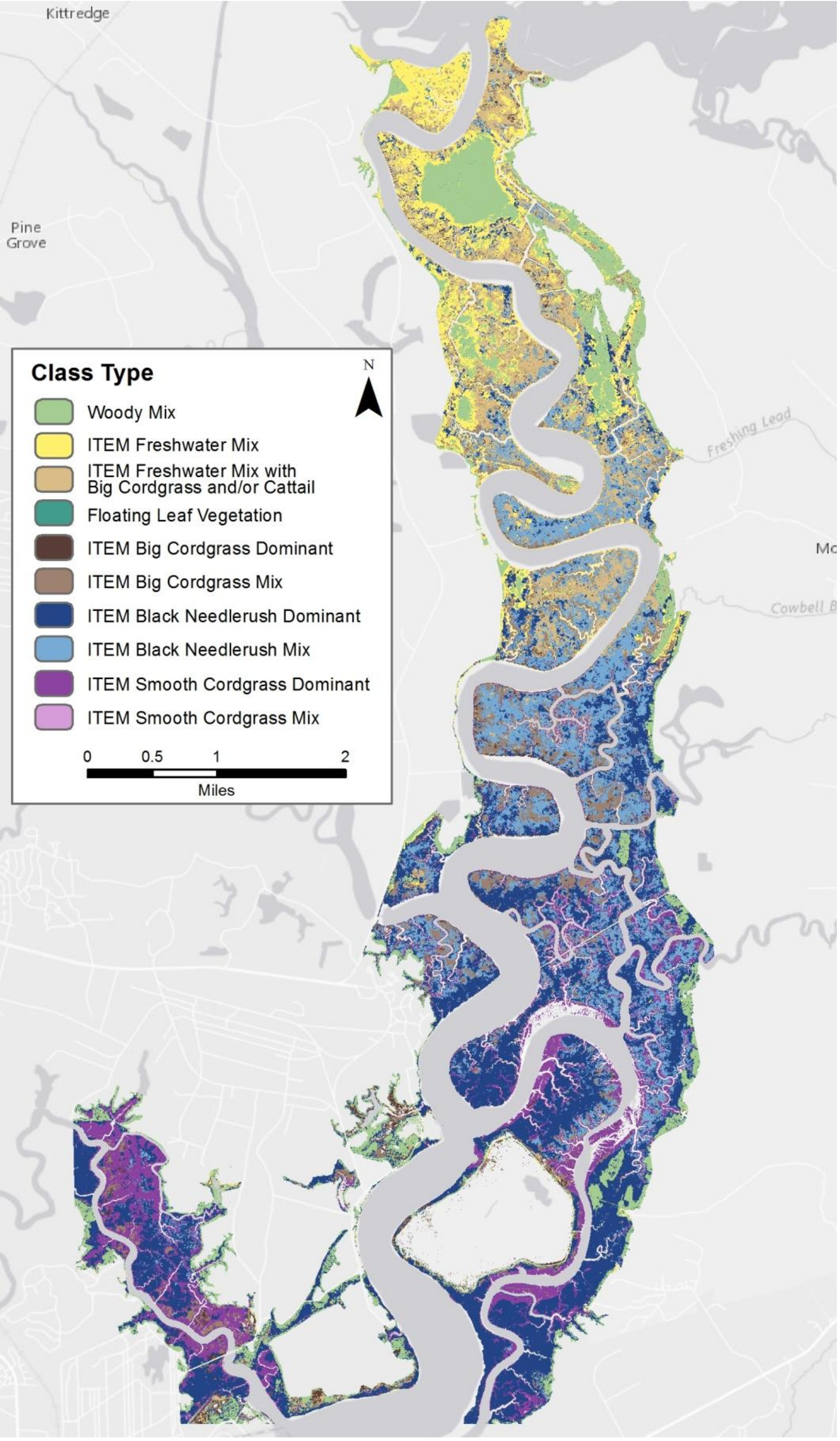


Figure 5. Classification map using the January 2017 WV-3 imagery

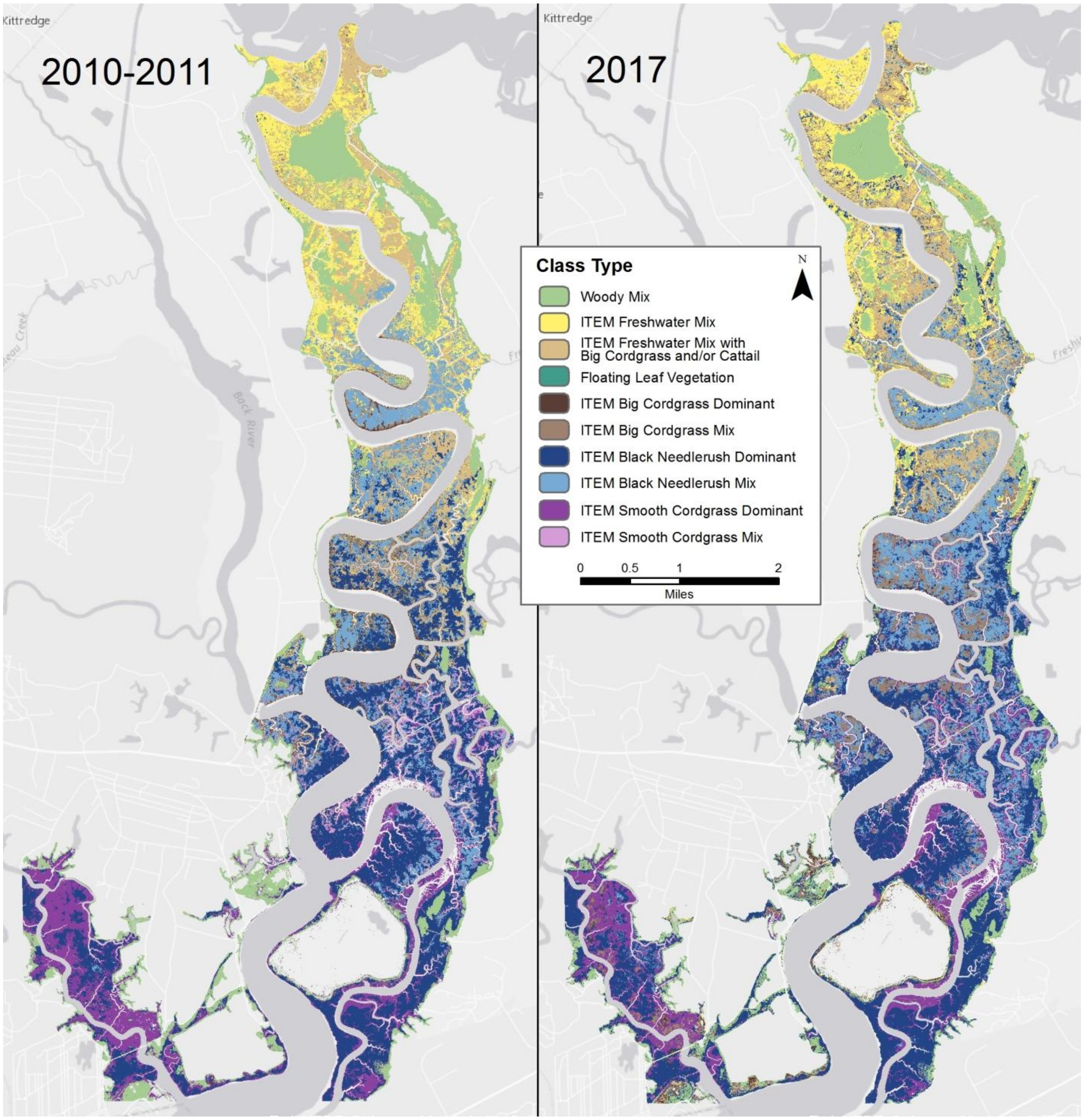


Figure 6. Comparison of 2010-2011 and 2017 classification results

Table 1. Percent area for 2010/11 and 2017 wetland classifications

Class	2010/11 COUNT	2010/11 %Area	2017 Count	2017 %Area
(2) ITEM Freshwater Mix	899,211	11.51%	693,980	8.88%
(3) ITEM Freshwater Mix w/Big Cordgrass or Cattail	1,097,238	14.05%	867,234	11.10%
(4) Floating Leaf Vegetation	6,455	0.08%	14,685	0.19%
(6) ITEM Big Cordgrass Dominant	179,053	2.29%	132,423	1.70%
(7) ITEM Big Cordgrass Mix	408,473	5.23%	840,789	10.76%
(8) ITEM Black Needlerush Dominant	2,518,732	32.24%	2,569,339	32.89%
(9) ITEM Black Needlerush Mix	1,366,942	17.50%	1,664,015	21.30%
(11) ITEM Smooth Cordgrass Dominant	1,153,485	14.77%	1,019,143	13.05%
(12) ITEM Smooth Cordgrass Mix	182,609	2.34%	10,590	0.14%
TOTAL	7,812,198	100%	7,812,198	100.00%

Table 1 shows percent area for each wetland class (excluding woody mix) by year for the area of interest. Note that numerical grid code values are listed in the class name (e.g. (2) ITEM Freshwater Mix) and are used in the change detection analysis. To compare the classification results more directly, a change detection calculation was performed. To do that, the Difference algorithm in the ArcGIS Image Analysis Window was used to perform a basic difference between the two grids. It's a simple, pixel to pixel comparison resulting in a difference between the images (using the grid code values). Figure 7 shows the result of the Difference algorithm whereby 2017 was subtracted from 2010/11. Pixels with no change are reflected in yellow (0 values). Positive change values (in orange/pink) are the result of a higher grid code (salt and brackish communities) minus a lower grid code (freshwater communities). Conversely, negative change values (in blue) are the result of a lower grid code (freshwater communities) minus a higher grid code (salt and brackish communities).

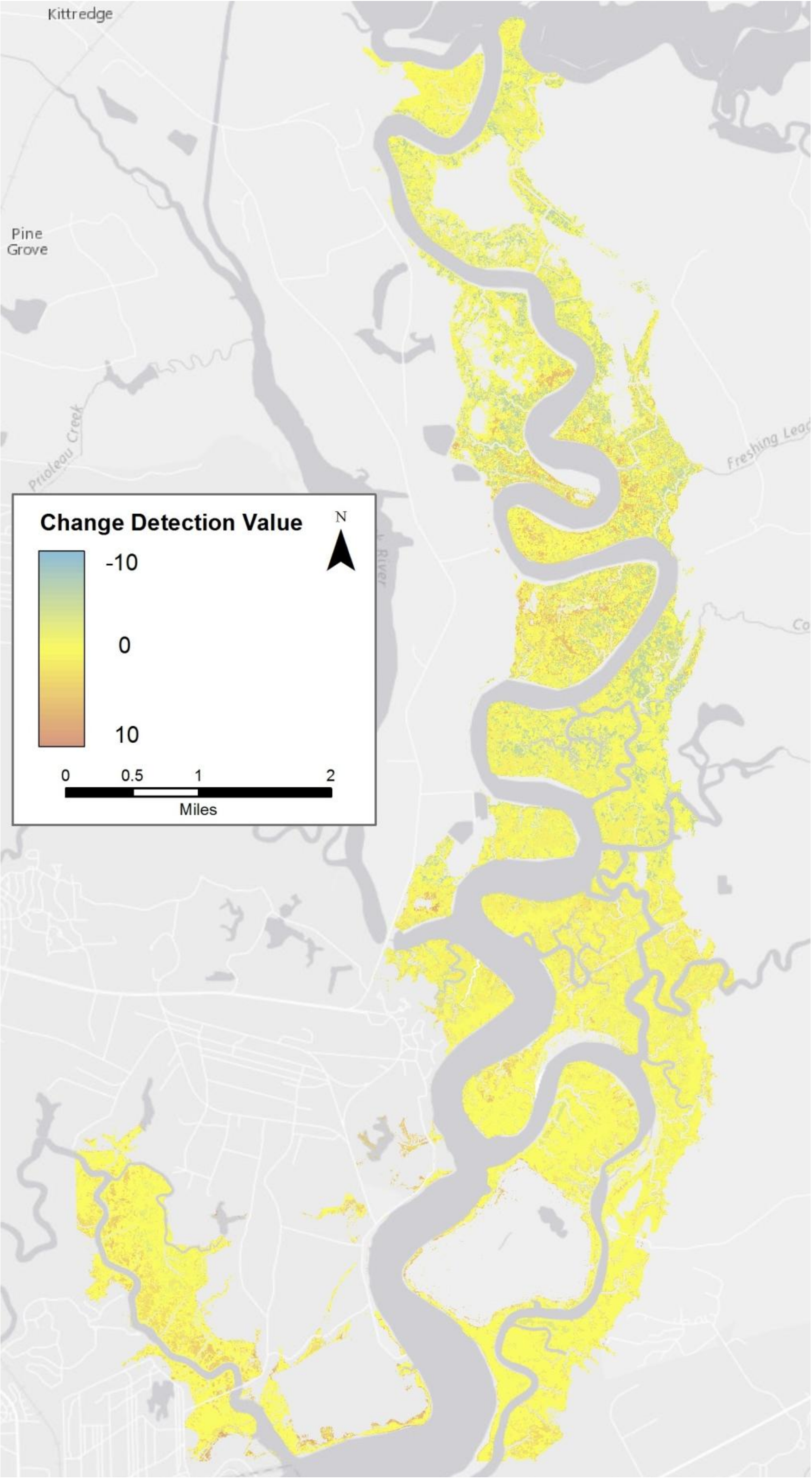


Figure 7. Change detection between 2010/11 and 2017 (difference calculation)

One drawback to classical change detection methods is that they do not account for overlap or gradual changes between class types. In this study, the classes were selected in order to be able to cross-walk them to neighboring mapping efforts conducted by the Citadel (Rice Field Study, 1989-2006) and the South Carolina Department of Health & Environmental Control's Ocean & Coastal Resource Management (Reif, 2013). As such, it is acknowledged that there is overlap between class types and that some communities during a given part of the growing season may exhibit signs of belonging to multiple community types. For example, ITEM Big Cordgrass Mix may appear similar to ITEM Freshwater Mix with Big Cordgrass or Cattail or vice versa depending on seasonality, the growth stage of certain species, and dominance of the overstory canopy. With such heterogeneous and overlapping community types, mixed and dominant classes were developed in an attempt to help address this issue as well as acquiring data in both summer and winter seasons. To help overcome the drawbacks of traditional change detection and to deal with overlapping or imprecise community designations, fuzzy logic can be used to illustrate degrees of change or the likelihood for change (Metternicht, 2001).

In a fuzzy logic approach, rule sets are determined reflecting membership grades to evaluate the certainty or magnitude of change. For this study, typical degrees of change likelihood were established in Table 2.

Table 2. Likelihood of changes expressed in terms of possibility from a class in year 2010/11 to a class in year 2017

New Class Code	Degree of Possibility
0	None
1	Very Unlikely
2	Unlikely
3	Possible
4	Somewhat Likely

The classes presented in table 2 were used to characterize class changes from 2010/11 to 2017 by way of a fuzzy logic matrix (Table 3).

Table 3. Change matrix (2010/11 – 2017), in which class changes are assigned a degree of possibility class code from Table 2

		2016-2017 Classification								
		2	3	4	6	7	8	9	11	12
2010-2011 Classification	2	0	1	1	2	2	3	2	4	3
	3	1	0	3	1	1	3	2	4	3
	4	1	3	0	3	3	3	4	4	3
	6	2	1	3	0	1	3	2	4	3
	7	2	1	3	1	0	3	2	3	3
	8	3	3	4	3	2	0	1	2	2
	9	2	2	4	3	2	1	0	2	2
	11	4	4	4	3	3	2	2	0	1
	12	3	3	3	3	2	2	2	1	0

In the change detection grid, each possible class change was assigned a value from Table 2 using the matrix defined in table 3. Thus, change values were reassigned one of 5 values depending on how likely a class changed from one value to another. For example, if a pixel with a value of 2 (ITEM Freshwater Mix) in 2010/11 was mapped with a value of 3 (ITEM Freshwater Mix with Big Cordgrass and/or Cattail) in 2017, the change detection value was reassigned a value of 1, meaning that change was very unlikely because of the higher potential for class overlap and confusion between those two communities. Conversely, if a pixel with a value of 8 (ITEM Black Needlerush Dominant) in 2010/11 was mapped with a value of 4 (Floating Leaf Vegetation) in 2017, the change detection value was reassigned a value of 4, meaning that the change is somewhat likely given the lower potential for class overlap and confusion between those two communities. In general, changes involving mixed communities were assigned a lower value since they generally have higher potential for overlap or confusion with other communities versus dominant communities which have less potential for overlap or confusion. In addition, changes between mixed and dominant variations of the same community type (I.e. ITEM Black Needlerush Mixed vs. ITEM Black Needlerush Dominant) are generally assigned a lower value because they have a higher potential for overlap between them. Figure 8 shows the result of the fuzzy logic map result. Table 4 shows the area statistics for the 5 degrees of possible change.

Table 4. Percent area for change detection classes as expressed in terms of 5 degrees of possible change

New Class Code	COUNT	%Area
0	4,137,330	52.96%
1	1,617,396	20.70%
2	1,548,971	19.83%
3	443,501	5.68%
4	65,000	0.83%
	7,812,198	100.00%

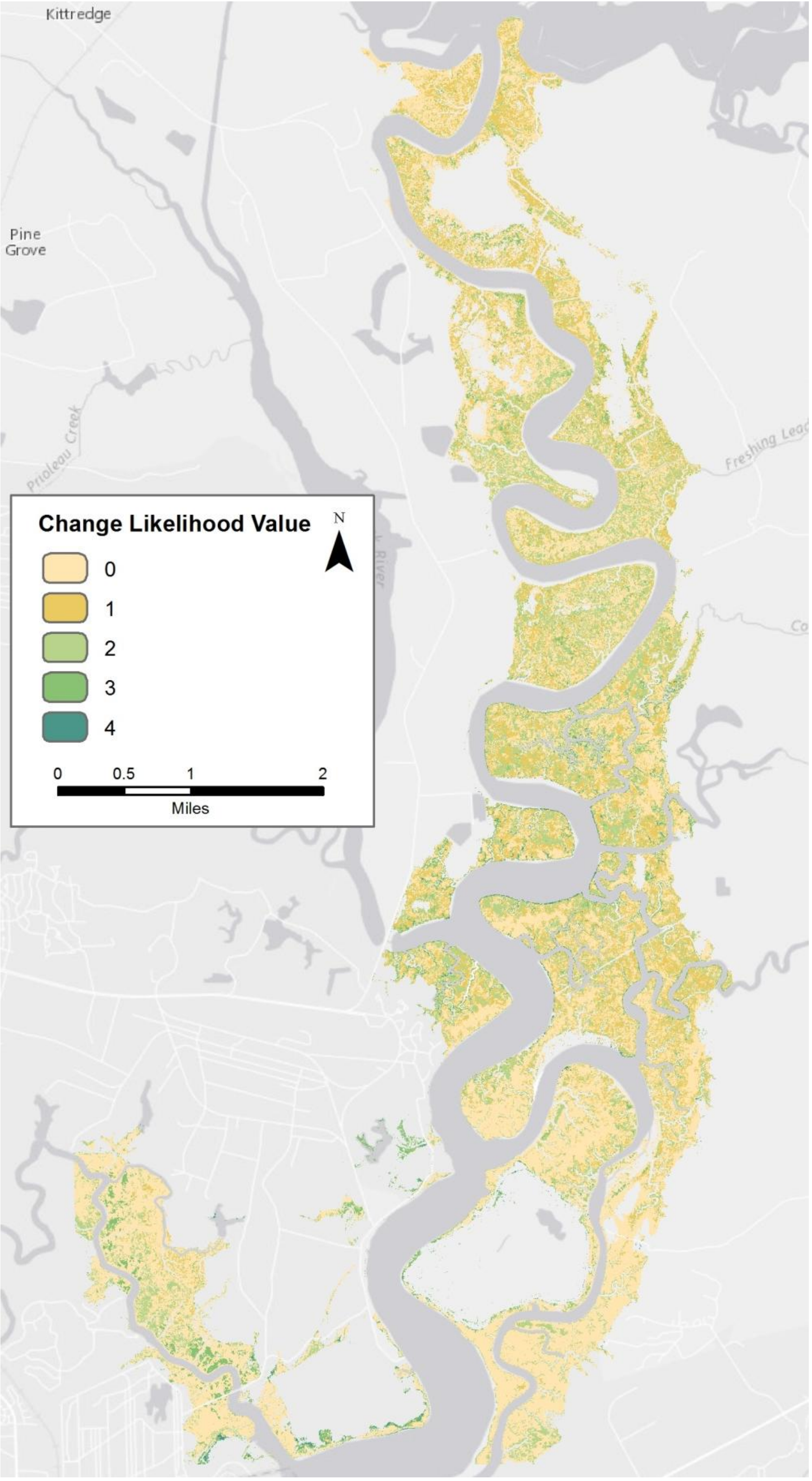


Figure 8. Change likelihood map using fuzzy logic and relationships in Tables 2 and 3

Similar to previous efforts that the District used to estimate salinity transition zones expressed in terms of vegetative communities (Figure 9), the change detection data were used to visualize the mean degree of change possibility (as expressed in 5 class codes, ranging from 0 to 4). Figure 10 shows the mean degree of possible change values in longitudinal blocks along the area of interest.

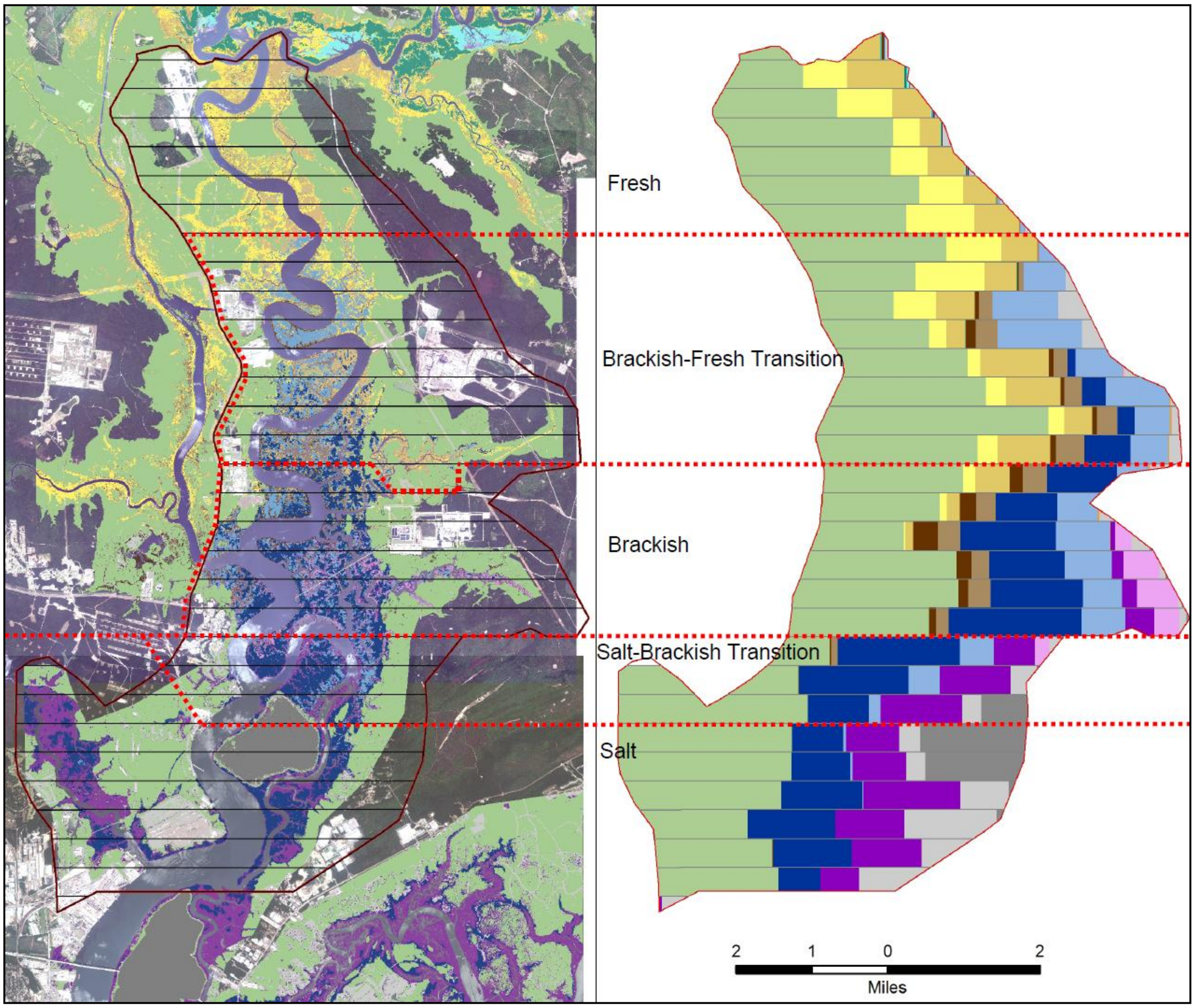


Figure 9. Salinity transition zones delineated by the District using the wetland communities mapped with 2010/11 imagery

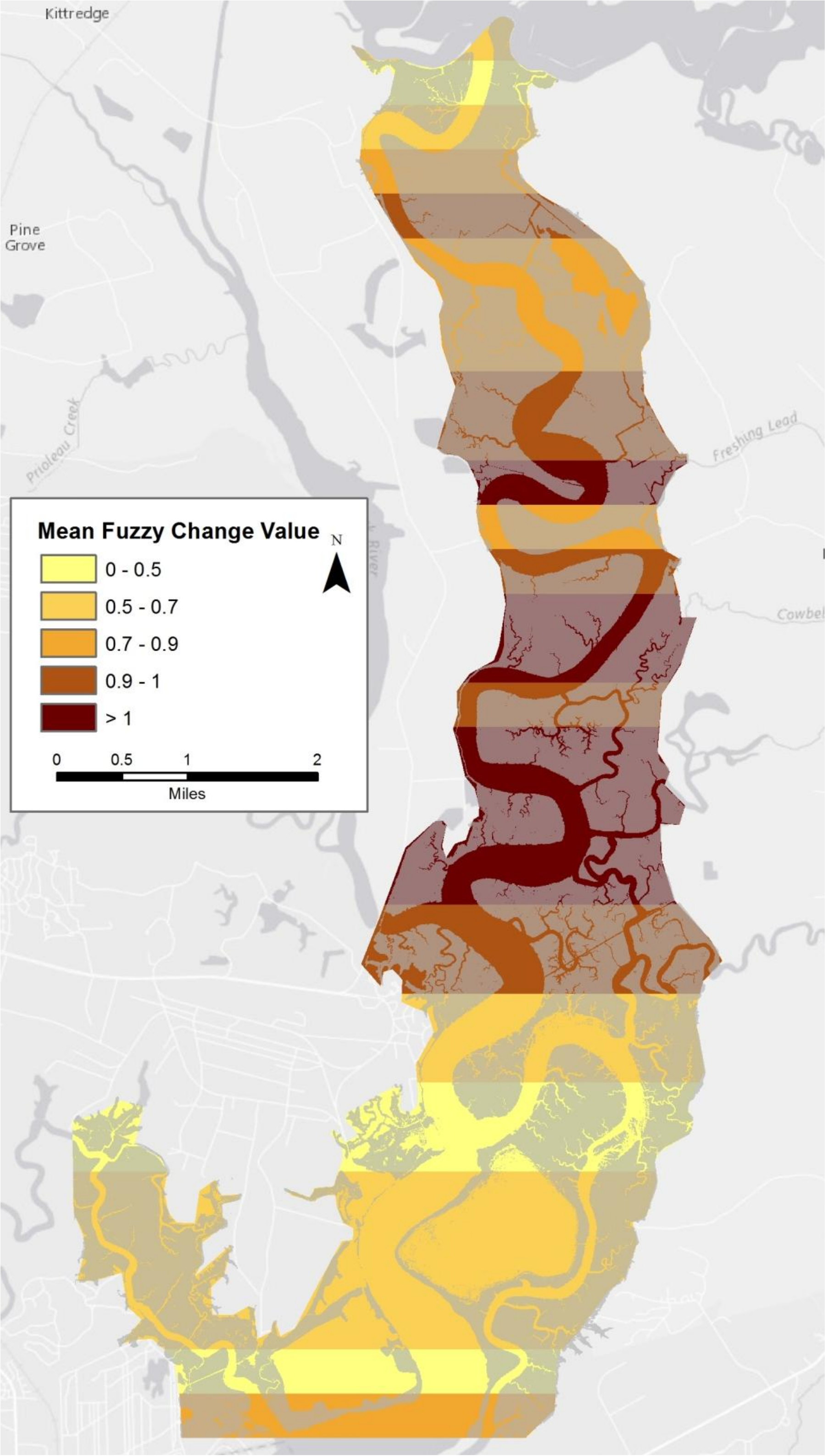


Figure 10. Mean degree of possible change value in longitudinal blocks along the area of interest

Discussion

There are two primary challenges with interpreting change detection results: 1) classification error and 2) class overlap. It's difficult to separate changes resulting from error and overlap versus actual class changes; however, steps can be taken to minimize classification error and class overlap. In this study, steps were taken to replicate classification methods and application of the classification schema across years to help reduce error and to establish practices for long term monitoring. Because there is overlap between classes, a fuzzy logic approach was used to help interpret results and potentially isolate actual class changes while minimizing overlap and potential confusion between classes, which is a common practice in ecological mapping (Metternicht, 2001). As seen in Figure 7 and Table 5, a little over 50% of the area experienced no change, while 40% experienced very unlikely and unlikely changes due to class overlap during the period 2010/11-2017. In contrast, approximately 6% of the area experienced what could be possible or somewhat likely changes. In summary, class changes are as follows:

- A decrease in ITEM Freshwater Mix area - 11.51% to 8.88%; class changes were mostly to ITEM Freshwater Mix w/Big Cordgrass or Cattail and ITEM Big Cordgrass Mix
- A decrease in ITEM Freshwater Mix w/Big Cordgrass or Cattail area – 14.05% to 11.10%; class changes were mostly ITEM Freshwater Mix and ITEM Big Cordgrass Mix
- An increase in Floating Leaf Vegetation area – 0.08% to 0.19%; class changes were mostly to ITEM Freshwater Mix and ITEM Freshwater Mix w/Big Cordgrass or Cattail
- A decrease in ITEM Big Cordgrass Dominant area – 2.29% to 1.70%; class changes were mostly to ITEM Big Cordgrass Mix, ITEM Black Needlerush Dominant, ITEM Black Needlerush Mix, and ITEM Smooth Cordgrass Dominant
- An increase in ITEM Big Cordgrass Mix area – 5.23% to 10.76%; class changes were mostly to ITEM Black Needlerush Mix and ITEM Smooth Cordgrass Dominant
- An increase in ITEM Black Needlerush Dominant area – 32.24% to 32.89%; class changes were mostly to ITEM Black Needlerush Mix
- An increase in ITEM Black Needlerush Mix area – 17.50% to 21.30%; class changes were mostly to ITEM Black Needlerush Dominant
- A decrease in ITEM Smooth Cordgrass Dominant area - 14.77% to 1305%; class changes were mostly to ITEM Black Needlerush Dominant
- A decrease in ITEM Smooth Cordgrass Mix area – 2.34% to 0.14%; class changes were mostly to ITEM Black Needlerush Dominant and ITEM Black Needlerush Mix

While most of the class changes were between overlapping classes, evidence of some confusion or changes exists between such classes as ITEM Big Cordgrass Dominant and Mix classes which experienced some interplay with ITEM Black Needlerush Mix, ITEM Black Needlerush Dominant, and ITEM Smooth Cordgrass Mix classes. Some of this change was observed along the edge of the marsh along the Cooper River channel itself. A zoomed in area of Figure 8, illustrates the higher change likelihood values along the channel edge (Figure 11). It could be that these areas are more dynamic and subject to change compared to the marsh interior, thus the class changes. However, class confusion could also be a factor. This is due in part to the 2017 classification relying solely on the winter scene since the summer scene had clouds and cloud shadows. In the 2017 January image, dead vegetation looks darker and was sometimes mistaken for naturally darker vegetation classes such as black needlerush. It is likely that the increase in black needlerush mix and dominant classes (even though most change was between those two classes) was due to vegetation appearing darker. Without the summer scene, freshwater class signatures tended to be dampened with certain vegetation species being absent or dormant and may be underrepresented.

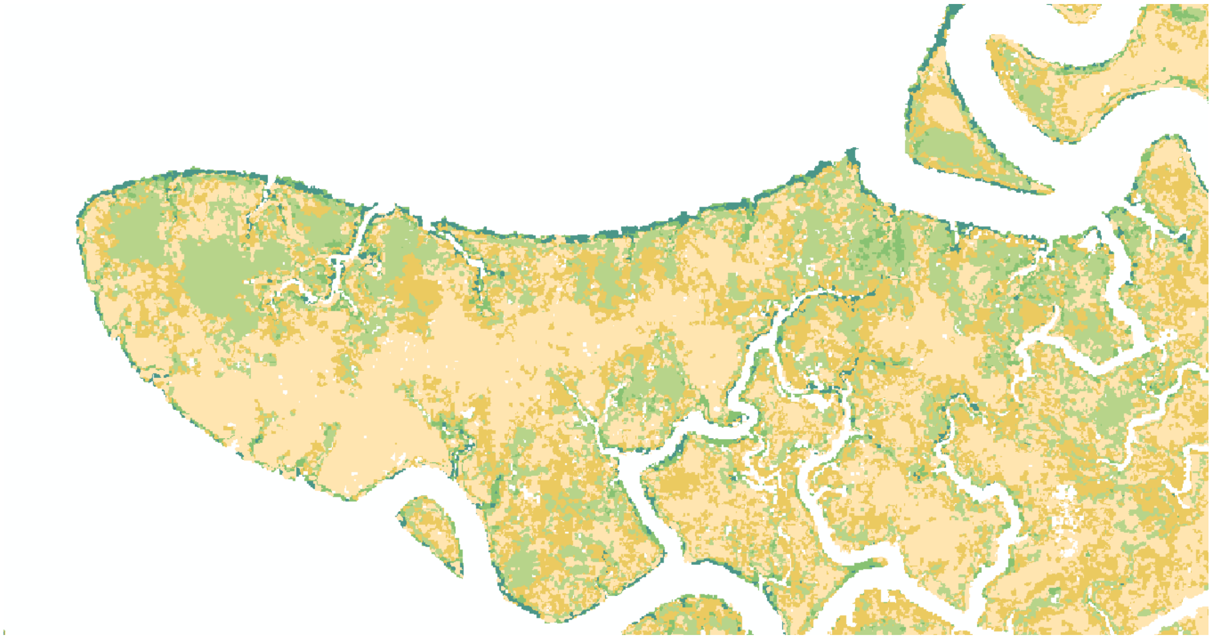


Figure 11. Zoomed in area of Figure 8, illustrating higher change likelihood values (darker blue) along the edge of the marsh along the channel

Regardless of some confusion between classes, the overall change trends are stable, especially in the extreme northern and southern ends of the area of interest. Figure 10 illustrates this effectively, with mean change likelihood values being closer to 0 in the northern and southern longitudinal blocks. More interestingly, the middle section of the area of interest, which corresponds to the transition from brackish to fresh zones delineated by the District (Figure 9), shows higher mean change likelihood values (around 1). This is not surprising given that this transition zone is likely more dynamic and apt to exchanges between certain classes depending on seasonal and annual cycles.

It has been acknowledged that the area of interest along the Cooper River has remained stable in terms of habitat changes in recent history. Between the period of 2017 and 2010/11, the wetland community mapping and change detection reflects this trend. It also highlights where changes may tend to occur such as along channel edges and the central part of the study area in the transition zone from brackish to fresh. This information can serve as a useful benchmark for future monitoring efforts especially in looking for indicators of potential deepening impacts as expressed through vegetative communities along this section of the Cooper River.

References

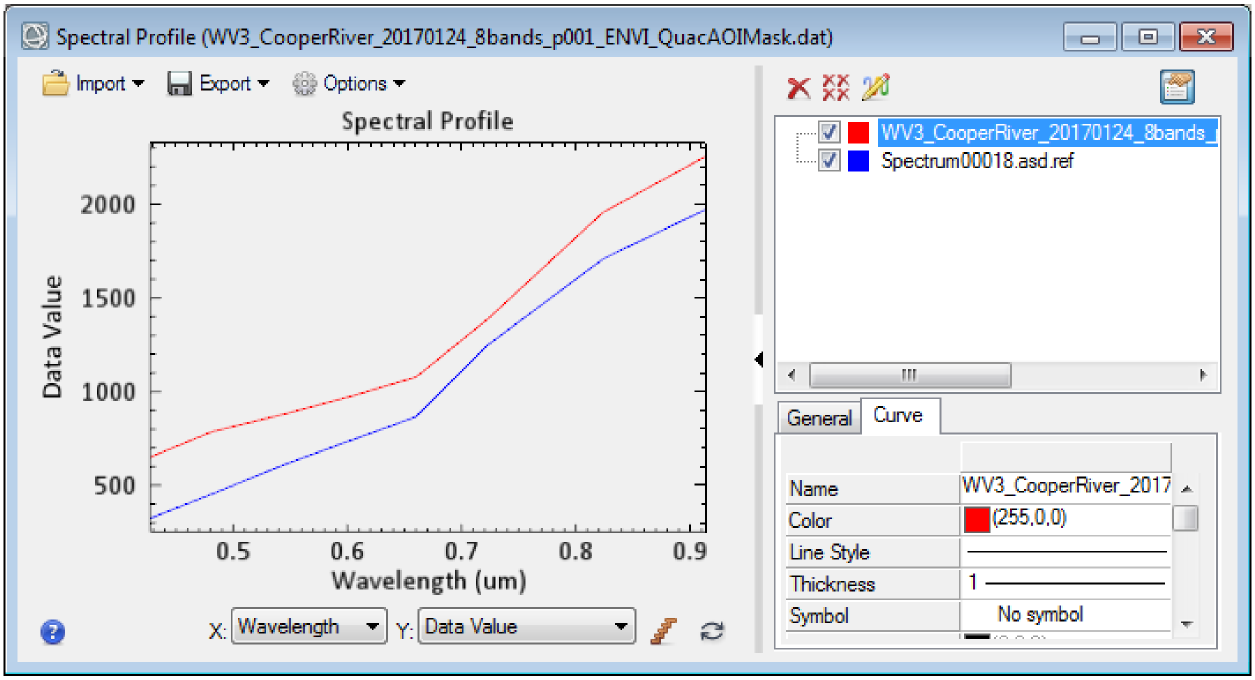
Foody, G.M., Campbell, N.A., Trood, N.M., and Wood, T.F. 1992. Derivation and application of probabilistic measures of class membership from the maximum likelihood classification. *Photogrammetric Engineering & Remote Sensing*, Vol. 59. 1335-1341.

Lillesand, T.M.; Kiefer, R.W., and Chipman, J.W. 2008. Remote Sensing and Image Interpretation, 6th edition. Hoboken, New Jersey: John Wiley & Sons, 804p.

Metternicht, G. 2001. Assessing temporal and spatial changes of salinity using fuzzy logic, remote sensing and GIS. Foundations of an expert system. *Ecological Modelling*, 144, 163–177.

Reif, M.K. 2013. Wetland Classification Study Cooper River, South Carolina Final Report to the U.S. Army Corps of Engineers, Charleston District**.** (internal report submitted to the USACE Charleston District).

Appendix A: Comparison of Field Spectra vs. Image Spectra



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☑ 🟦 Spectrum00018.asd.ref

Name	WV3_CooperRiver_2017
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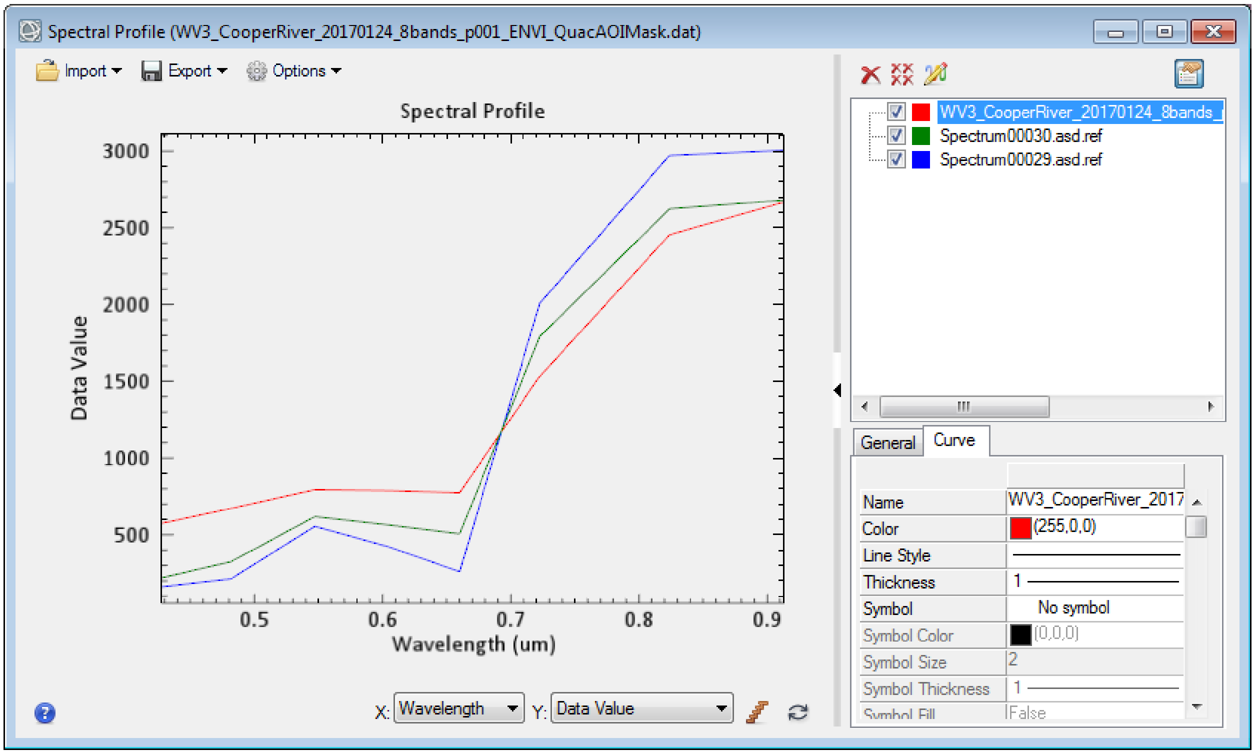
Line Style	
Thickness	1
Symbol	No symbol

X: Wavelength Y: Data Value

SiteID 6 (from Jan 2017 field survey) of ITEM Freshwater Mix (mostly white marsh); Red = image spectra, blue = ASD-measured spectral reflectance.



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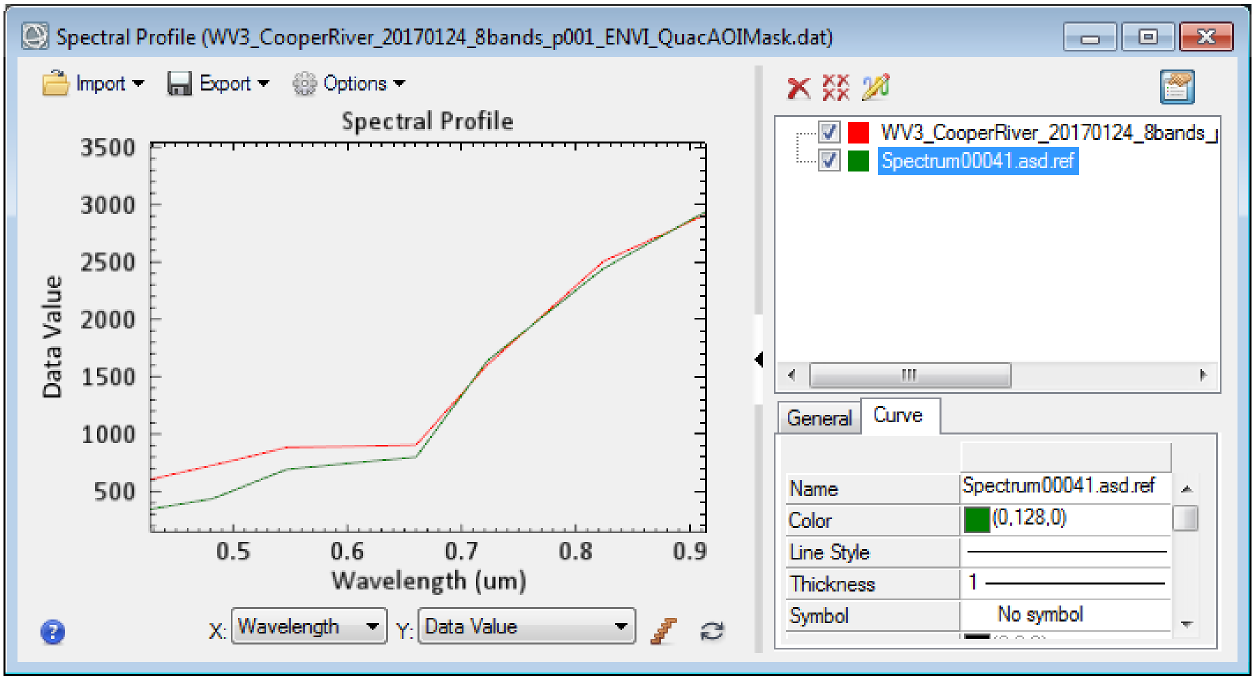
Thickness	1
Symbol	No symbol
Symbol Color	■ (0,0,0)
Symbol Size	2
Symbol Thickness	1
Symbol Fill	False

X: Wavelength Y: Data Value

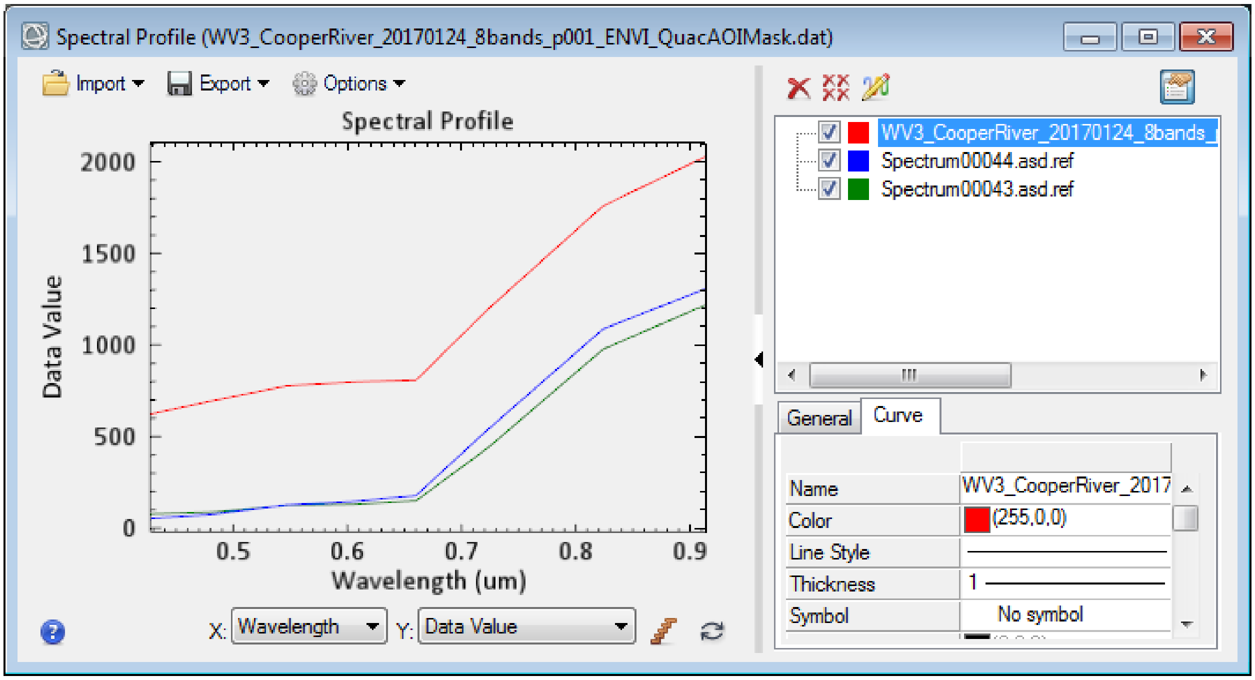
SiteID 11 (from Jan 2017 field survey) of ITEM Freshwater Mix (mostly scirpus); Red = image spectra, blue and green = two samples of ASD-measured spectral reflectance.



☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟩 Spectrum00041.asd.ref

Name	Spectrum00041.asd.ref
Color	🟩 (0,128,0)
Line Style	
Thickness	1
Symbol	No symbol

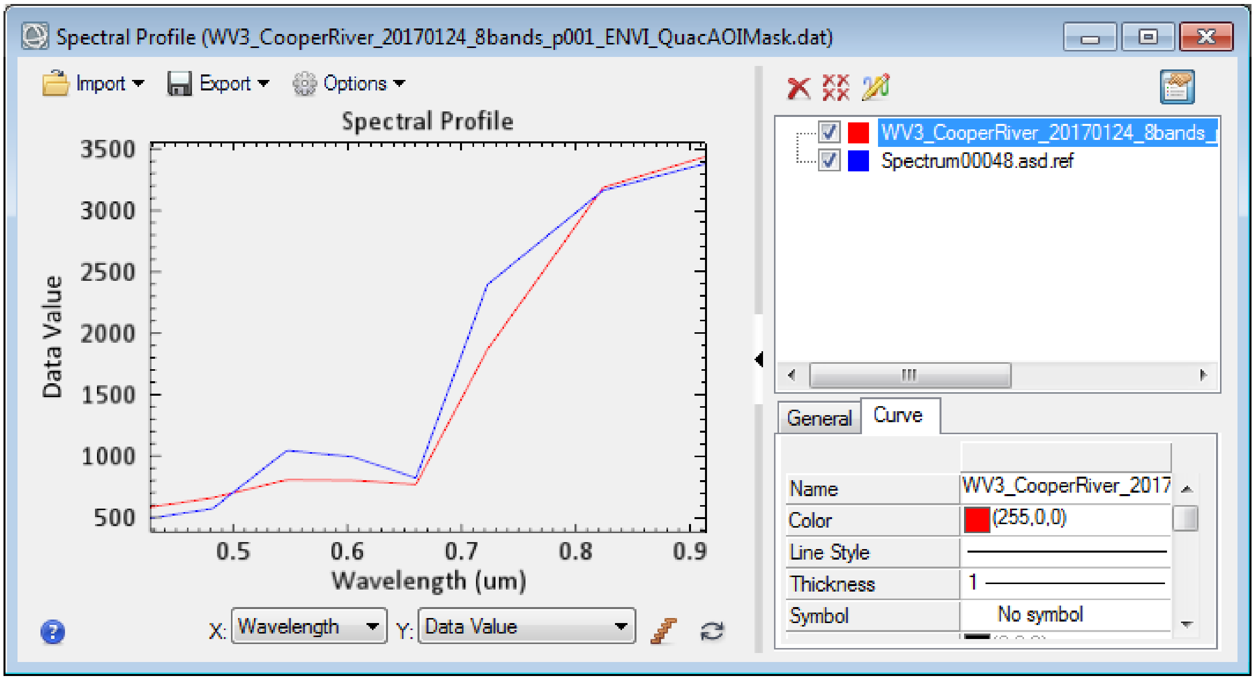
SiteID 18 (from Jan 2017 field survey) of ITEM Freshwater Mix (mostly caladium patch); Red = image spectra, green = ASD-measured spectral reflectance.



☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟦 Spectrum00044.asd.ref
☑ 🟩 Spectrum00043.asd.ref

Name	WV3_CooperRiver_2017
Color	🟥 (255,0,0)
Line Style	
Thickness	1
Symbol	No symbol

SiteID 19 (from Jan 2017 field survey) of ITEM Black Needlerush Dominant (with water understory); Red = image spectra, blue and green = two samples of ASD-measured spectral reflectance.



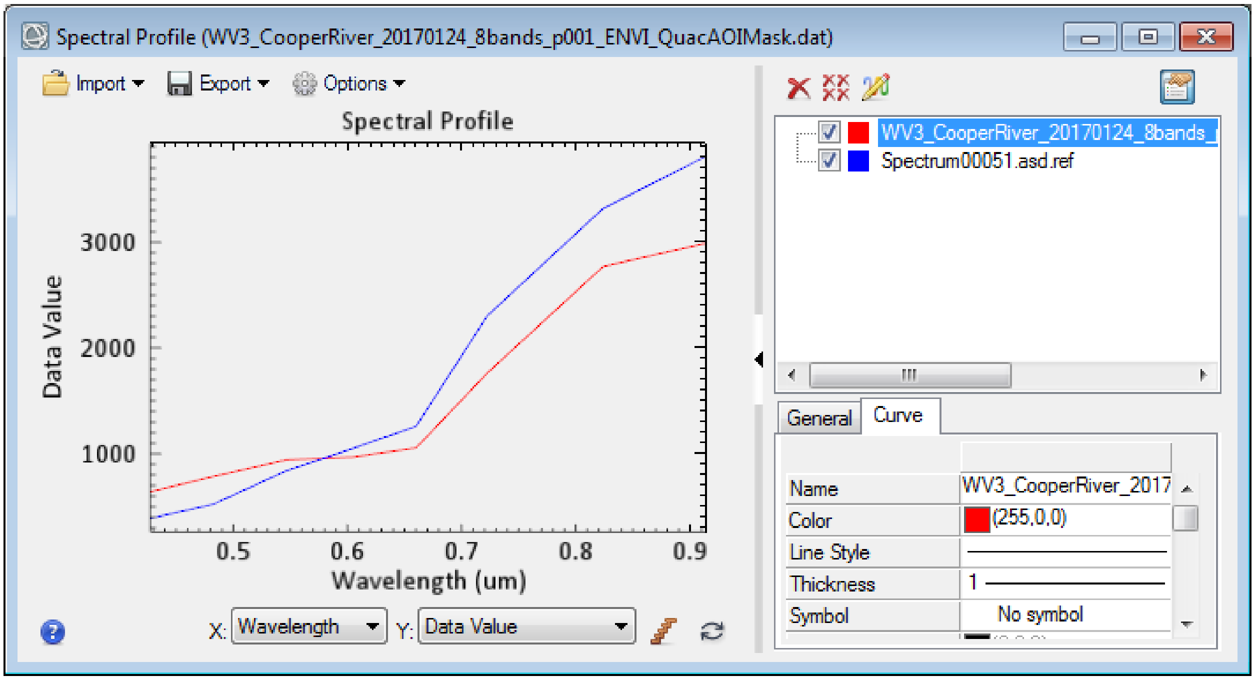
Spectral Profile (WV3_CooperRiver_20170124_8bands_p001_ENVI_QuacAOIMask.dat)

☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟦 Spectrum00048.asd.ref

Name	WV3_CooperRiver_2017
Color	🟥 (255,0,0)
Line Style	
Thickness	1
Symbol	No symbol

X: Wavelength
Y: Data Value

SiteID 33 (from Jan 2017 field survey) of ITEM Freshwater Mix (mostly caladium); Red = image spectra, blue = ASD-measured spectral reflectance.



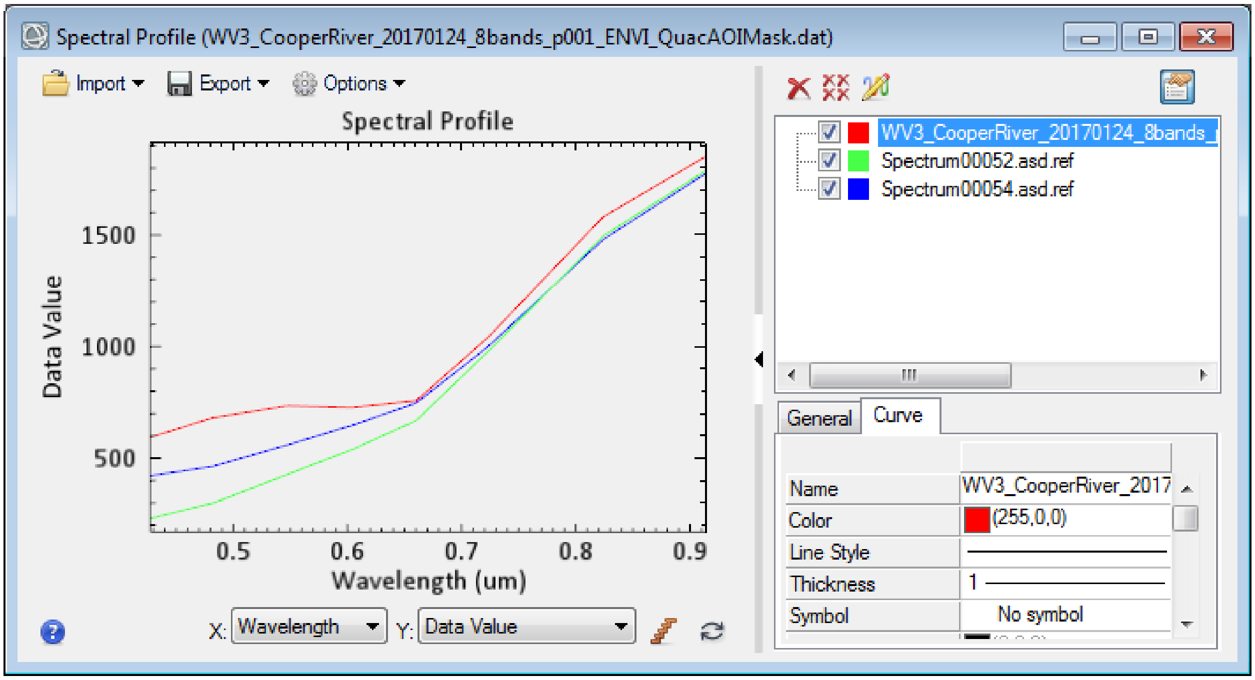
Spectral Profile (WV3_CooperRiver_20170124_8bands_p001_ENVI_QuacAOIMask.dat)

☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟦 Spectrum00051.asd.ref

Name	WV3_CooperRiver_2017
Color	🟥 (255,0,0)
Line Style	
Thickness	1
Symbol	No symbol

X: Wavelength
Y: Data Value

SiteID 34 (from Jan 2017 field survey) of ITEM Freshwater Mix with Big Cordgrass and/or Cattail (pretty mixed with Big Cordgrass and Cladium); Red = image spectra, blue = ASD-measured spectral reflectance.

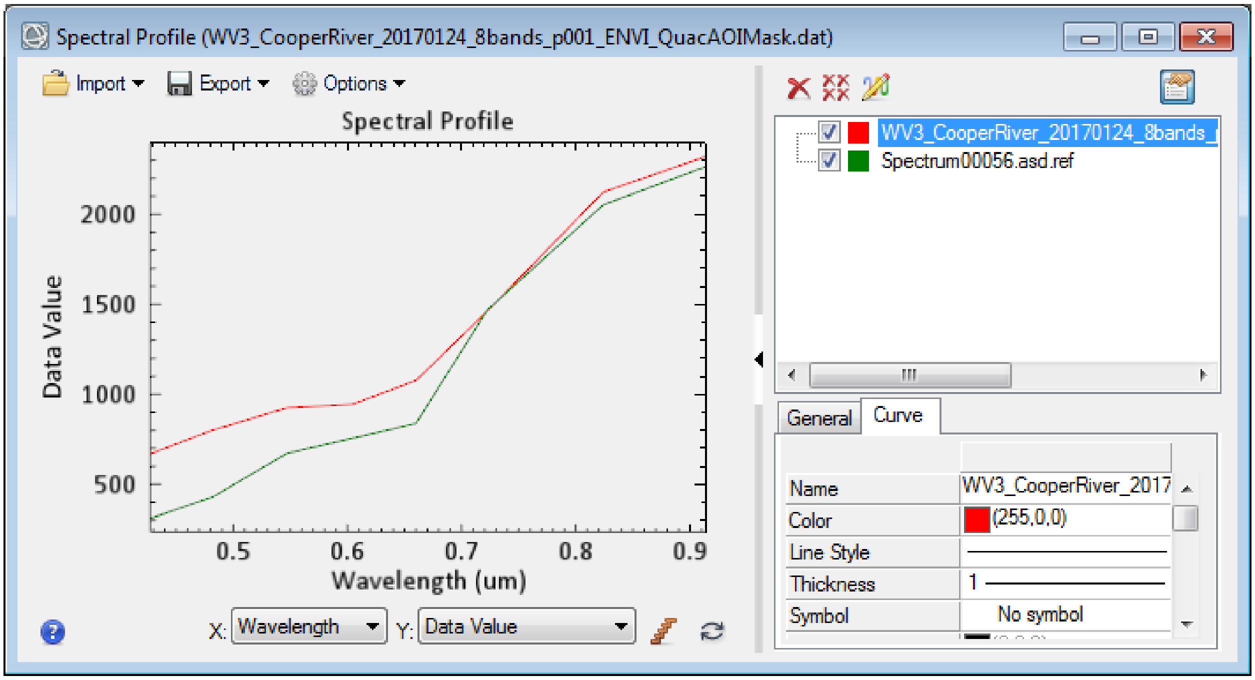


Spectral Profile (WV3_CooperRiver_20170124_8bands_p001_ENVI_QuacAOIMask.dat)

☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟩 Spectrum00052.asd.ref
☑ 🟦 Spectrum00054.asd.ref

Name	WV3_CooperRiver_2017
Color	🟥 (255,0,0)
Line Style	
Thickness	1
Symbol	No symbol

SiteID 35 (from Jan 2017 field survey) of ITEM Black Needlerush Mix (mixed with Big Cordgrass and understory species); Red = image spectra, blue and green = two samples of ASD-measured spectral reflectance.

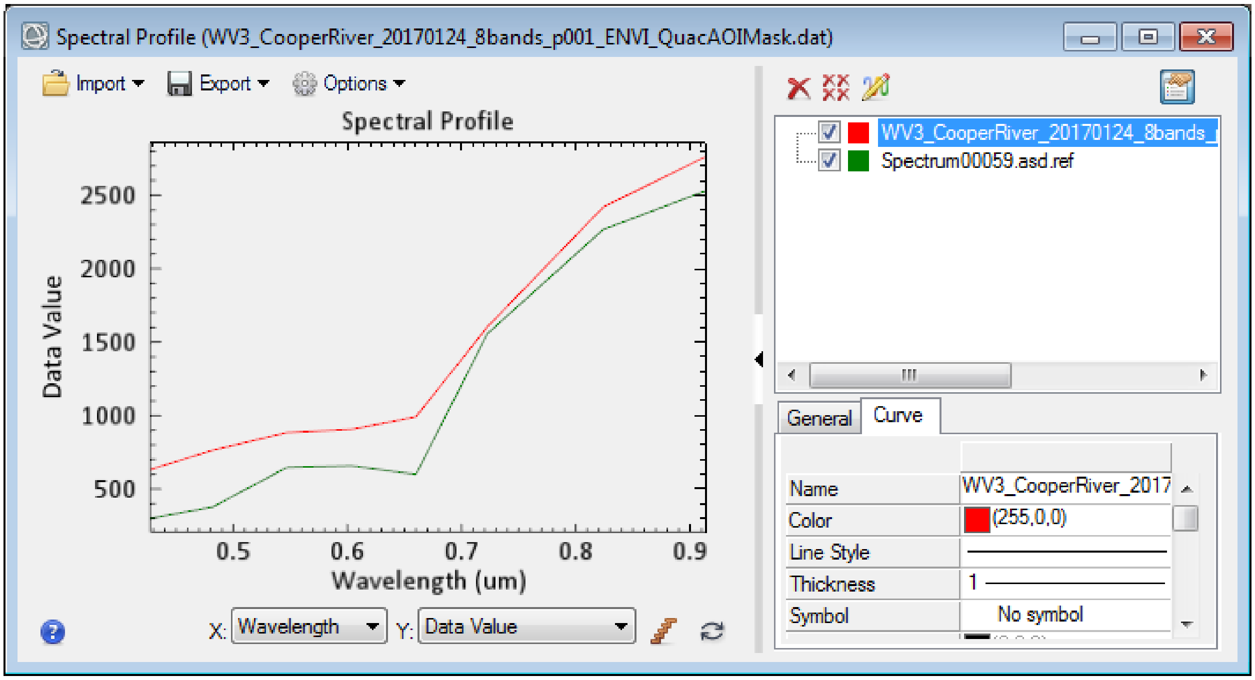


Spectral Profile (WV3_CooperRiver_20170124_8bands_p001_ENVI_QuacAOIMask.dat)

☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟩 Spectrum00056.asd.ref

Name	WV3_CooperRiver_2017
Color	🟥 (255,0,0)
Line Style	
Thickness	1
Symbol	No symbol

SiteID 36 (from Jan 2017 field survey) of ITEM Freshwater Mix (mostly white marsh); Red = image spectra, green = ASD-measured spectral reflectance.

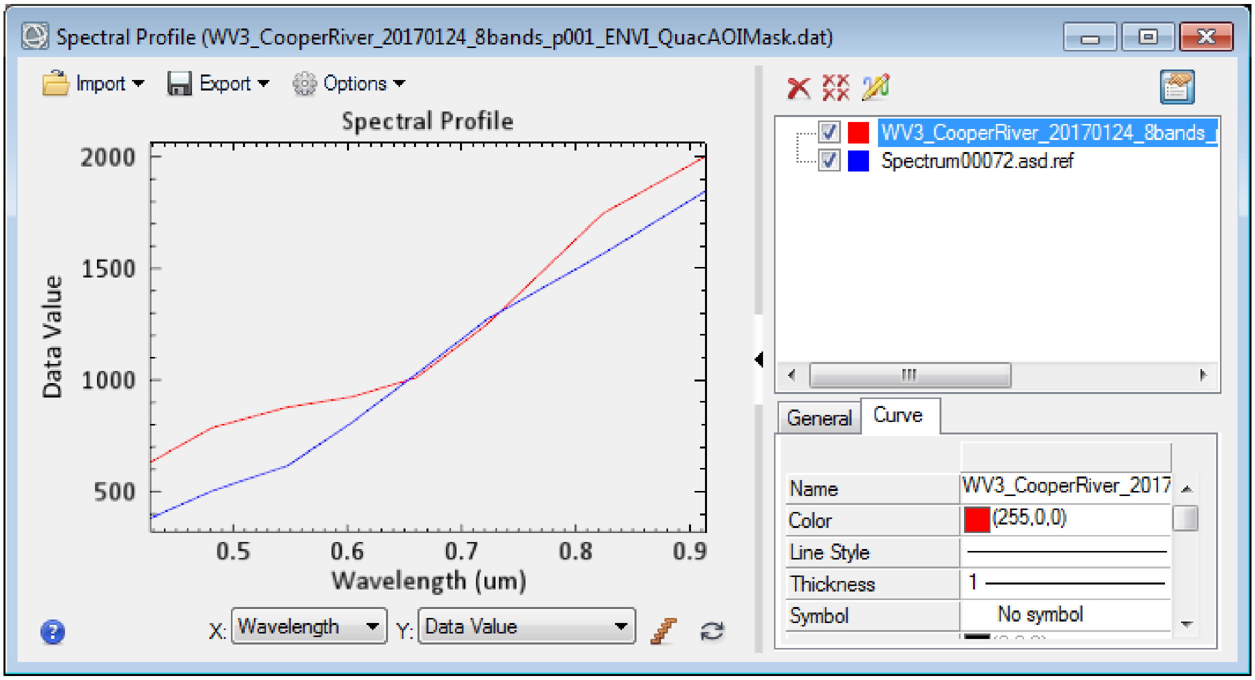


☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟩 Spectrum00059.asd.ref

X: Wavelength
Y: Data Value

Name	WV3_CooperRiver_2017
Color	🟥 (255,0,0)
Line Style	
Thickness	1
Symbol	No symbol

SiteID 41 (from Jan 2017 field survey) of ITEM Freshwater Mix (mostly cladium); Red = image spectra, green = ASD-measured spectral reflectance.



☑ 🟥 WV3_CooperRiver_20170124_8bands_
☑ 🟦 Spectrum00072.asd.ref

X: Wavelength
Y: Data Value

Name	WV3_CooperRiver_2017
Color	🟥 (255,0,0)
Line Style	
Thickness	1
Symbol	No symbol

SiteID 53 (from Jan 2017 field survey) of ITEM Big Cordgrass Mix (very mixed with black needlerush, understory species etc); Red = image spectra, blue = ASD-measured spectral reflectance.