Allouez Bay Project Report

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Project Description

The Audubon Society, along with partners and data providers at the Wisconsin Division of National Resources (DNR) needed to analyze drone imagery from part of the Allouez Bay (Figure 1). The goal of this project was to begin to understand the composition and state of the project site with special attention given to the eastern portion of the provided imagery.

The Wisconsin DNR provided raster imagery consisting of two processed images as well as two DEM models and two additional raster layers which had been enhanced using the DEMs prior to delivery. Only the two processed layers of the delivered data were used for the purpose of classification in ArcGIS Pro version 2.7. The classified layers were then exported to a prepared folder and analyzed for interspersion and other metrics using a R-Script similar to what was in a previous Audubon project “Quantifying Wetland Habitat Interspersion Using Drone Imagery”. The R-script used, the geodatabase containing the processed imagery and excel document with the processed results are included in the project deliverables.

Figure 1: Drone Imagery of Allouez Project Site

Data Processing

The two processed images were loaded into ArcGIS Pro and stored in a mosaic dataset. Two definition queries were constructed for the classification stage. Pyramids and statistic building tools were run on each image to ensure a smooth classification process. The coordinate system was also updated to UTM zone 15 because meters were required for the analysis process.

Once the coordinates were adjusted the training sets were created using the training sample manager accessed through the upper tool bar under the "Imagery" tab and "Classification Tools" dropdown menu (Figure 2).

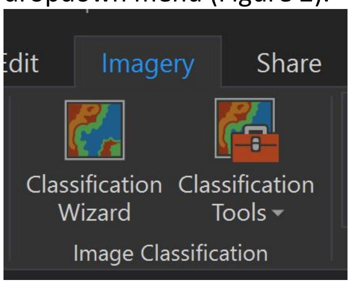


Figure 2:Classification Toolbar

The iterative process of creating the training sets took most of the project time—all but three days—and were built over the course of about eight weeks containing about 3,000 samples each. These samples were needed to train to the classifier. The classification method "Support Vector Machine" was used to test the accuracy and usability of the training sets. The vector machine method was chosen over the classic Majority Likelihood method as it produced a more accurate result, based on visual check, and ran much more quickly.

The training sets used in the final classification layers "Classification Part 1" and "Classification Part 2" contain five classes (Water, Mud, Floating Vegetation, Emergent Vegetation and Shrubs/ Trees). The vector machine classifier produced layers with a resolution of 0.1. Audubon had specified 0.01 to 0.05, but the 0.1 resolution, while coarser, gave better results, based on visual comparison to the source imagery. The final classification layers appeared to be accurate enough to be used and representative of the imagery.

There was an attempt to include floating vegetation as well, but the spectral similarity between that class and the others was too close and caused too much error, so that class was eliminated.

With more time, measured in months, the same classification could be done at a finer resolution.

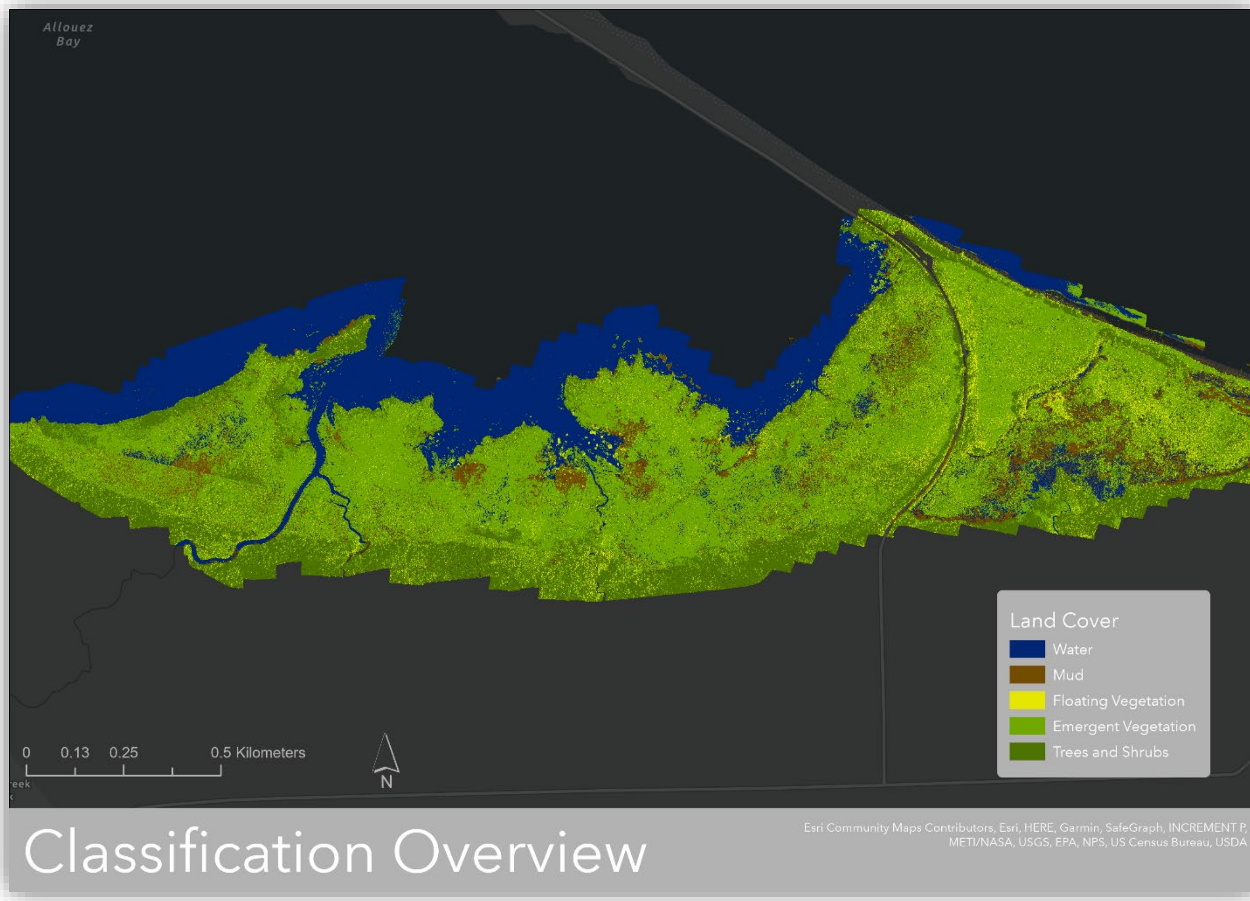


Figure 3: Allouez Bay Classification

In addition to the two classified layers, a polygon section feature layer was created to store the polygons used to clip the classified imagery down to smaller pieces so that several focused analyses could be performed on specific areas on the eastern portion of the project site (Figure 4).

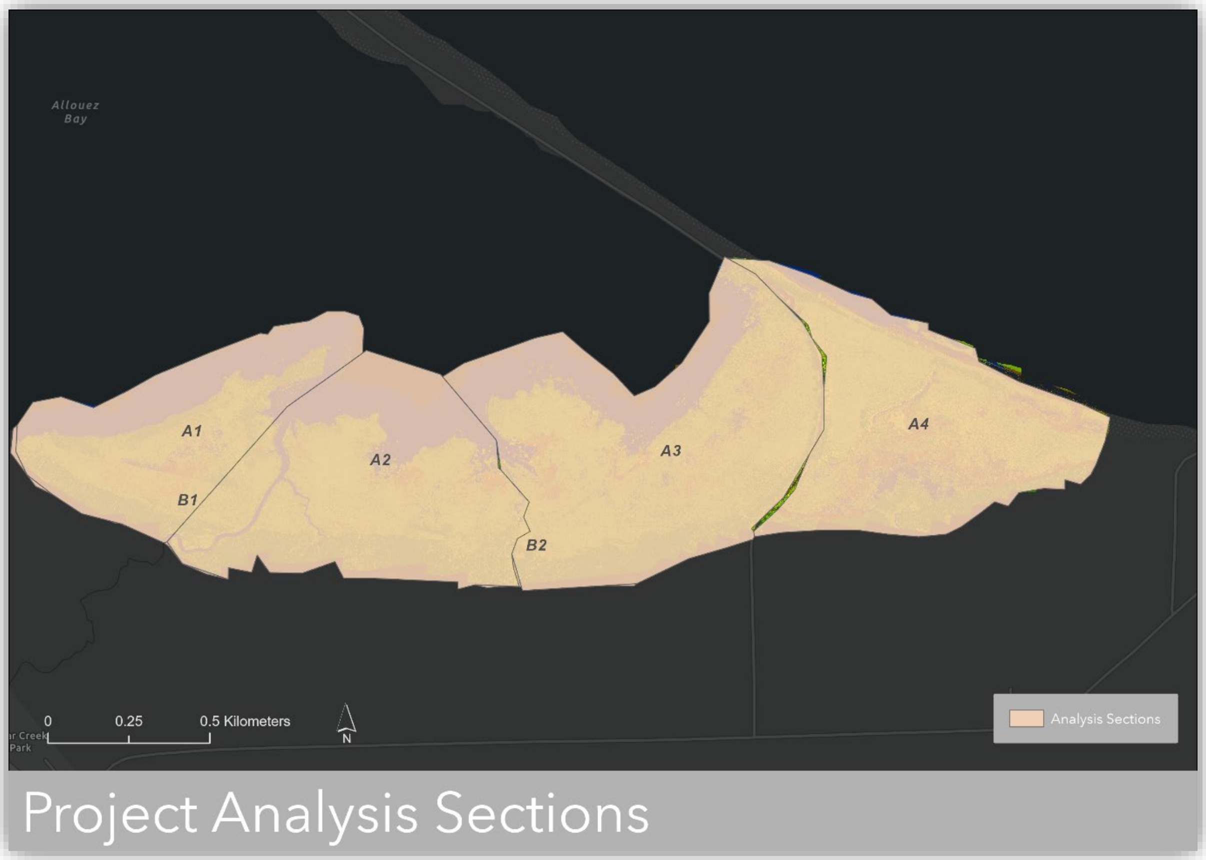


Figure 4: Analysis Sections

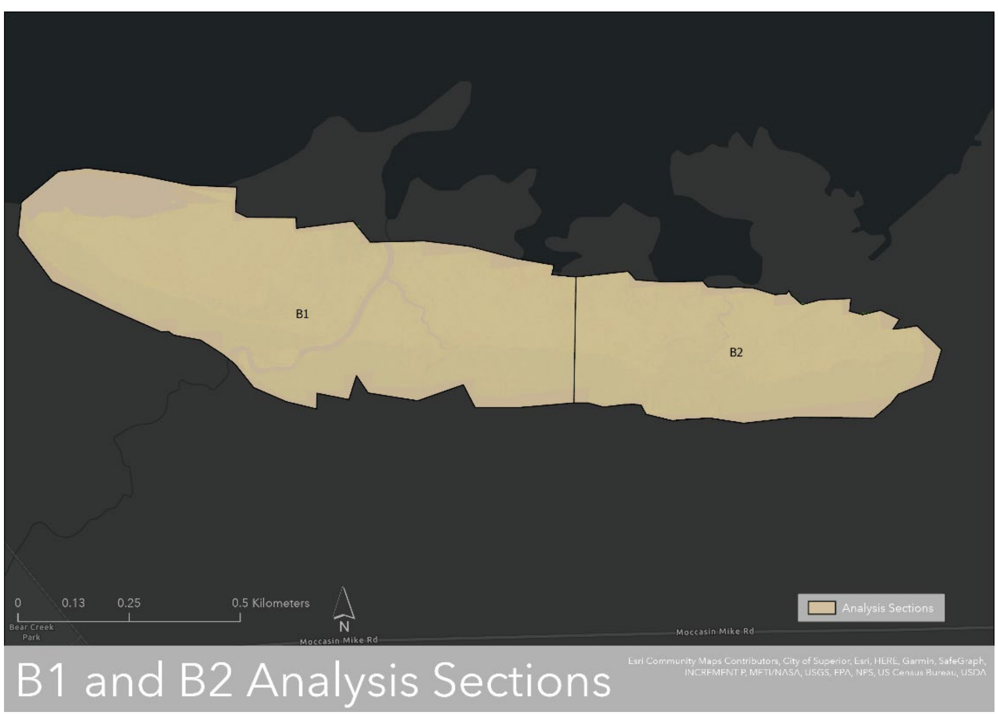


Figure 5: Analysis Sections for B1 and B2

As shown in the maps above, the sections were labeled from A1-4 for the larger classification layer and B1 and B2 for the second, smaller classification layer located south of the larger image (Figure 4). Note that B1 and B2, shown in Figure 5, overlap with the southern portions of A1-4. This was how the drone imagery was collected and processed.

Floating vegetation was removed from both the main two classification layers and six clipped sections. The main two classification layers with floating vegetation removed were saved as Overview 1 and Overview 2. All eight filtered versions were used for analysis (Overview 1, Overview 2, A1-4, B1-2).

Analysis

The primary metric used was the Interspersion and Juxtaposition (IJI) provided within the Landscapemetrics R-Library. Interspersion was a way of quantifying the intermixing of class types and presents the results as a percentage overall at the landscape level and on a per category basis at the class level. The more interspersion the better as bird species are more diverse in varied landscapes rather than where one landcover type dominates.

Additional metrics included at the class level were the “Clumpiness Index” and “Percentage of Landscape class.” At the landscape level both “Joint Entropy” and “Simpson’s Diversity Index” were included to give more insight into the character and composition of the areas and are included in the project package for all sections.

Metrics

The table below summarizes the metrics used and the reason for including them:

Table 1:Metric Overview

	Landscape Level	*Class Level*	*Reason to include*	*Output Range and other notes (“What is a good result”)*
Interspersion and Juxtaposition (IJI)	x	x	Shows how mixed the included classes are within a landscape or between each class	0% <= IJI <= 100% Approaches 0% as interspersion decreases (bad) Approaches 100% as interspersion increases (good)
Clumpiness Index (CLUMPY)		X	Measure of adjacency, indicates the extent of aggregation or fragmentation of each class type within a landscape	-1 <= CLUMPY <=1 Equals -1 when class is totally disaggregated or fragmented, (good) 0 when randomly distributed (neutral)

				1 when class is maximally aggregated (bad)
Percentage of Landscape (PLAND)		X	Reports the percentage of total landscape belonging to any one class. Measure of composition, directly comparable among landscapes with different areas It is a relative measure	0% < PLAND <=100% PLAND approaches 0 when proportional class presence area is decreasing Equals 100 when only one patch is present. Neither extreme is good, unless invasive species are the class declining
Simpson's Diversity Index (SIDI)	x		Widely used in ecology and biodiversity. Interpreted as the probability that two cells belong to the same class	0<=SIDI<1 Equals 0 when only one patch is present Approaches 1 when number of class types increases while proportions are equally distributed
Joint Entropy (JPONENT)*	X		"Represents the uncertainty in determining the category of the focus cell and adjacent cell" (Nowosad & Stepinski, 2019)	The smaller the diversity of values, the larger the value of joint entropy Lower score = better (less uncertainty)

*Please see attached article "Information Theory as a Consistent framework for Quantification and Classification of Landscape Patterns" provided with this report for more information on the Joint Entropy metric.

Analysis Procedure

Once the eight classified layers were complete and stored in the Classified tiff folder, the layers were read and stored within R Studio for analysis. There were four main parts of the script: read the data, check for accuracy and usability, analysis, and exporting the results. Once the results were saved as CSV files, the data was combined and processed as a single .xlsx file. The analysis workflow is shown in Figure 6 starting with the standard procedures when working with GIS data: loading libraries, checking the R-Bridge connection, setting the working directory, and reading in data.

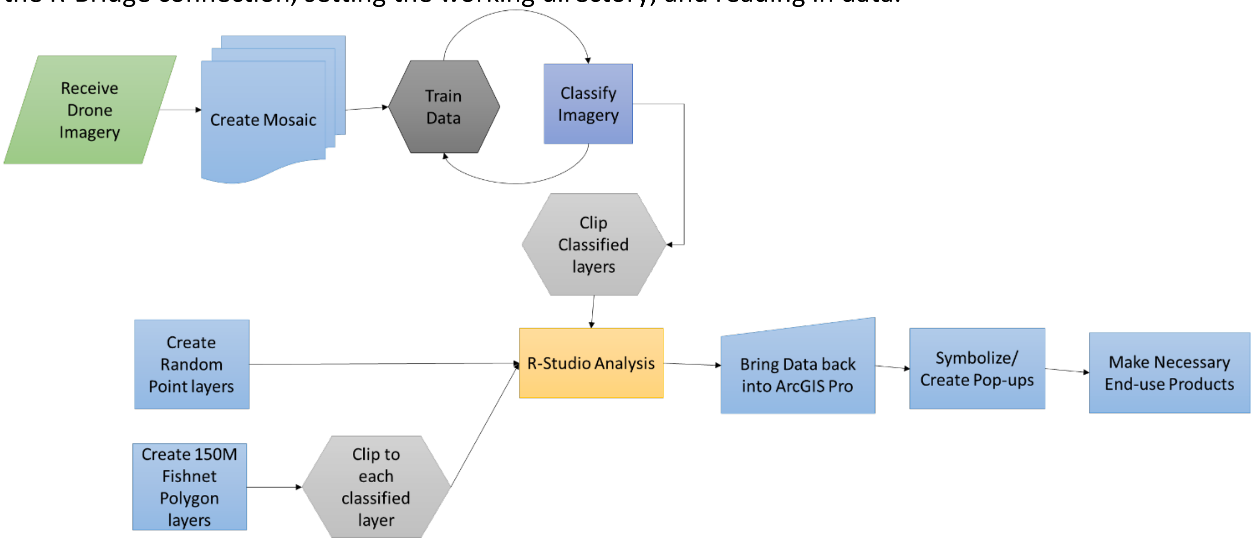


Figure 6: Allouez Bay Project Workflow

The libraries used for this project were Raster, Landscapemetrics, ArcGIS Binding, gdalUtils, SP, and dplyr which was used for dataframe and table manipulation. In this case, combining results into one table per raster layer facilitated the exporting of results.

After setting the working directory, each raster layer was called and stored under a variable name. The variable names match the names given to the exported files in the Classified Tiffs folder.

The next step in the workflow was to check the landscape using a built in command from the Landscapemetrics library "check_landscape()" to ensure that all were read correctly, the coordinates were metric based, and that the correct number of classes were recorded.

All layers had the landscape and class level interspersion (IJI) metric applied to them, but only A3, A4, and B2 had the additional metrics applied as they fell in the eastern portion of the project site—where the Audubon requested more statistics to be run.

The results from the analysis were then exported as CSV files to the folder set at the working directory. From there the data was copied, saved, and processed in an excel .xlsx format spread sheet. From there the data was loaded back into ArcGIS Pro and used to create maps and media. The processed results are expanded upon in the next section.

Raw Results

The Interspersion section below is organized with the Overview layer results first, then A layers, and finally the B layer results. The landscape level tables are identified by the Overview layer number (1 or 2. The Land Cover Type or class types in tables and graphs are recorded as 1 for water, 2 for mud, 3 for emergent vegetation and 4 is for shrubs/trees. Following these general results is a section on management implications and includes maps to provide a better visual of the analysis results.

Interspersion Results

Table 2 :General Landscape Interspersion

Layer	*Level*	*Class*	*ID*	*Metric*	*Value*
1	landscape	NA	NA	iji	*75.7%*
2	landscape	NA	NA	iji	*46.1%*

For "Class" in the charts below, 1 = water, 2 = mud, 3 = emergent vegetation and 4 = shrubs/ trees.

Table 3: Overview 1 Class Level Interspersion

Layer	*Level*	*Class*	*ID*	*Metric*	*Value*
1	class	1	NA	iji	*62.7%*
1	class	2	NA	iji	*82.2%*
1	class	3	NA	iji	*91.0%*
1	class	4	NA	iji	*31.3%*

Table 4: Overview 2 Class Level Interspersion

Layer	*Level*	*Class*	*ID*	*Metric*	*Value*
2	class	1	NA	iji	*58.8%*
2	class	2	NA	iji	*36.1%*
2	class	3	NA	iji	*61.2%*
2	class	4	NA	iji	*18.9%*

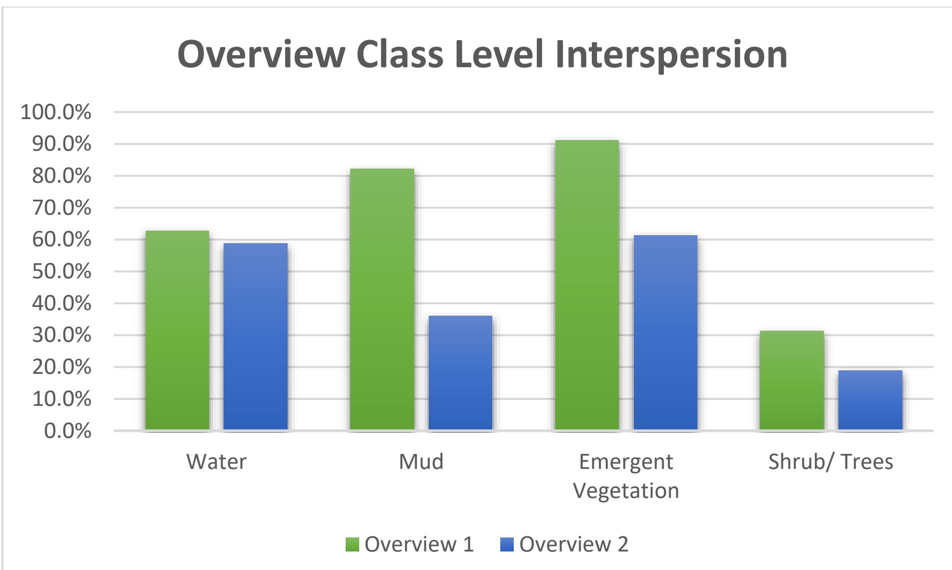


Figure 7:Class Level Interspersion for Overview Layers 1 & 2

Assessment:

Overall, as Table 2 shows, Overview 1 had a higher interspersion percentage than Overview 2 at the landscape level (75.7% vs 46.1%). Of the class interspersion results the mud class from Overview 2 (in blue) had the smallest interspersion result meaning there are large patches of just mud. Both Overview layers had low shrub/tree class interspersion meaning there were large clumps of trees which is easily seen on the classification imagery in Figure 8, Figure 9 and in the class level results.

Figure 8: Overview 1 Analysis Classification

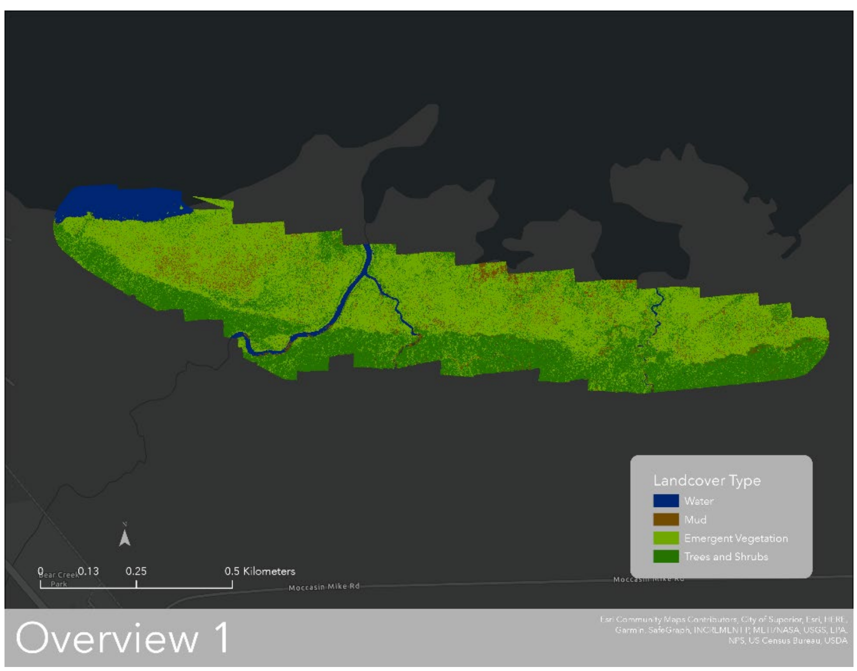


Figure 9: Overview 2 Analysis Classification

Table 5: Landscape Level Interspersion for Layers A1-A4

Layer	*Level*	*Class*	*ID*	*Metric*	*Value*
1	landscape	NA	A1	iji	*68.0%*
1	landscape	NA	A2	iji	*67.7%*
1	landscape	NA	A3	iji	*76.2%*
1	landscape	NA	A4	iji	*78.4%*

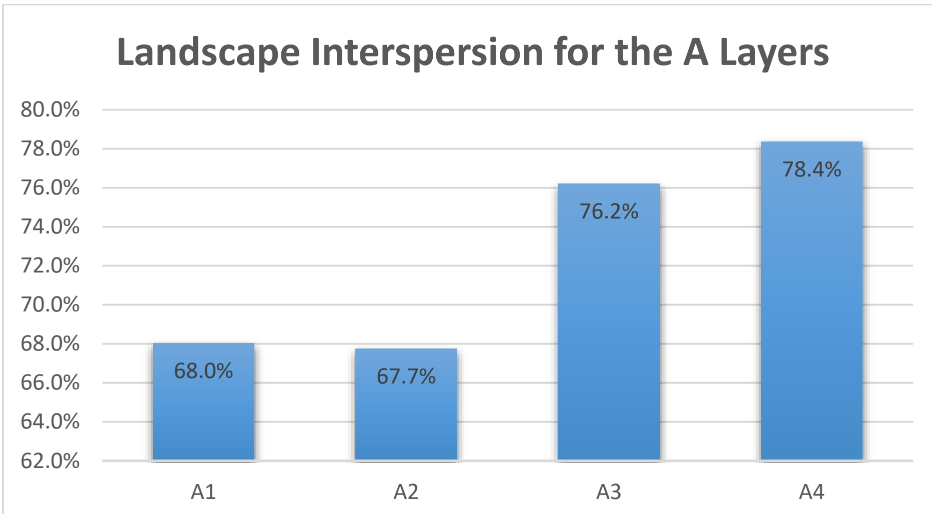


Figure 10: Landscape Level Interspersion for A Layers

Out of the four A Layer sections, A3 and A4 had the highest landscape level interspersion rates, this could be due to the increased presence of trees and mud patches that were less prominent in the western portion of Overview 1. Overall, the interspersion results at the landscape level were similar in the northern portion of the imagery; there was a 10.7 range in the results.

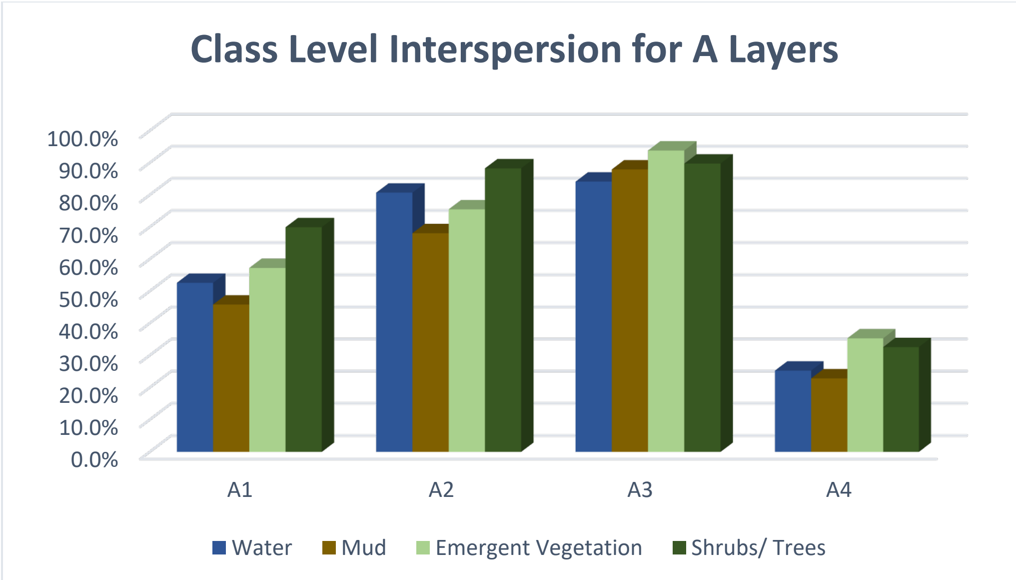


Figure 11: Class Level Interspersion for A1 – A4

A4 shows far less interspersion at the class level than the other three sections with A1 having the second least. This was noteworthy because at the landscape level A4 has one of the highest interspersion percentages. This may have happened because each individual patch of a class was more cohesive, but still contained more intermixing because of the quantity of each class. Interspersion does not tell how much of a class there is, just how much landcover complexity or mixing is present.

Table 6: Landscape Level Interspersion for B Layers

Layer	*Level*	*Class*	*ID*	*Metric*	*Value*
2	landscape	NA	B1	iji	*46.0%*
2	landscape	NA	B2	iji	*45.5%*

Overall, Overview 2 had slightly less interspersion than Overview 1 and this is further confirmed by the results from the B1 and B2. As seen in Table 6, both received a result under 50% at the landscape level, consistent with 46.1% for Overview 2 or the B layers overall.

Table 7: B1 Class Interspersion

Layer	*Level*	*Class*	*ID*	*Metric*	*Value*
2	class	1	B1	iji	*63.5%*
2	class	2	B1	iji	*34.4%*
2	class	3	B1	iji	*61.5%*
2	class	4	B1	iji	*18.0%*

Table 8: B2 Class Interspersion

Layer	*Level*	*Class*	*ID*	*Metric*	*Value*
2	class	1	B2	iji	*66.1%*
2	class	2	B2	iji	*50.3%*
2	class	3	B2	iji	*54.6%*
2	class	4	B2	iji	*26.7%*

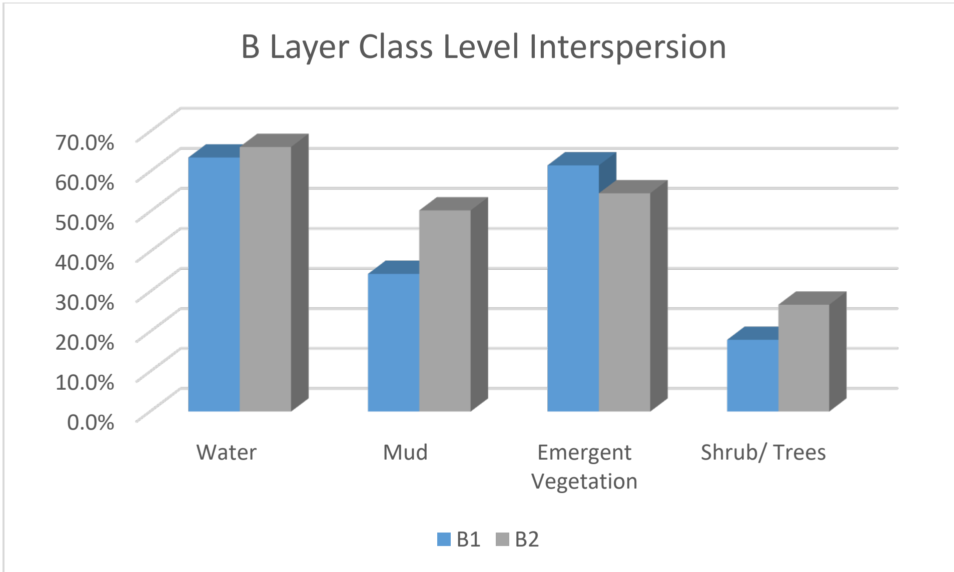


Figure 12: Class Interspersion for Layers B1 and B2

Out of the four classes, Shrub/Trees from both B1 and B2 had the least interspersion. Mud had the second least, but that class tends to show in large patches. Most of the woody plants in Overview 2 were in the lower portion of the image, without much contact with the other land cover types and had a low score.

Final Maps and Discussion

Management Implications

To provide an interpretation of the interspersion data that allows for a finer comparison of results, 150-meter fishnet grids were generated across the entire site and then separately for each of the five regions. Interspersion metrics calculated uniquely for each cell in the grid allows for a quicker comparison of landscape features of any given region compared to the analysis of an entire region or the whole site, as each 150-by-150 grid occupies an area of about 5.5 acres, with the cells classified based on their rate of interspersion. Each of these 5.5-acre units can be considered separately for monitoring and management planning.

The grid analysis was performed for the whole site and for each individual region to generate a two-tiered interpretation of the data. At the regional level, the interspersion rates show the relative difference in wetland composition. At the site level, the interspersion rates show the absolute difference across the whole system, which serves to highlight the highest and lowest rates of interspersion across the site. For example, a cell in region A1 may have the highest interspersion score compared to the rest of the cells in region A1. When compared to the entire site, however, the interspersion rate may be significantly lower than interspersion rates in a different region. This allows land managers the ability to compare site conditions to plan for management.

In addition, 3-4 random points were generated within each region, to provide an even finer interpretation of the classification data. This scale of analysis includes a representation of the classified data and a breakdown of the percentage of classified landcovers, to provide landowners with an interpretation of the site conditions. This is an important additional layer to consider for land management. Interspersion metrics alone cannot inform land use decisions as an understanding of the underlying structure of a given area is needed before decisions can be made, as interspersion metrics inform a percentage of patchiness rather than any physical description of the site.

For example, an area with a low interspersion rate may suggest that landowners should work to thin or remove vegetation to increase the rate of interspersion. That would be true if the dominant landcover was emergent vegetation. However, the underlying landcovers may show that the rate of interspersion is low because of a large amount of water. This shows that vegetative control would not increase interspersion in the system, and that alternative strategies to increase that the enhancement of, rather than the control of, vegetation is needed to increase interspersion in the system.

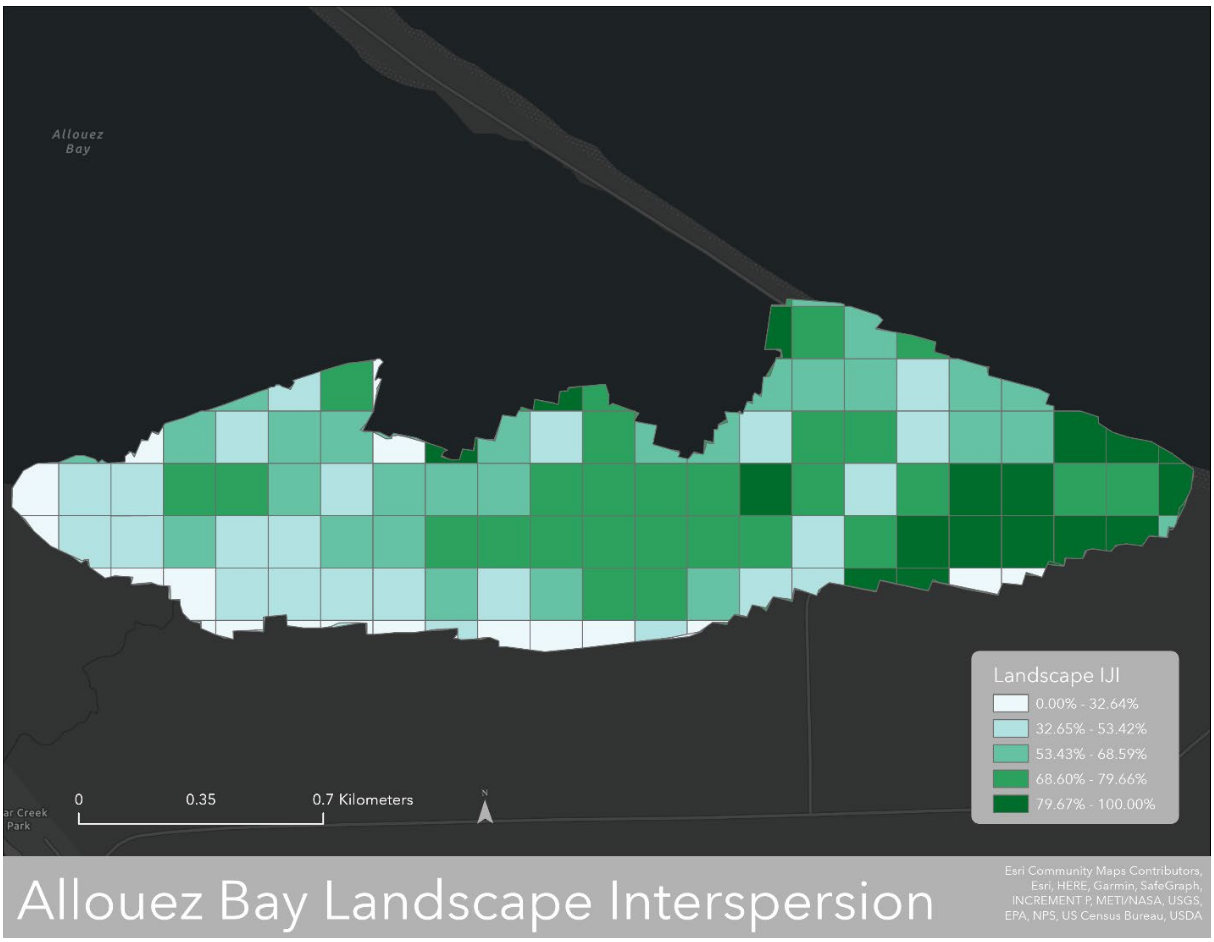


Figure 13: Allouez Bay Fishnet Interspersion

Management Implications: A1

The center of Region A1 exhibits high interspersion, with rates between 70-100% interspersion. When compared to the rest of the site, however, the amount of interspersion in this segment is less than other areas. In general, A1, and the western half of the site in general, see lower rates of interspersion than the center and easternmost wetlands. The patchiness in this region is generated from a mix of woody vegetation following what may be a ridgeline along the western edge of the wetlands.

There are significant patches of water throughout the center of region A1, with a large patch of mud at the southern end of that area. These two features, and the patchy but abundant emergent vegetation between the two create the most interspersion in this region. In periods of low water, it would be prudent to protect this area from woody encroachment.

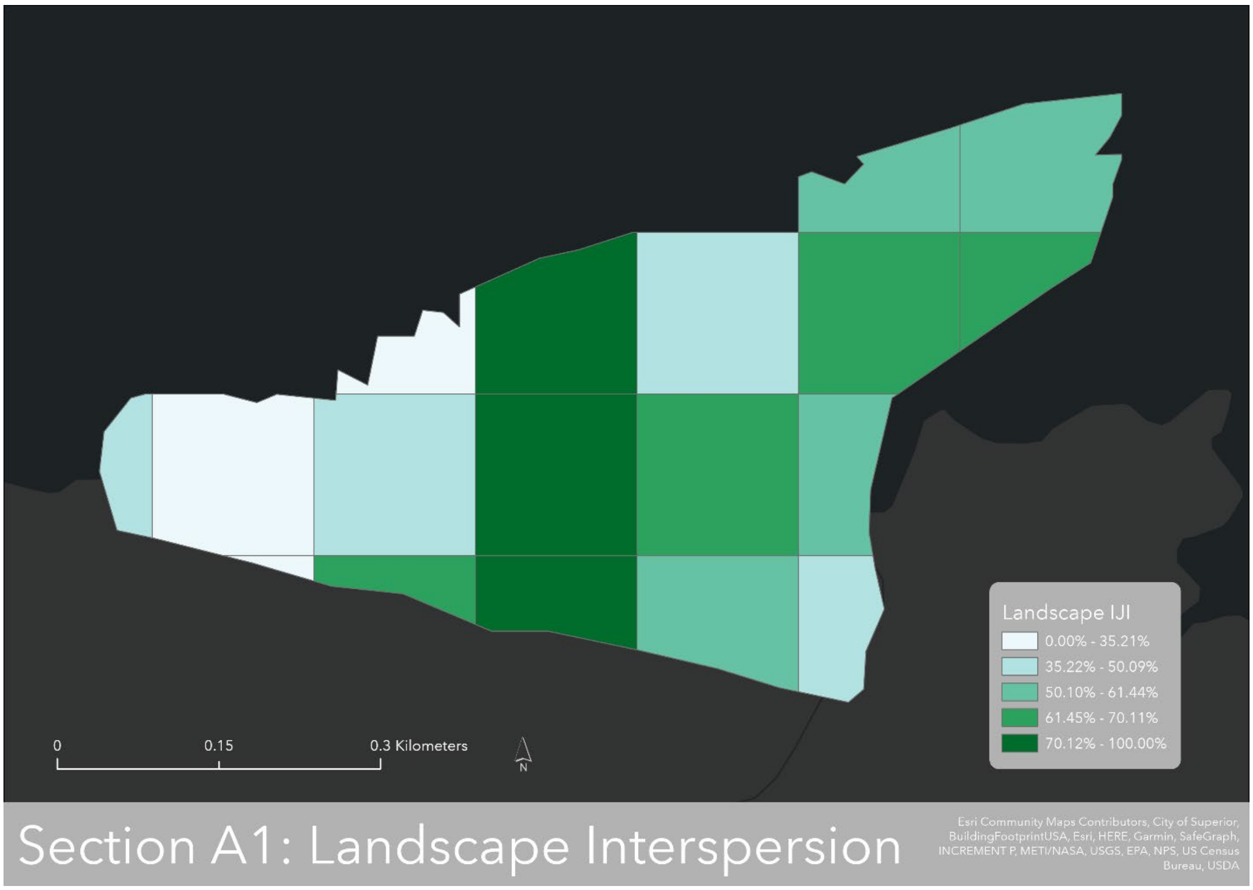
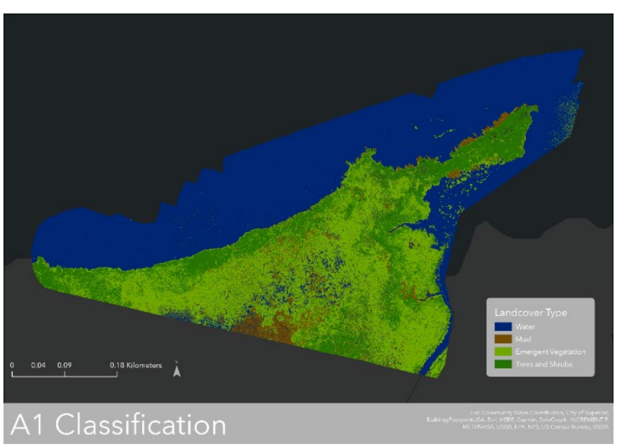


Figure 14: Section A1 Fishnet Interspersion



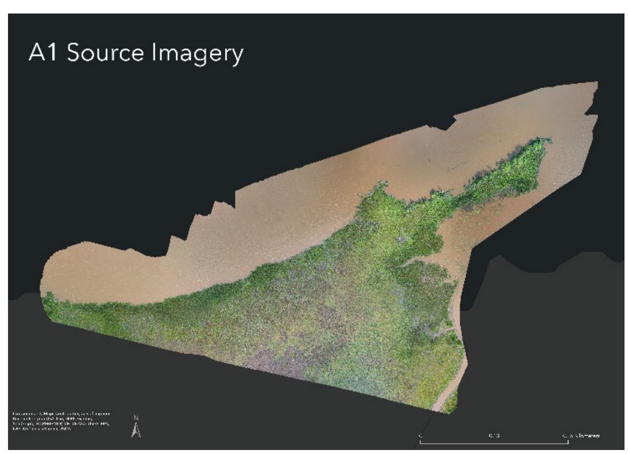


Figure 15: A1 Classification

Figure 16: A1 Imagery

Management Implications: A2

Region A2's analysis suggests high amounts of interspersion along the emergent vegetation – open water interface on the region's northern edge. When compared to the entire site, the entire region maintains high amounts of structural diversity, particularly along the water's edge. Because Allouez Bay currently has high water levels, these areas may be of interest in the near future when water levels drop once again. Emergent vegetation can fill in where water levels recede, reducing overall interspersion.

Considering this is the stretch of wetlands adjacent to the deeper body of water of Allouez Bay with the highest amount of interspersion, it may be prudent to monitor how this section responds to changing water levels. Other areas of high interspersion throughout the site may be more protected from these changes. This region may be the most structurally diverse stretch of wetlands at Allouez Bay, so care and management into protecting that diversity is a strategic investment.

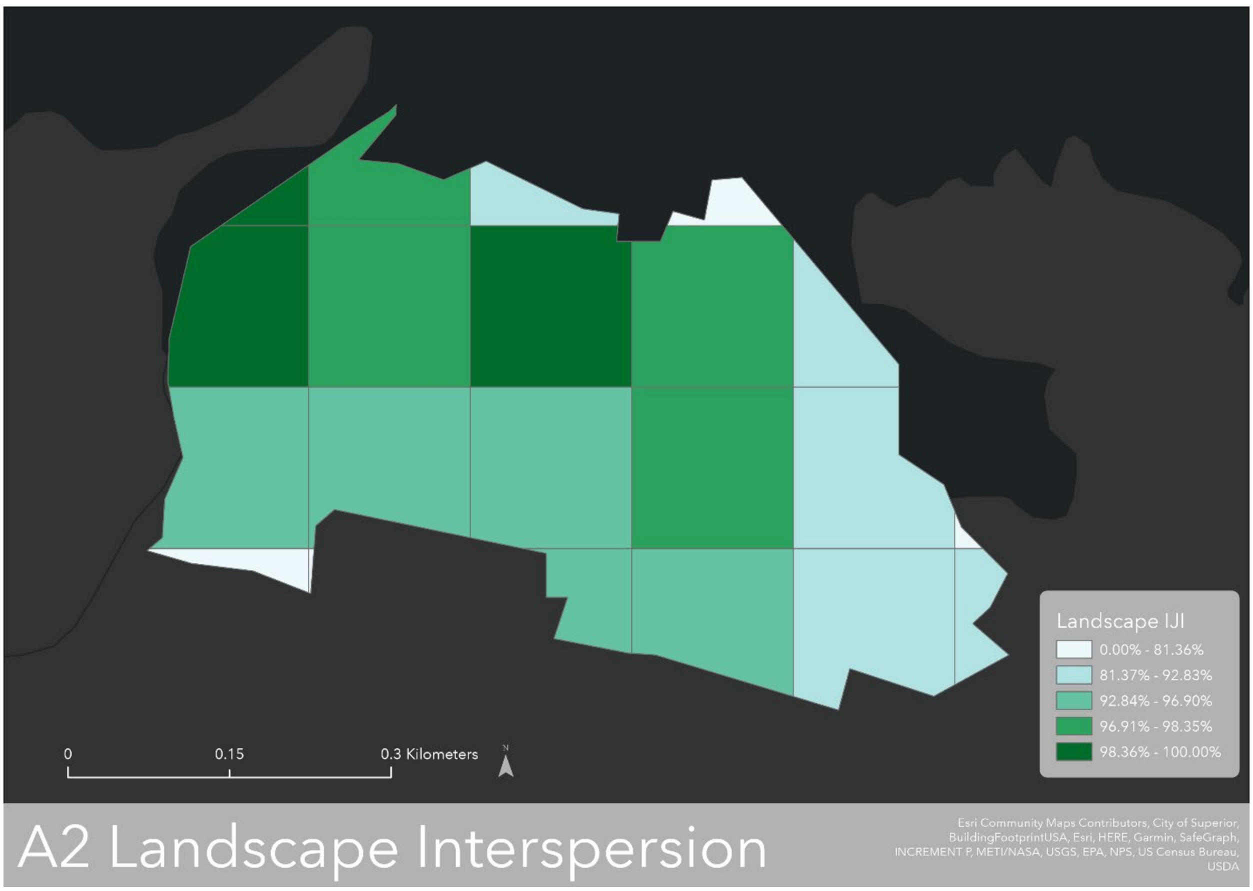
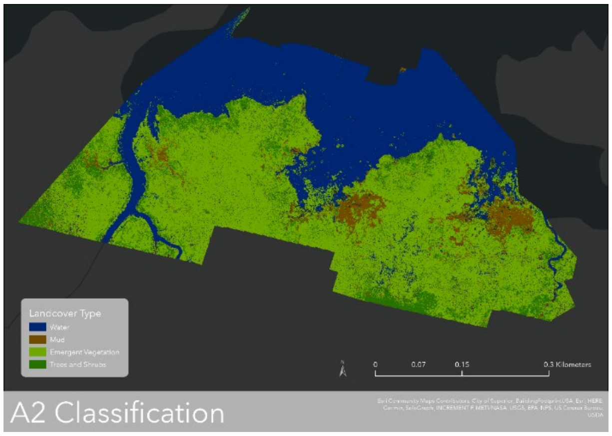


Figure 17: Section A2 Fishnet Interspersion



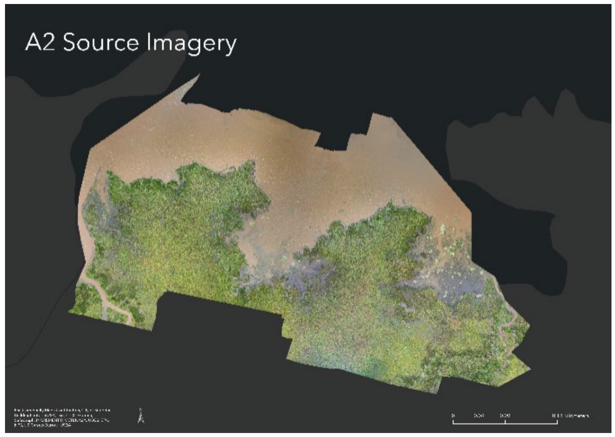


Figure 18: A2 Classification

Figure 19: A2 Imagery

Management Implications: A3

Region A3 has significant interspersion throughout. However, the northern edge of the wetland, where it interfaces with the deeper water of Allouez Bay, seems to have a bit of an elevated ridge, as there are woody plants and trees along the edge. There is relatively little interspersion at this edge as well, with a consistently sharp edge between open water and woody plans and/or emergent vegetation.

The interior of A3 is more interspersed, with higher amounts of water and exposed mud creating a structurally diverse system. Without a better understanding of the bathymetry, it seems that these interior patchy wetlands may be at risk of filling in with emergent vegetation and woody plants if water levels were to drop, as there are no rivers or streams in this section that can provide consistent water. Thinning and removing emergent and woody vegetation may help prevent an encroachment of vegetation into these fairly well interspersed inland areas.

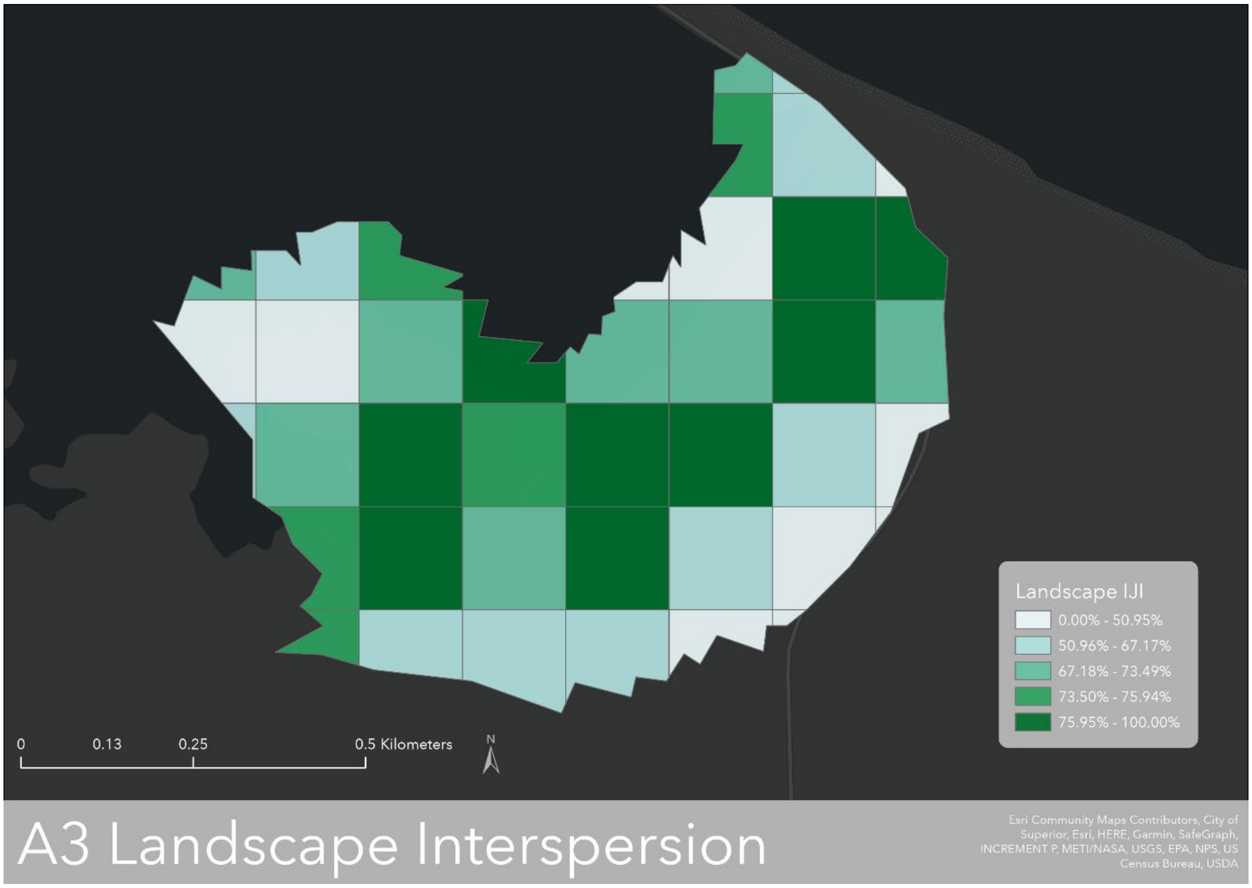
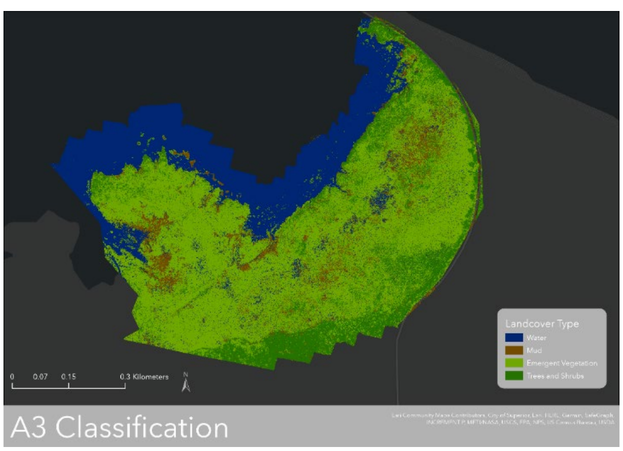


Figure 20: Section A3 Fishnet Interspersion



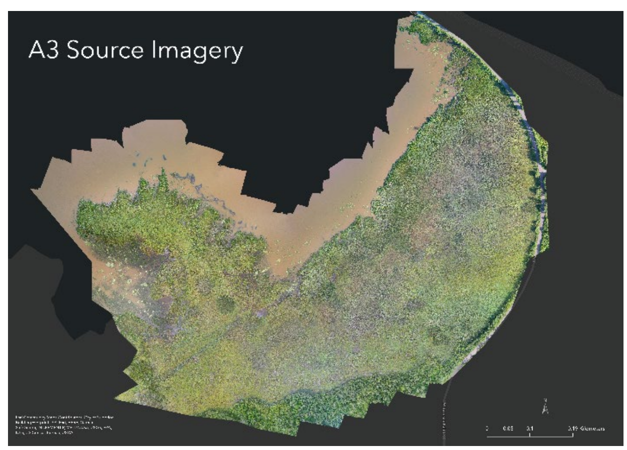


Figure 21: A3 Classification

Figure 22: A3 Imagery

Management Implications: A4

As shown by the site-wide analysis, Region A4 has some of the highest interspersion rates of all of Allouez Bay. Compared to the other sites, this area has significantly more patches of exposed mud throughout the region and the patches of exposed mud are larger, creating many habitat patches between the emergent vegetation and pools of open water. The northern section of A4, presumably the location of the old landfill, is less interspersed and is dominated by emergent vegetation, while the lower half exhibits very high interspersion.

In periods of low water, the exposed mud and open water pools may be at risk of infill from the surrounding vegetation. Work in this region would likely focus on maintaining rather than recreating the overall structural diversity of the wetlands. Because this section is less influenced by Allouez Bay water levels and its seiche effects, a drop in water levels may quickly alter the structure of this site as it may be less likely for water to enter the system.

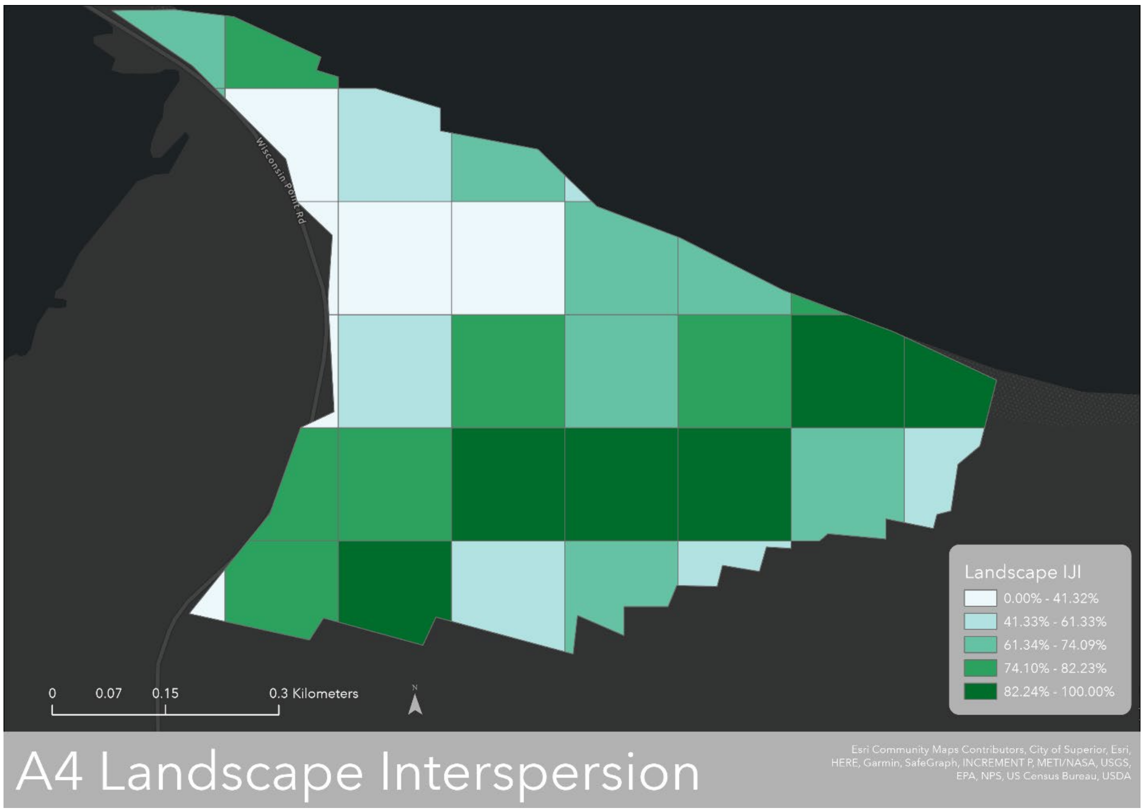


Figure 23: Section A4 Fishnet Interspersion

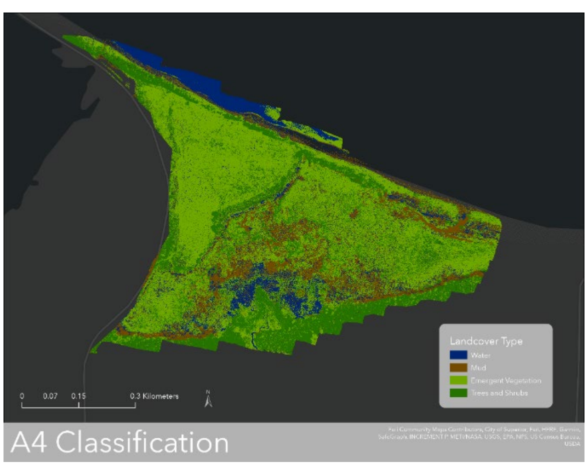


Figure 24: A4 Classification

Figure 25: A4 Imagery

Management Implications: B1

Region B1 has some of the lowest interspersion rates as compared to the rest of the region. What interspersion exists in the region is mostly due to patchiness generated from patches of woody plants encroaching into emergent vegetation, rather than a true hemi-marsh mixture of emergent vegetation, exposed mud, and open water.

The easternmost region of B1 has higher interspersion than the rest of the region due to an increase in the amount of mud and open water in the system, mostly due to the mouth of Bear Creek. Reducing woody encroachment can diversity the wetland structure. Further, introducing additional channels or potholes within the Bear Creek system can encourage wetter conditions that can increase the patches of open water and exposed mud throughout the region can be suitable for enhancing structural diversity.

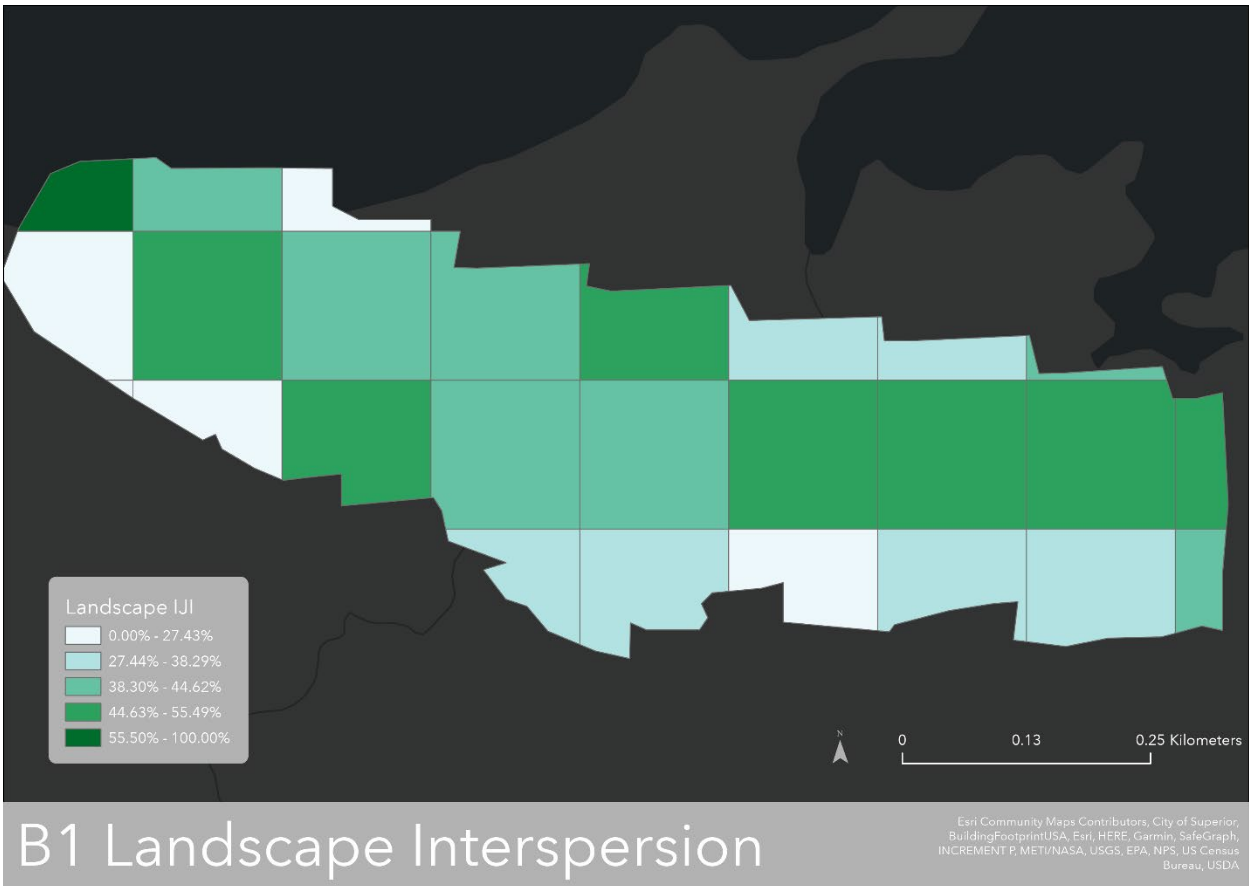
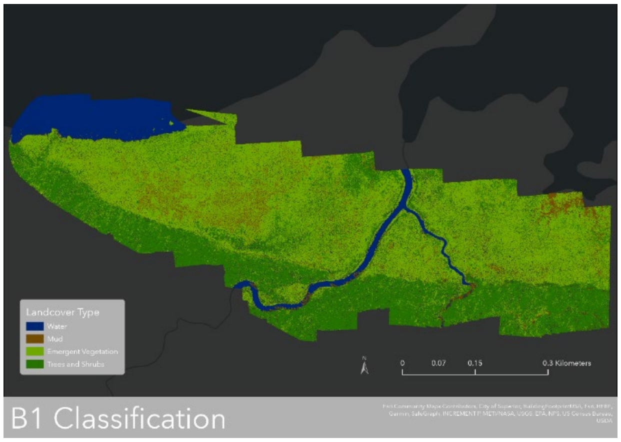


Figure 26: Section B1 Fishnet Interspersion



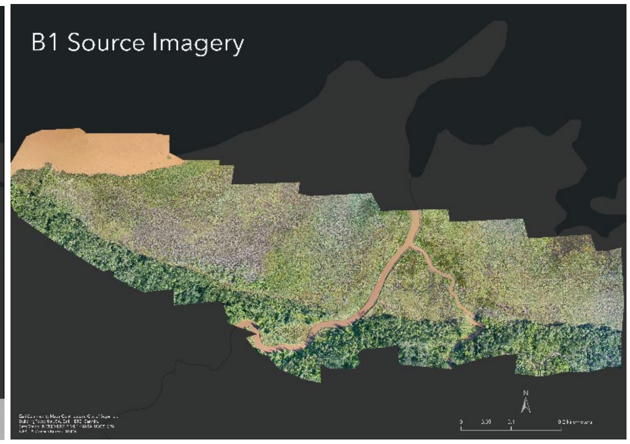


Figure 27: B1 Classification

Figure 28: B1 Imagery

Management Implications: B2

Region B2 may exhibit the lowest interspersion rates within the whole site. Compared to the rest of the site, the easternmost cells of B2 are highly interspersed, though the cell with the second highest interspersion rate has a rate of 46.4%, which is lower than average. Further, the interspersion in this section is a result of a high amount of intermixing between emergent and woody vegetation, with a heavy amount of tree cover dominating the southern edge of the region.

Further analysis is needed, but aside from channeling and potholing to encourage more open water and exposed mud, there may be little opportunity to enhance interspersion in this region. There simply may not be enough water to create a diverse hemi-marsh habitat. One consideration would be to reduce woody encroachment in the emergent vegetation. This may can create a more ideal habitat for marshbirds, who at present would avoid this area due to the high present of woody vegetation.

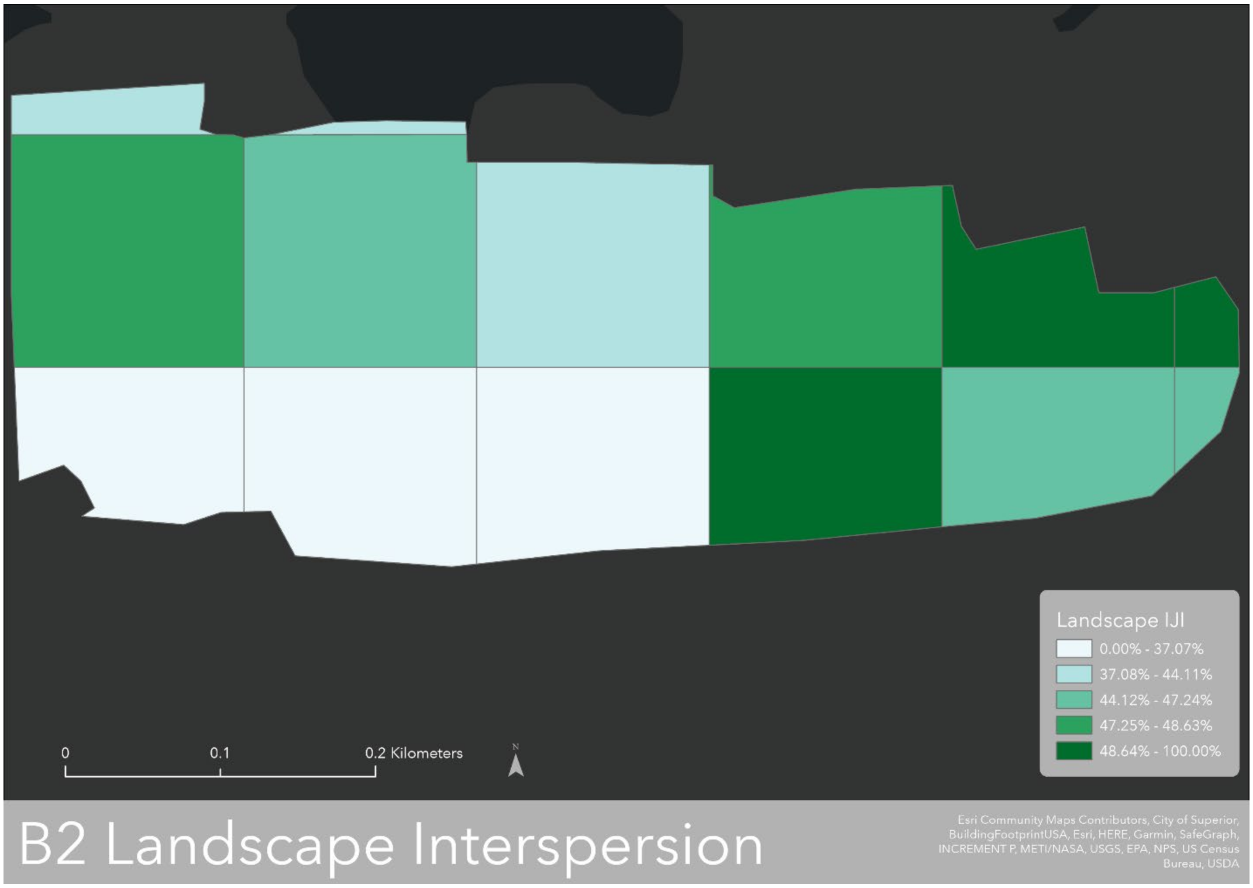


Figure 29: Section B2 Fishnet Interspersion

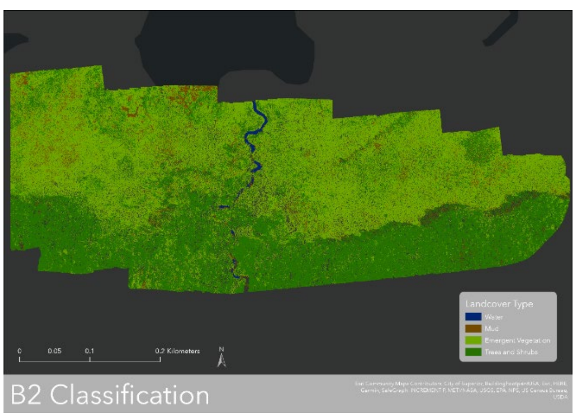


Figure 30: B2 Classification

Figure 31: B2 Imagery

Overall Management Recommendations

Regions A2 and A4 currently have the highest amount of interspersion. While this is desirable, the presently high water levels of Allouez Bay suggest that as water levels recede, these highly interspersed areas are at risk of filling in with vegetation. While that is a natural dynamic of coastal wetlands, care should be taken in monitoring how the wetlands and the marshbirds that depend on them are responding to water levels. If these currently highly interspersed areas appear to be filling in with vegetation, it may be prudent to prevent extensive encroachment or create additional interspersion elsewhere.

In regions like A1, A3, and B1, creating structural diversity through the cutting or removal of vegetation, both woody and emergent, can provide benefits to wildlife. Further, digging potholes and additional channels to encourage more water to stay within the system may create more permanent means of increasing structural diversity in the interior of this coastal wetland system.

Continued monitoring is necessary to understand how this system responds to fluctuations in water levels. The peninsula-like ridge in region A1 may protect the wetlands on its south, landward side. Opportunities to create structural diversity of shallow water, muddy patches, and emergent vegetation in this pocket of mostly open water and floating vegetation may be fruitful for attracting wildlife of interest.

Discussion and Conclusion

The goal of this project was to obtain a baseline understanding of habitat composition and Interspersion for a site in the Allouez Bay with emphasis on the eastern portion. To complete the task, drone imagery was compiled in ArcGIS Pro and classified in two parts, Overview 1 and 2. These two layers were then further sectioned off into smaller portions A1-4 for Overview 1, B1&2 for Overview 2, Figures 4 and 5. All classified layers were filtered from an original five classes down to four eliminating floating vegetation as that class was not very prominent in the landscape, then all were exported and analyzed.

In general, the Allouez bay has moderate interspersion with the upper portion belonging to Overview 1 being better than the lower, southern Overview 2. At the class level both had the least amount of interspersion in Class 4 (shrubs/ trees), likely because most grew in tighter clumps in the south eastern portion of the imagery. This pattern was further proven in Figure 11 where the diversity index showed both A sections having a higher index result than the B2 layer. It is possible that some mud or emergent vegetation was present but covered by canopy and therefore not picked-up in the classification. The Eastern portion of Overview 1—A3 and A4—have the highest interspersion rates, but their class make-up is quite different as shown in figures 15 and 16 and can be further explored within the project layers.

The two sections of Overview 2, B1 and B2 had much less interspersion than Overview 1 sections. Between the two, B1 had slightly better results, but it was also bigger and the classes within it were visibly more interspersed with patches of mud mixing with emergent more frequently.

From the compiled metrics a general understanding of habitat composition is easily obtained though some further investigation will be necessary to gain more specific information if a more targeted analysis is necessary. The script used to run the analysis is provided as a deliverable and the metrics used can be switched out, as necessary. In the future for longer term projects, the traditional Majority Likelihood classification method is a better option for fine detail work—especially if species specific classification is needed. The vector machine method used in this project is good for more generalized analysis and produces accurate results quicker because the output image is aggregated to a courser resolution.

At the highest, simplified level, Overview 1 looks the best for habitat especially in the most east portion covered by Sections A3 and A4. The lower portion of the imagery covered by Overview 2 needs further investigation for conservation as it received the less desirable results and the management implementation guide included in the previous section provides some measures for moving forward.

Works Cited

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