2016 MBNEP Uplands/Wetlands Habitat Mapping Project

Trend Analysis Report

Introduction

To support the MBNEP mission and objectives, an analysis of the trends in changes to landcover types has been conducted. The goal is to provide an analysis of the landcover changes detected during the time period between MBNEP's two most recent upland/wetland habitat mapping efforts (2002 and 2016). The results of this analysis are meant to highlight habitat losses or gains and net changes in Cowardin/Anderson landcover types between the two time periods in Mobile and Baldwin Counties and explain the limitations and constraints of the analysis to aid interpretation.

Study Area Datasets

The geographic focus of the MBNEP study area includes both Baldwin (1,074,510 acres) and Mobile (816,680 acres) counties, which together comprise 1,892,190 acres.

2002 Data - USGS National Wetlands Research Center

In 2002, MBNEP contracted with USGS National Wetlands Research Center (NWRC) in Lafayette, LA to acquire color infrared (CIR) aerial photography at 1:40,000 scale of Mobile County. In 2003, USGS NWRC produced upland/wetland habitat maps of Mobile County using the 2002 color infrared photography. The wetlands were classified in accordance with national federal standard FGDC-STD-004 (also referred to as Cowardin wetland classification system (Cowardin et al., 1979)), and the uplands were classified using the Anderson Level II upland habitat classification system. Between 2004-2006, USGS NWRC collected color infrared aerial photography, classified it using a Cowardin/Anderson habitat classification system, and produced upland/wetland habitat maps of Baldwin County. Habitat features were delineated using a manual digitizing methodology to create feature (vector) polygons. This classification is hereby called "*2002*" or "*2002 classification*" throughout the remainder of this report.

2016 Data

In 2016, Radiance Technologies partnered with Quantum Spatial (QSI) to acquire, 4-band CIR ortho-imagery over Baldwin and Mobile Counties. Nine QSI aircraft flights collected data between January 17, 2016 - February 10, 2016 using a Leica ADS 100 camera. In accordance with FGCD Wetlands Mapping Standard FGDC-STD-015-2009, the imagery acquired was color infrared, 1m resolution (1:12,000 scale), cloud-free and leaf off, with a winter tasking acquisition window.

Using the 2016 imagery, the Radiance Technologies Team utilized an object-oriented segmentation classification approach to produce an Upland/Wetland Habitat Map (Figure 1). Consistent with the previous 2002 USGS classification scheme, the 2016 data was also classified using the FGDC-STD-004 Cowardin/Anderson classification scheme.

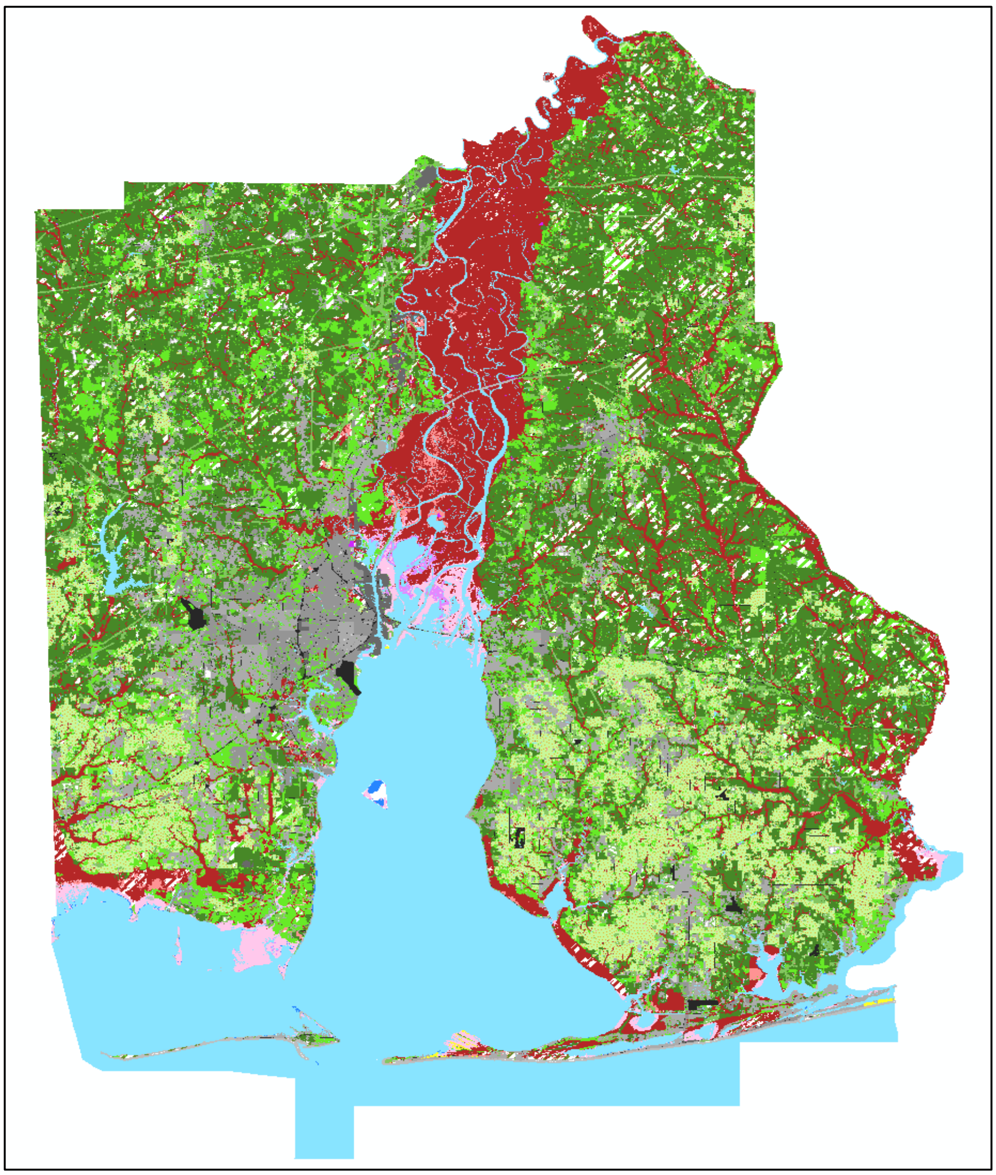

FIGURE 1. 2016 UPLAND/WETLAND HABITAT CLASSIFICATION MAP

Trend Analysis

Classification Structure

The structure of the Cowardin/Anderson classification is hierarchical - progressing from Systems, Subsystems, and Classes (Figure 2) at the most general levels to more specific Subclass and Modifier descriptions (see Appendix B: Upland/Wetland Classification Hierarchy Data Scheme included in this delivery for a full diagram of the classification structure). The entire hierarchical system is complicated, with 242 uniquely identified habitats in the 2016 upland/wetland habitat map alone. To simplify the trend analysis, both the 2002 classification and the 2016 classification were consolidated to the class level (see Table 1). The habitat code includes the respective System, Subsystem (if applicable), and Class attributes for each feature.

TABLE 1. COWARDIN/ANDERSON SYSTEM-SUBSYSTEM-CLASS CODES AND DESCRIPTIONS

Cowardin/Anderson Classification Codes	Description
E1AB	Estuarine Subtidal Aquatic Bed
E1UB	Estuarine Subtidal Unconsolidated Bottom
E2EM	Estuarine Intertidal Emergent
E2FO	Estuarine Intertidal Forested
E2SS	Estuarine Intertidal Scrub/Shrub
E2US	Estuarine Intertidal Unconsolidated Shore
L1AB	Lacustrine Limnetic Aquatic Bed
L1UB	Lacustrine Limnetic Unconsolidated Bottom
L2UB	Lacustrine Littoral Unconsolidated Bottom
M1UB	Marine Subtidal Unconsolidated Bottom
M2US	Marine Intertidal Unconsolidated Shore
PAB	Palustrine Aquatic Bed
PEM	Palustrine Emergent
PFO	Palustrine Forested
PSS	Palustrine Scrub/Shrub
PUB	Palustrine Unconsolidated Bottom
PUS	Palustrine Unconsolidated Shore
R1UB	Riverine Tidal Unconsolidated Bottom
R2UB	Riverine Lower Perennial Unconsolidated Bottom
R2US	Riverine Lower Perennial Unconsolidated Shore
R4SB	Riverine Intermittent Streambed
UA	Upland Agriculture
UB	Upland Barren
UF	Upland Forest
UR	Upland Range
USS	Upland Scrub/Shrub
UU	Upland Urban

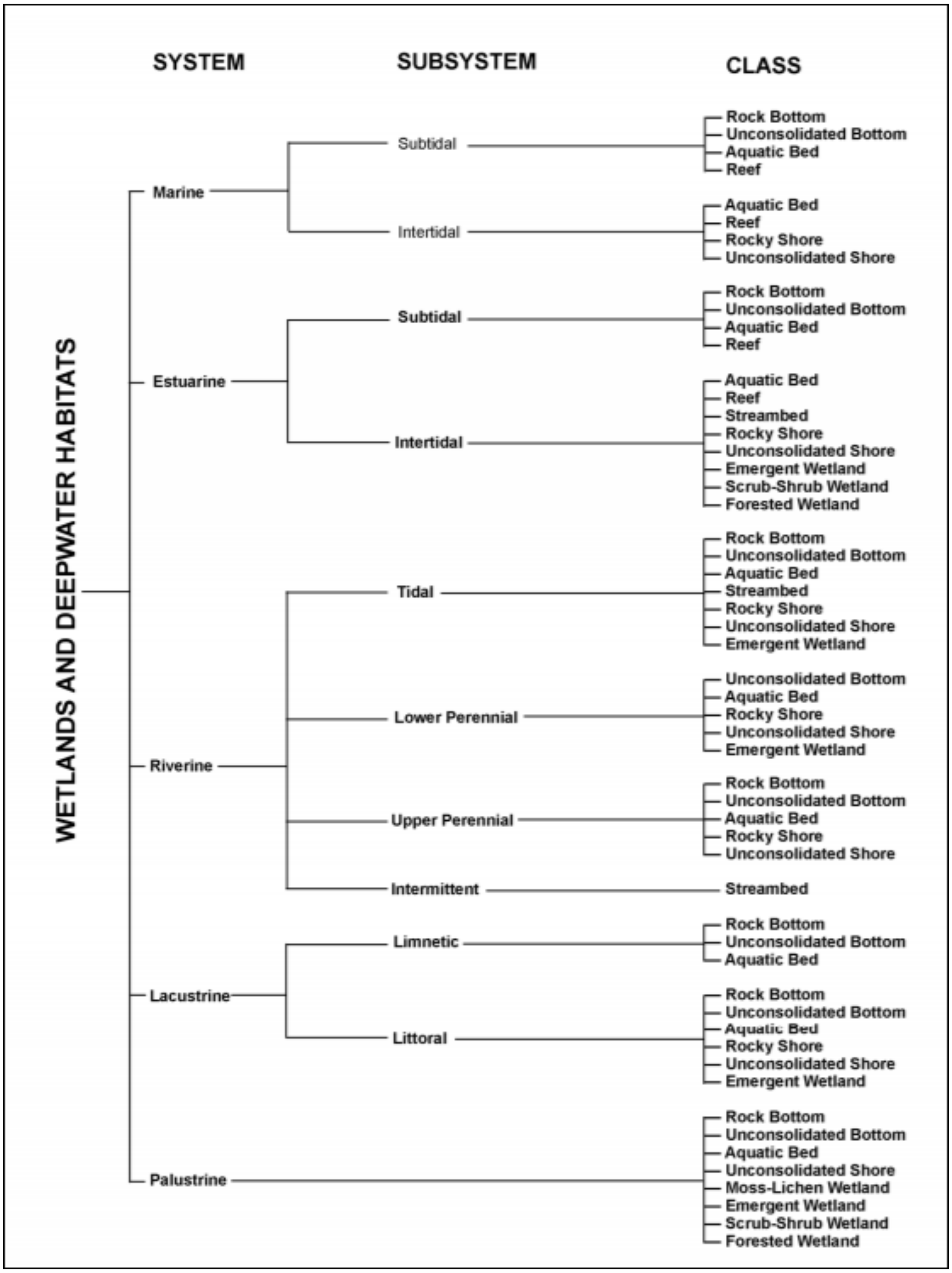

FIGURE 2. CLASSIFICATION HIERARCHY OF WETLANDS AND DEEPWATER HABITATS, SHOWING SYSTEMS, SUBSYSTEMS, AND CLASSES. THE PALUSTRINE SYSTEM DOES NOT INCLUDE DEEPWATER HABITATS. (IMAGE CREDIT: COWARDIN, ET AL. 1979)

Trend Analysis Methodology

In order to conduct the trend analysis, we converted the vector habitat datasets to thematic raster formats in ESRI ArcGIS. The raster image outputs were then migrated to the IDRISI Landcover Change Modeler. Change detection algorithms were applied to the 2002 and 2016 datasets. In order for the change detection to work, the two landcover maps required matching classification legends and spatial characteristics so the 2002 dataset was spatially clipped to the 2016 dataset. Change detection calculations were then processed on a pixel-by-pixel basis to identify differences between the two landcover images. If the pixel classification was the same between the two datasets, known as ***persistence***, the pixel was excluded from change detection metrics. A Landcover Persistence Map is shown in Figure 3. Figures 4 and 5 below outline the resulting ***overall change*** area statistics in graphical format.

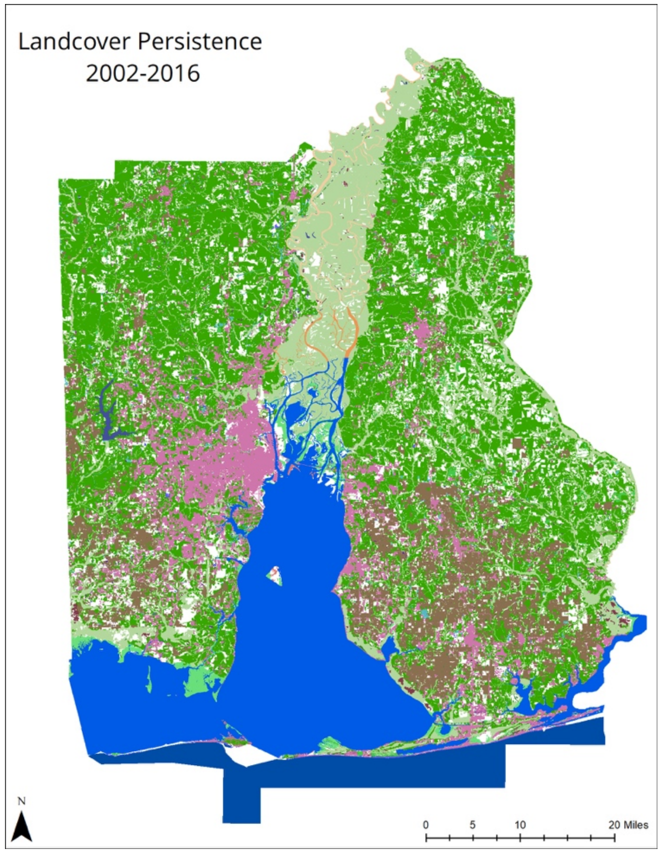

FIGURE 3. LANDCOVER PERSISTENCE (2002-2016) MAP

In addition, we examined particular classes - especially those that experienced significant changes - and identified the landcover classes contributing to these transitions. Selected outcomes are detailed in the Results section of this report. Furthermore, the raw statistics for gains, losses, and net change are included in an Excel spreadsheet as part of the trend analysis products delivery.

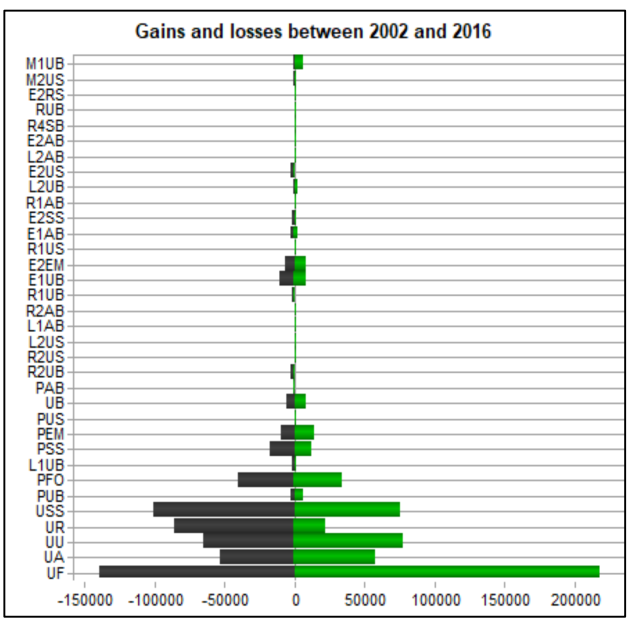

FIGURE 4. GAIN AND LOSSES FOR ALL CLASSES

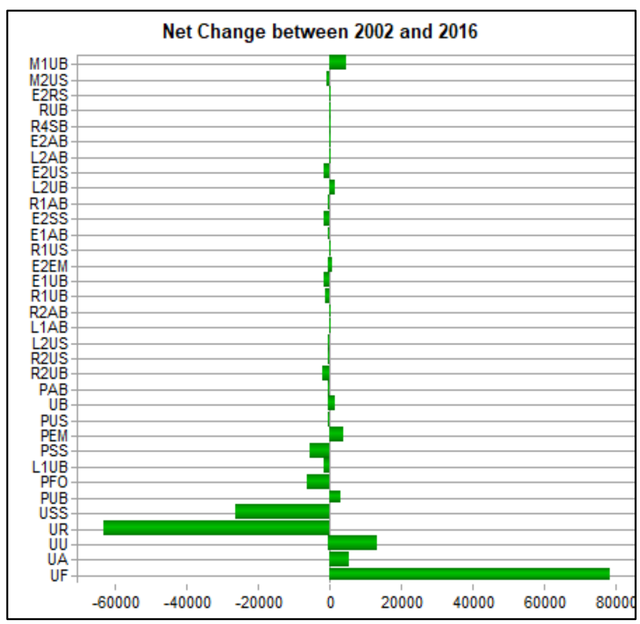

FIGURE 5. NET CHANGE FOR ALL CLASSES

Discussion: Limitations, Constraints, Issues

The differences in methodology should be understood as a part of the interpretation of results. The methodologies used to create the habitat change maps in 2002 and 2016 were vastly different and did not employ a pixel-based classification with same spatial configuration (identical pixel rows and columns). Therefore, any output evaluating the differences between them, including change detection metrics or trend analysis, may suggest erroneous or misleading outputs for many of the areas that were identified as changed.

The classification conducted by USGS NWRC between 2003-2006 on the 2002 imagery was developed utilizing a manual digitization method. Imagery analysts visually evaluated the CIR imagery characteristics, made a determination of what habitat type they were looking at (using their own image interpretation skills, individual subject matter expertise, and ancillary data), and then traced the outline of each habitat in a vector-format polygon. Digitizing methodologies typically employ a standard scale at which the habitat features are drawn and often use multiple personnel to map an area, especially if the area is large - as in the case of Mobile and Baldwin counties. This 'trace-over' method can be quite accurate – for example, an analyst will typically not be fooled by shadows and can properly delineate edges even when they are obscured by tree canopy or overhangs, if these details are observable at the scale being mapped. However, this method is also subject to inaccuracies due to variation in feature interpretation between analysts and inconsistencies in detail across the entire study area.

In contrast, for the 2016 classification effort, the Radiance Team utilized an object-oriented image analysis (OBIA) method using Hexagon Geospatial's ERDAS Imagine Objective. This object-oriented approach uses software that accepts training samples, delineated by a human image analyst, and then uses algorithms that emulate human visual processing by analyzing the data; not only spectrally on a pixel-by-pixel basis, but also by looking at contiguous object-based measures such as shapes, size, and texture. Traditional pixel-based landcover classifications typically do not incorporate spatial context in the classification; whereas, object-based image analysis groups pixels with similar properties (e.g. radiance, reflectance, texture, etc.), thereby potentially providing higher mapping accuracy. The OBIA model is an improvement over traditional pixel-based classification methods because it reduces classification error in the small scale of a pixel (or small selection of pixels) that may be spectrally similar to other landcover classes. It also relies heavily on computer processing; thus, saving time and expense compared to manual digitizing methods.

The inherent differences between the 2002 and 2016 classification methodologies also create variance in the boundaries of the polygons. These differences will lead to uncertainty in the trend analysis that any given loss or gain in any specific habitat feature is derived from geometry differences based on the methodology to create habitat polygons and not actual change in the habitat. For this reason, change analysis is typically performed on pixel-based classifications that use identical classification methodology to reduce uncertainty. For example, the USGS warns users not to use the 1992 National Landcover Data (NLCD) in change detection analysis with the NLCD 2001, 2006, or 2011 data (Fry et.al). Because of differences in methodology, the datasets are not compatible for accurate comparison.

Due to the inherent differences in the methodology used on the classifications conducted on the 2002 imagery vs. the methodology used on the 2016 classification – ***the trend analysis will produce significant amounts of landcover differences that are not due to genuine landcover conversion, but instead represent artifacts of mismatched habitat geometries that were derived using different methods***. Additionally, inherent errors exist independently between the two mapping efforts. These errors are identified through the accuracy assessment section of the Final Report for the 2016 dataset and should be considered when interpreting the change detection results. Therefore, there will be differences in landcover classes between the two datasets that are products of both 1) Inherent errors from the respective mapping efforts and 2) Errors resulting from geometric uncertainty between the 2002 and 2016 datasets. All differences can be categorized as such:

1. Errors in classification made by humans in 2002 which were correctly classified in 2016
2. Errors made by the software in 2016 which were correctly classified in 2002
3. Errors made in both 2002 AND 2016 that are different, but both incorrect
4. Differences in the segment delineation in 2002 and/or in 2016 that do not match each other
5. Genuine land conversion

There is not a comprehensive, time-efficient methodology for identifying which one of the five reasons above is responsible for any particular change.

There was no low-limit size threshold applied to the change detection products. The IDRISI module does not allow the option to select a transition threshold for the graphical and tabular data, but does allow for a threshold in the mapped products. However, the lowest acreage limit that could be applied was 15 acres due to a software constraint of exceeding a transition limit. In order to not select a value based on software limitations or

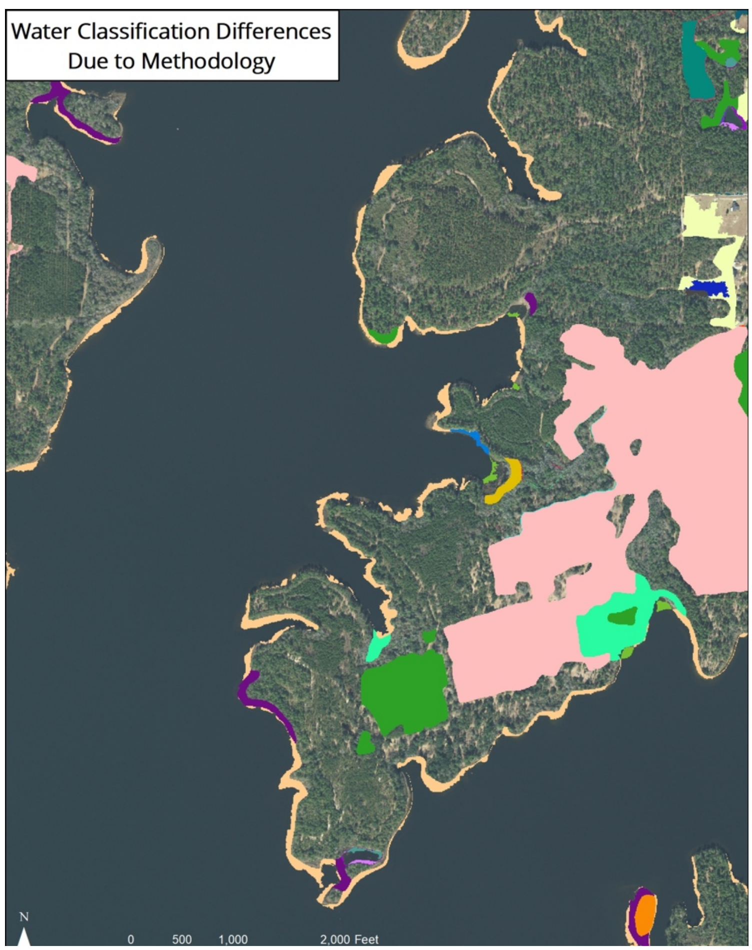

FIGURE 4. DIFFERENCE IN FEATURE DELINEATION BETWEEN THE METHODS. AREAS OF WATER (BEIGE/TAN) CLASSIFIED AS UPLAND OR SHORE IN 2002

select an arbitrary value, the change map reflects all changes calculated by the analysis. To reduce the number of transitions that may be due to methodological differences, the user of the data may instead apply an acreage threshold to the change raster in a GIS platform. This thresholding will not, however, account for all change misidentified because of the differing methodologies. For example, along the banks of water bodies there is change indicated (Figure 6). This is due to the different classification methodologies. In 2016, we used a Normalized Difference Vegetation Index (NDVI) to segregate water from surrounding landcover classes. We feel the NDVI method is more accurate, but we are unable to quantify the accuracy difference. It is important to note that there is little to no change in these areas yet the size incorporates a larger area than a potential minimum threshold. Our resultant analysis between the two-time periods is described in the section below, ***but caution should be used in planning strategic conservation or restoration efforts using this data.***

Trend Analysis Results

The results indicate that the landcover classes that experienced the most significant change between the 2002 and 2016 classifications were in the uplands. The five most changed landcover classes were Upland Forests (UF), Upland Scrub-Shrub (USS), Upland Urban (UU), Upland Range (UR), and Upland Agriculture (UA). These results point to both legitimate conversion between upland classes and differences in classification methodology. For example, Figure 7 shows substantial gains *and* losses in Upland Scrub-Shrub (USS) and Upland Forest (UF). This is likely the product of a timber harvest–reforestation cycle throughout the study area. Areas that were harvested closer to the 2002 imagery collection have now regenerated enough to be classified as Upland Forest. Conversely, some areas that were mature forested areas in 2002 may have been recently harvested. The contributors to net change in Upland Scrub-Shrub (Figure 8) back up this analysis even further. It shows losses in Upland Scrub-Shrub to Upland Forest being the largest contributor.

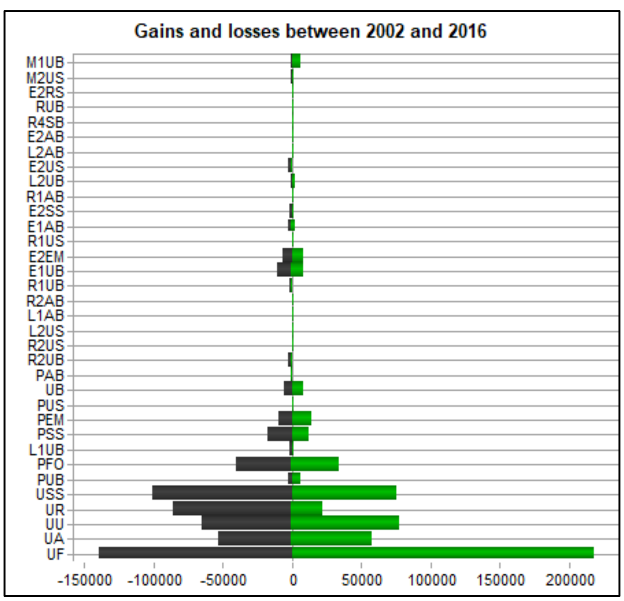

FIGURE 6. GAINS AND LOSSES PER CLASS

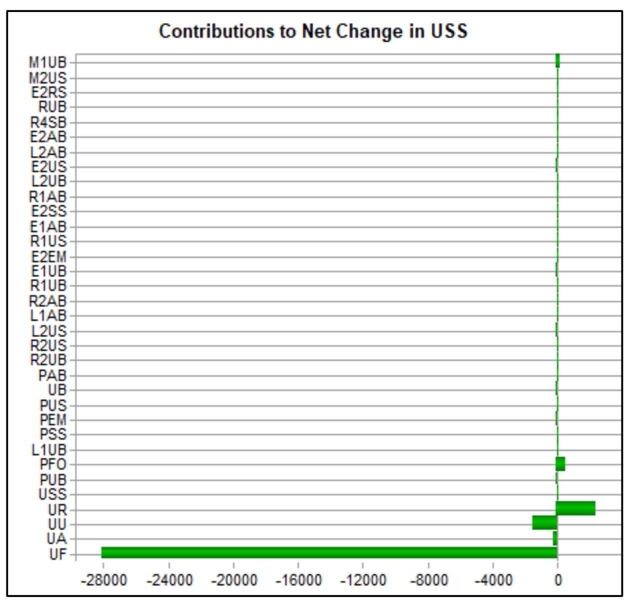

FIGURE 6. CONTRIBUTIONS TO UPLAND SCRUB/SHRUB (USS) HABITAT CHANGE

Upon closer inspection, we can look at the classes that contributed to the net change in Upland Forest in Figure 9. This view validates the assumption that Upland Scrub-Shrub is one of the biggest contributors to net change in the Upland Forest landcover class. However, Upland Range is actually an even larger contributor. This is likely due to a combination of regrowth in previously sparse Upland Range areas and differences in how the classification was determined in thinly forested lands during the mapping effort in 2002 and in 2016.

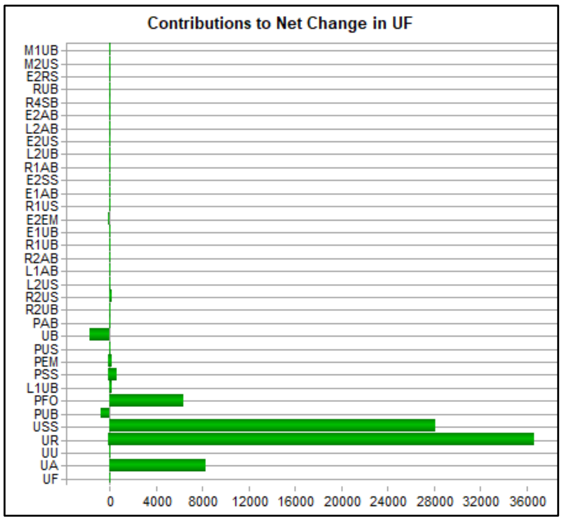

FIGURE 7. CONTRIBUTIONS TO UPLAND FOREST (UF) HABITAT CHANGE

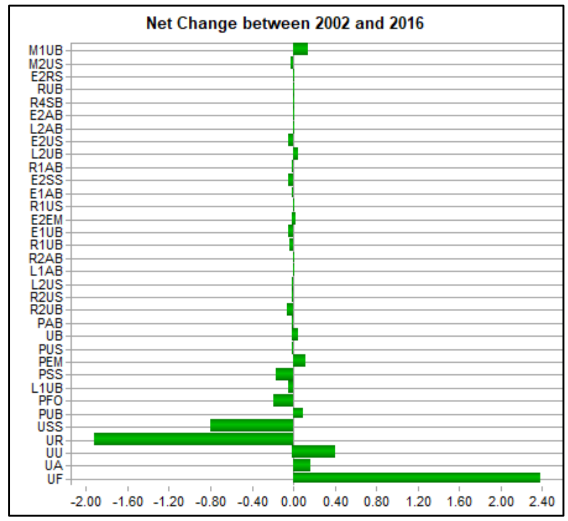

FIGURE 8. NET CHANGE IN UPLAND FOREST (UF) AS EXPRESSED BY % AREA CHANGE OVER ALL OF THE STUDY AREA

Palustrine Forest is also a significant contributor to the net increase in Upland Forest. This is likely due to differences in visibly saturated soils at the time of imagery collection or differences in the ancillary data sources used in differentiating wetland from upland.

Another interesting view of the net change in Upland Forest is viewing the change in tems of overall percentage of landcover. If looking at the gains and losses in Upland Forest (Figure 7) one will notice a loss of 139,514 acres and gains of 217,804 acres (net change of +78,290 acres). These seem like extremely large numbers but Figure 10 indicates this is less than 2.4% of the Upland Forest landcover class.

Figure 11 shows contributions to net change in Estuarine Unconsolidated Bottom. This graph highlights that many of the changes identified in this trend analysis are also related to classification decisions. For example, the different line drawn between the leeward and windward side of southeast Dauphin Island in 2002 and 2016 contributed to the change from Estuarine Unconsolidated Bottom (E1UB) to Marine Unconsolidated Bottom (M1UB). Another example of differences in methodology for water classification can be seen in Figure 12. The blue color represents Estuarine Unconsolidated Bottom that was mapped in 2016 to a much greater detail than in the 2002 data and includes smaller tidal creeks and ponded areas that were previously classified as marsh, aquatic beds, and unconsolidated shore. The comprehensive change detection map for the entire study area can be seen in Figure 13.

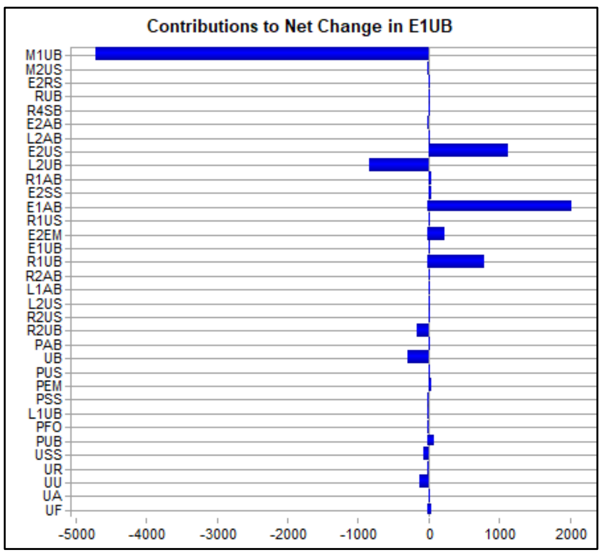

FIGURE 11. CONTRIBUTION TO ESTUARINE SUBTIDAL UNCONSOLIDATED BOTTOM (E1UB) HABITAT CHANGE

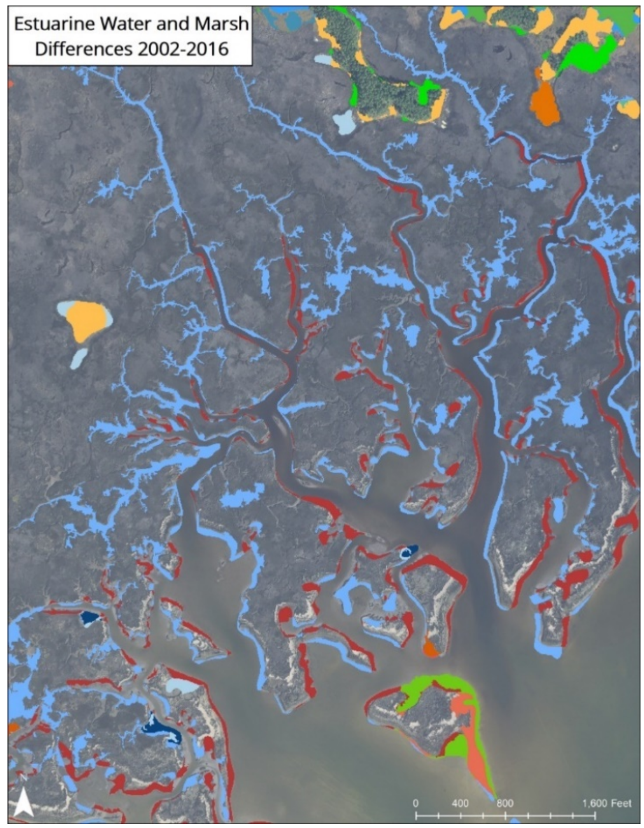

FIGURE 12. ESTUARINE SUBTIDAL UNCONSOLIDATED BOTTOM (E1UB) HABITAT CHANGE DUE TO DIFFERENCES IN MAPPING METHODOLOGY

It is difficult to concisely summarize the results of the trend analysis. To be clear, there are legitimate landcover transitions throughout the study area. However, the process differences between the two mapping efforts makes those transitions quite difficult to distinguish from methodological variance. Therefore, it is the Radiance Team's recommendation that for any critical conservation planning, the trend analysis products discussed in this report be used as reference data only. For areas in which significant change is indicated or where the transition landcover types are highly important to the MBNEP and its constituent agencies, a more thorough inspection and validation occur. The Radiance Team recommends reviewing the most recent high-resolution imagery or habitat map to validate the landcover class and the older imagery or mapping products to validate the indicated change.

FIGURE 13. LANDCOVER CHANGE MAP FOR MOBILE AND BALDWIN COUNTIES, ALABAMA

Deliverable Products

As part of the Trend Analysis task, the Radiance Team developed a number products to accompany this report. The deliverable products will, cumulatively, help to support the Mobile Bay National Estuary Program and constituent organizations' strategic conservation plans. The products can also be used to help validate change in particular areas. All of these products listed below (except the two .pdf items 6 (this Trend Analysis report) and item 7 Appendix B) are submitted as a part of a File Geodatabase called *Trend_Analysis_Nov17.gdb.*

The products are summarized as follows:

1. Consolidated Vector Files – These vector-format datasets were generated by consolidating all polygons from the original habitat mapping feature class (*MBNEP_HABITAT_MAP*) with identical system-subsystem-class identifiers. This is different from the more detailed habitat map that included subclasses and modifiers. This product was created to generalize the analysis. This was completed for both the 2002 data and 2016 datasets.
    - Two feature class datasets named *MBNEP_2002_Consolidated_Habitat_Classes* and *MBNEP_2016_Consolidated_Habitat_Classes*
2. Consolidated Raster Files – the vector datasets were then converted to thematic raster datasets. These raster datasets were created as a pre-processing step that was necessary for the IDRISI Landcover Change Modeler to generate change statistics.
    - Two raster datasets named *MBNEP_2002_Consolidated_Habitat_Classes_Raster* and *MBNEP_2016_Consolidated_Habitat_Classes_Raster*
3. Change Metrics – Tabular format indicating losses, gains, and net change (in acres) for each landcover class.
    - Included as a file geodatabase table called *Change_Stats_Trend_Analysis* and provided separately as an Excel spreadsheet called *Change_Stats_Trend_Analysis.xls*
4. Persistence Map – A raster image file indicating areas where landcover classes did not change from 2002 to 2016. The '*class_name'* attribute of each polygon identify the class.
    - A single raster dataset called *Persistence*
5. Change Map - A raster image file indicating landcover classes that changed from 2002 to 2016. The '*class_name'* attribute of each polygon indicate what class the area changed from (2002) and to (2016)
    - A single raster dataset called *Change*
6. Trend Analysis Report
    - *Trend Analysis Report.pdf*
7. Appendix B: Upland/Wetland Classification Hierarchy Data Scheme
    - *AppendixB_Classification_Scheme_Data_Organization.pdf*

References:

Cowardin, L. M., Carter, V., Golet, F. C., & LaRoe, E. T. (1979). Classification of wetlands and deepwater habitats of the United States. US Department of the Interior, US Fish and Wildlife Service.

Fry, J.A., Coan, M.J., Homer, C.G., Meyer, D.K., and Wickham, J.D., 2009, Completion of the National Landcover Database (NLCD) 1992–2001 Landcover Change Retrofit product: U.S. Geological Survey Open-File Report 2008.

Keywords: trend analysis, wetlands, uplands; landuse, landcover, remote sensing, object-based image analysis, segmentation, habitat classification, Cowardin, Anderson, coastal restoration, digital change detection