Caribbean Marine Biodiversity Program

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Analysis on the Biophysical Conditions of Mangroves In the CMBP Seascapes

Submitted by Steve Schill, November 2016.

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In The Caribbean Marine Biodiversity Program Seascapes

BACKGROUND

The *Caribbean Marine Biodiversity Program (CMBP)* funded by USAID, aims to reduce threats to marine ecosystems in priority areas in the Caribbean such as coral reefs, mangroves, and seagrass beds, in order to achieve sustained biodiversity conservation, maintain ecosystem services, and reach tangible improvements in human wellbeing for communities adjacent to marine protected areas (MPAs/MMAs). An important component of the Program is to evaluate the status of mangroves and monitor any improvements or decrease in the system over time which may be due to natural occurrences or human interventions such as mangrove restoration. For the purpose of CMBP, mangrove extent cover and biomass are the biophysical indicators used to establish a baseline on the health status of mangroves in the targeted CMBP seascapes (Grenada, St. Vincent and the Grenadines, Haiti and the DR. The collected data indicate increases, decreases or no significant changes in mangrove systems at selected CMBP sites. Threats are documented were relevant. Baseline estimates at some targeted CMBP sites were collected as far back as the year 2000. A summary of the baseline assessments performed for all CMBP sites are described below. The full baseline assessment report can be reviewed in Appendix 1. Monitoring of these sites will continue in subsequent years and new data will be compared to the baseline to identify changes in extent cover and biomass within the targeted CMBP sites.

CMBP TARGETED MANGROVE SITES:

- *Parque Nacional Manglares Del Bajo Yuna, Dominican Republic*

The mangroves of Bajo Yuna are located on the western end of Samaná Bay, one of the largest semi-closed bays in the Caribbean. Within Parque Nacional Manglares Del Bajo Yuna, the mangrove area is approximately 3,456 hectares and supports various endemic species and located in a complex karstic estuarine wetland ecosystem that has been declared both a Ramsar site and National Park.

- *Tyrrel Bay, Carriacou, Grenada*

Tyrrel Bay is part of the Sandy Island Oyster Bed Marine Protected Area (SIOBMPA) that was established in 2009 and comprises an area of 787 hectares on the southwest coast of Carriacou, Grenada. The mangroves in Tyrrel Bay provide habitat for the mangrove oyster that grow on the roots of the red mangroves, serve as nursery grounds for several species of fish and, used by local boat to secure their boats during tropical storms.

- *Caracol and Fort Liberte, Three Bays National Park, Haiti*

In 2013, Three Bays National Park (3BNP) was designated by the Haitian Government. The protected area encompasses three bays: Limonade, Caracol, and Fort Liberté, as well as one of the largest inland brackish water lagoons – the Important Bird Area (IBA) of Lagon aux Boeufs – covering an area of 900km^2 (75,618ha). Three Bays National Park represents one of the largest protected areas of mangrove and coastal wetlands in Haiti (Aube and Caron 2001) comprising of 4,274 hectares of mangroves and represents about 20% of Haiti's remaining mangroves.

- *Ashton Lagoon, Union Island and St. Vincent and the Grenadines*.

Ashton Lagoon is the largest lagoon in Saint Vincent and the Grenadines and home to the largest mangrove forest in the country. The lagoon harbors abundant seagrass beds, fringing, patch, and barrier coral reefs, and an offshore island (Frigate) and mangrove wetlands that have been designated as Important Bird Area (IBA) by Birdlife International. Because of the rich ecological importance to the country, this area was formally designated a Conservation Area (under Schedule 11, Regulation 20, The Fisheries Act, 1986) in 1987.

DATA COLLECTION AND ANALYSIS:

Field Surveys

Field surveys were conducted within targeted mangrove sites (except for Tyrell Bay, Carriacou, Grenada) to document current mangrove conditions. Minimum parameters sampled included: 1) mangrove species composition; 2) canopy height; 3) DHB (diameter at breast height); and 4) species richness and percent cover (by species).

Remote Sensing

Remote sensing provides an excellent tool for identifying and monitoring changes in mangrove extent that can guide mangrove management actions. This process first begins with identifying satellite images that provide suitable spatial resolution in order to detect and map the mangroves. Although Landsat satellite has been used for national scale land cover mapping, the 30x30m pixel is not suitable for detecting fringing mangrove stands that have a width of less than 15m. The universal rule in remote sensing is that the pixel size (spatial resolution) needs to be half the smallest dimension of the feature to be detected. Consequently, satellite imagery over at least two time periods with a spatial resolution of 2x2m was used to detect changes in the mangrove forests.

The first public satellite to offer 2m multispectral imagery (i.e. multiple bands: blue, green, red, near-infrared) was the Quickbird satellite that was launched in October of 2001. Following an extensive search of the Quickbird image archive, the earliest images found suitable for mapping mangroves were used as the baseline. To measure changes since the baseline date, satellite imagery from the WorldView-2 satellite was used. Prior to classification, the images had to be radiometrically corrected and geometrically matched. Radiometric correction removes atmospheric errors and converts the pixel values to proper reflectance values that produce more accurate classification results. Geometric correction ensures that the pixels align with image dates in order to accurately define and detect change in mangrove areas. In the case of Haiti, image segmentation approach was used to classify the image instead of the pixel based classification described. Nonetheless all other aspects of the method described previously were used.

Satellite Image Classification

An object-oriented image analysis approach was applied to the radiometric and geometric correct Quickbird and WorldView-2 images to delineate mangrove extent. This approach contrasts the “pixel-based” unsupervised classifiers that have traditionally been used for land cover mapping. In object-oriented image analysis, satellite data is segmented into landscape objects that have ecologically-meaningful shapes, and classifies the objects across spatial, spectral, and textural scales. These segments represent distinct patches of uniform mangrove habitat. Since the non-spectral attributes of the imagery such as texture, spatial, and contextual information are allowed to be included into the classification workflow, object-oriented methods have shown to yield accuracy improvements when compared to conventional pixel-based image analysis techniques. The software used for mapping in this study is eCognition (v. 9.1, Trimble Inc.). Segmenting the image requires identifying the appropriate scale of segments that can adequately represent the features that are being mapped. After segmentation, samples of mangrove segments were selected and the statistics pertaining to the spectral and textural properties of the satellite imagery were used to identify all mangrove segments with the images. Mangrove segments that were adjacent to each other were merged the results were visually interpreted and manually cleaned to improve the final accuracy for both time periods.

Detection of Mangrove Biomass Change

Change detection of the mean Normalized Vegetation Difference Index (NDVI) value was calculated for each mangrove image segment using the Quickbird and WorldView-2 imagery. NDVI is a normalized ratio of red and NIR spectral reflectance (NDVI = (NIR − RED) / (NIR + RED)), and is one of the most widely used vegetation indices. NDVI is determined by the degree of absorption by chlorophyll in the red wavelengths, which is proportional to leaf chlorophyll density, and by the reflectance of near infrared (NIR) radiation, which is proportional to green leaf density and has been shown to be sensitive to the green leaf area or green leaf biomass or proxy of vegetation productivity. Therefore, the NDVI can be used as a surrogate to help evaluate the health status of mangroves. The NDVI model indicates areas of higher biomass in orange and red shades and lower biomass in blue and yellow shades. Some differences are the result of cloud shadow so caution should be taken while interpreting results. Areas where mangroves have been removed show the highest change in NDVI value. This tool is ideal for monitoring reduction or increase in biomass that can be an early detection system for recognizing stress and guiding management efforts.

RESULTS

DOMINICAN REPUBLIC - PARQUE NACIONAL MANGLARES DEL BAJO YUNA

A research consultant conducted field surveys in January and February, 2016 from 30 randomly selected plots (12.5m radius). The type of field data collected include those mentioned under the "DATA COLLECTION: Field Surveys" section of this report. Using remote sensing and satellite imagery, the core mangrove area (spatial cover) mapped comprised of 3,456 hectares) (Figure 1 – mangrove core area).

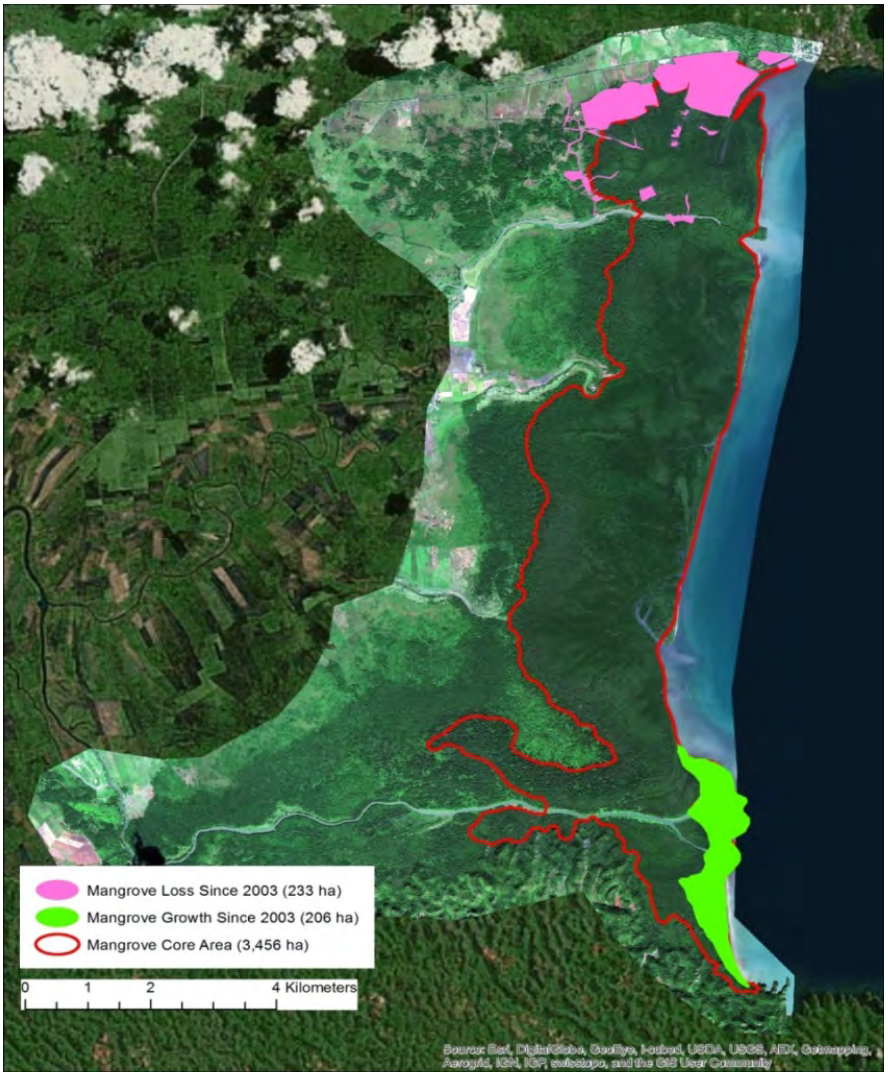
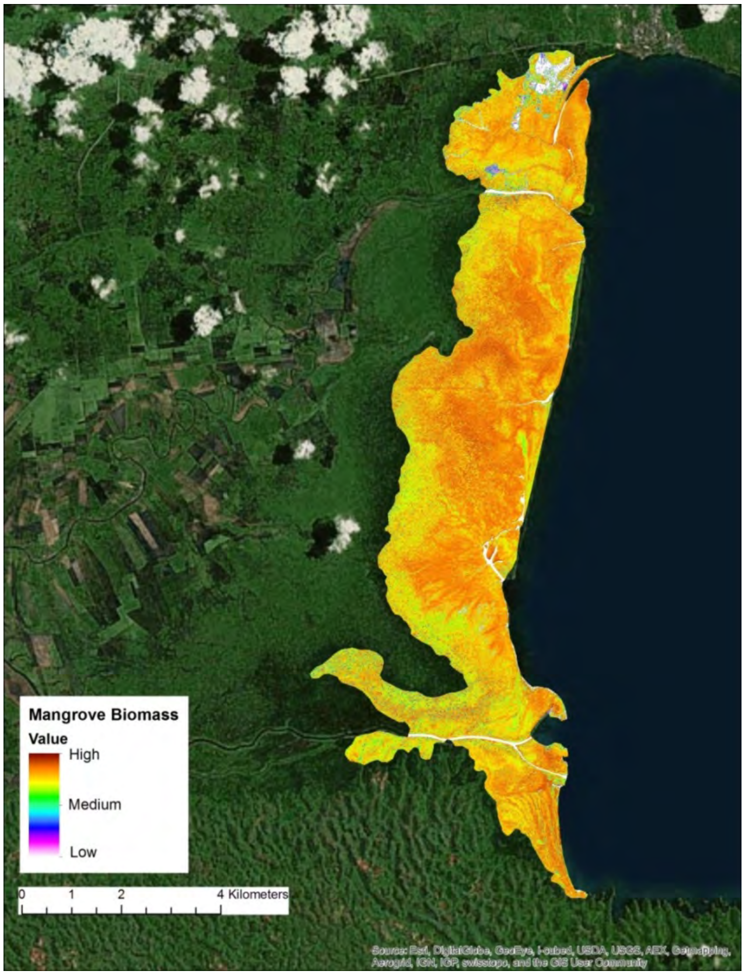


Figure 1. The mangrove core area, mangrove loss and growth in *Parque Nacional Manglares Del Bajo Yuna* since 2003.

Changes in mangrove cover since 2003 were also assessed (Figure 1). In the north, near the town of Sanchez, a total of 233 hectares of mangroves were removed within the National Park boundary (Figure 1). Records show that this was due largely to the expansion of shrimp aquaculture activities and reduced water quality due to municipality's land fill proximity. However, around the mouth of the Barracote River since 2001, mangrove cover has increased 206 hectares (Figure 1). This is a result of sedimentation deposition that decreased water depth and encouraged mangrove propagules to establish themselves across a wider area.



With regard to biomass, Figure 2 shows the results of the NDVI model which indicates areas of higher biomass in the orange and red shades and lower biomass in the blue and yellow shades. It is clear from the map that this area has fairly high mangrove biomass indicating a highly productive system.

Figure 2. Normalized Difference Vegetation Index (NDVI) calculated from WorldView-2 satellite imagery that can be used as a surrogate for estimating vegetation biomass and productivity.

Tyrrel Bay, Carriacou, Grenada

To calculate the mangrove spatial extent and biomass in Tyrrel Bay the following datasets were used:

- IKONOS satellite imagery acquired on November 2, 2000 (Figure 3)
- WorldView-2 satellite imagery acquired on January 10, 2010 (Figure 4)
- WorldView-2 satellite imagery acquired on November 12, 2014. (Figure 5)
- Drone imagery acquired from 400 ft (2cm resolution) on November 30, 2015 (Figure 6).

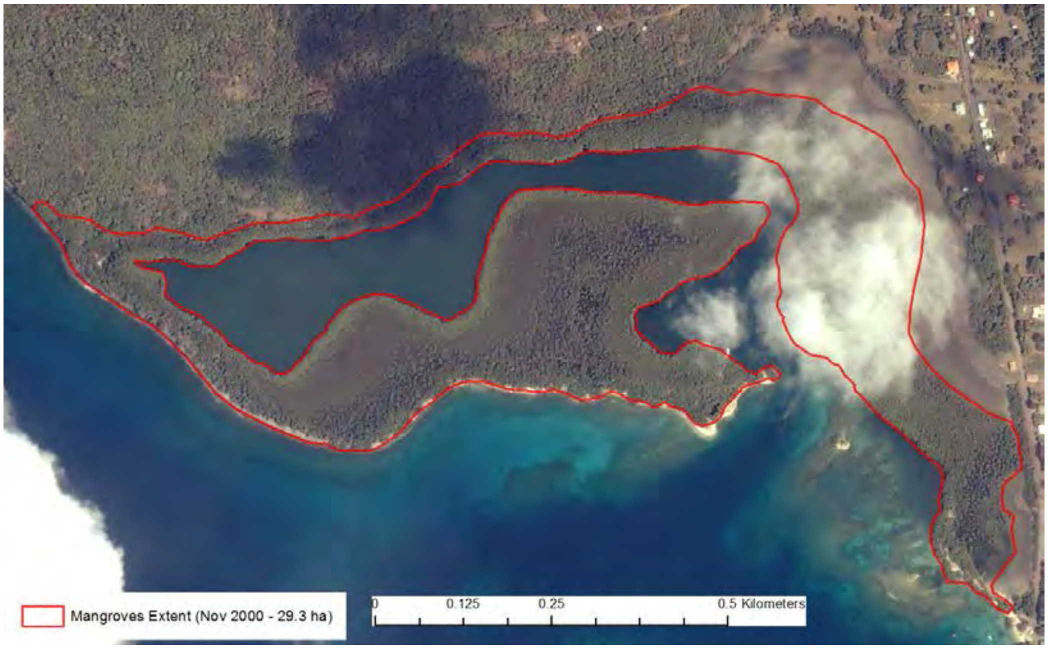


Figure 3. The extent of mangroves in Tyrrel Bay, Carriacou shown using IKONOS satellite imagery acquired on November 2, 2000.

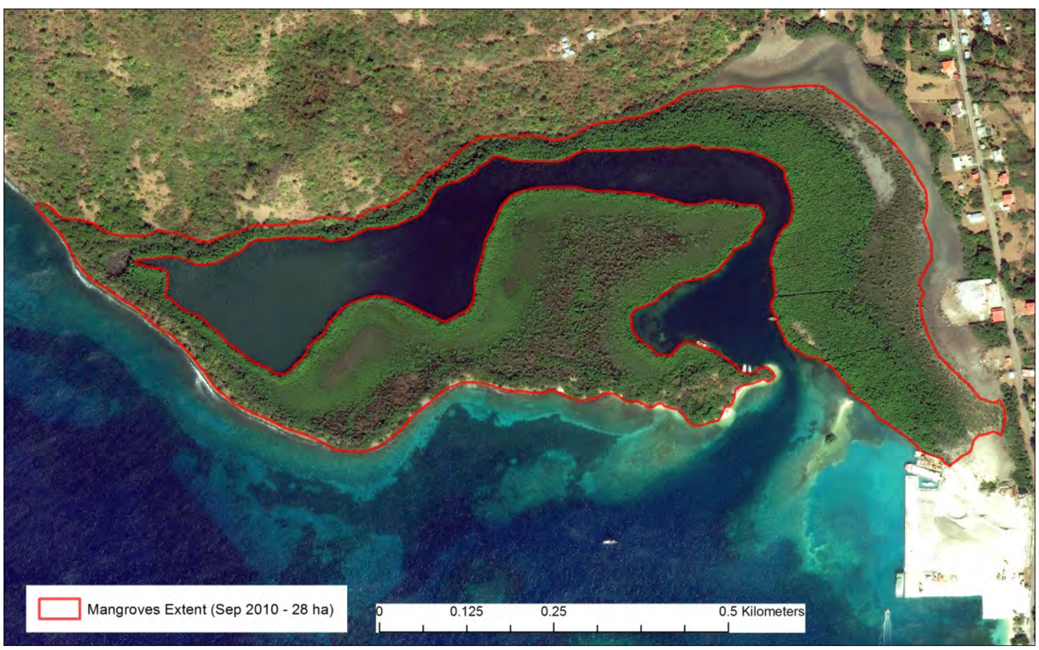


Figure 4. The extent of mangroves in Tyrrel Bay, Carriacou shown using WorldView-2 satellite imagery acquired on January 10, 2010.

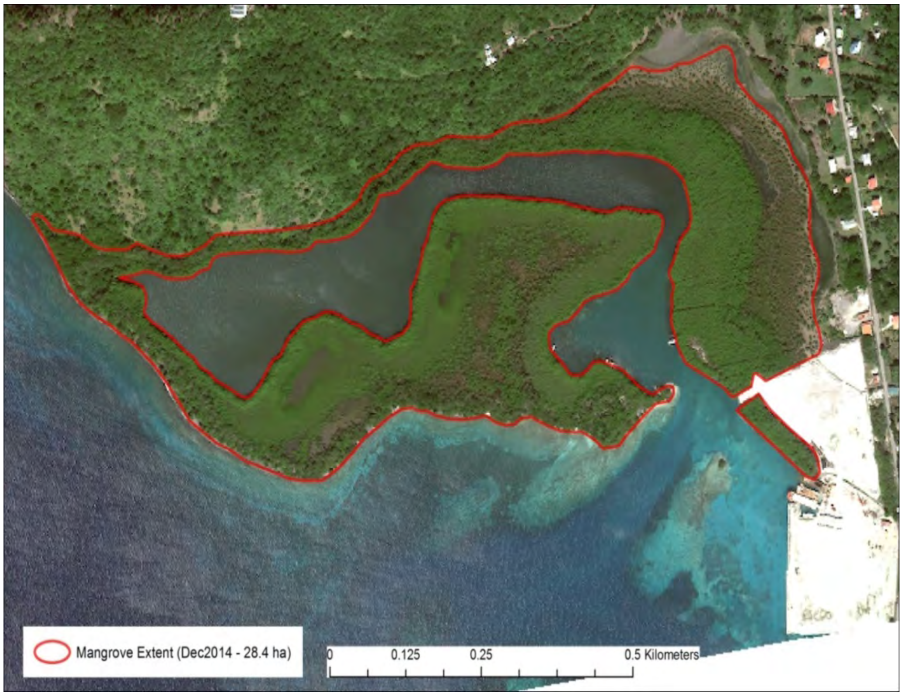


Figure 5. The extent of mangroves in Tyrrel Bay, Carriacou shown using WorldView-2 satellite imagery acquired on November 12, 2014.

Figure 6. A portion of Tyrell Bay showing the marina extent acquired using a 3DR Solo drone from 400 ft (2cm resolution) on November 30, 2015.

Using remote sensing and satellite imagery the core mangrove area was mapped for Tyrrel Bay and consists of 26.48 hectares (Figure 7). The main threat impacting this mangrove area is the continued construction of a marina in Tyrrel Bay which began in 2003. Dredging to accommodate yachts has destroyed seagrass beds, reduced water quality, and continues to negatively impact the Tyrrel Bay Mangrove ecosystem. Results following the assessments show that 13.8% of the mangroves were removed through clear-cutting and back-filling (Figure 7). In the northeastern part of the mangrove forest, dwarf mangroves have slowly expanded into the mud flats with a total expansion of 2.57 hectares. Though the dwarf mangroves are small with low biomass, nutrient levels have been restricted due to higher elevations and low tidal flushing.

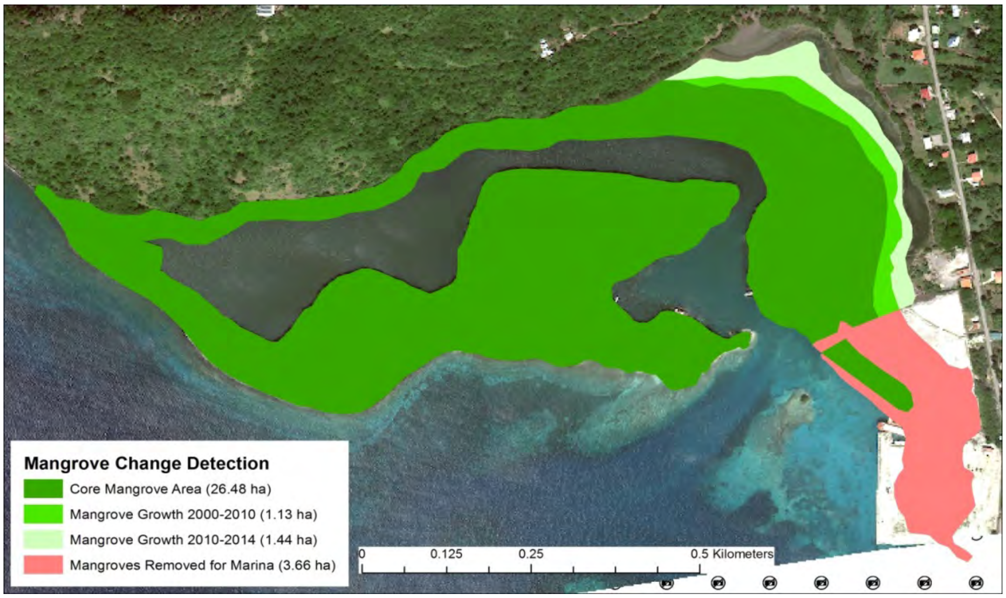


Figure 7. Mangrove change detection analysis of Tyrell Bay from 2000 – 2014.

To determine mangrove biomass for this area, the Normalized Vegetation Difference Index (NDVI) was calculated using the WorldView-2 imagery acquired on November 12, 2014 and is demonstrated in (Figure 8).

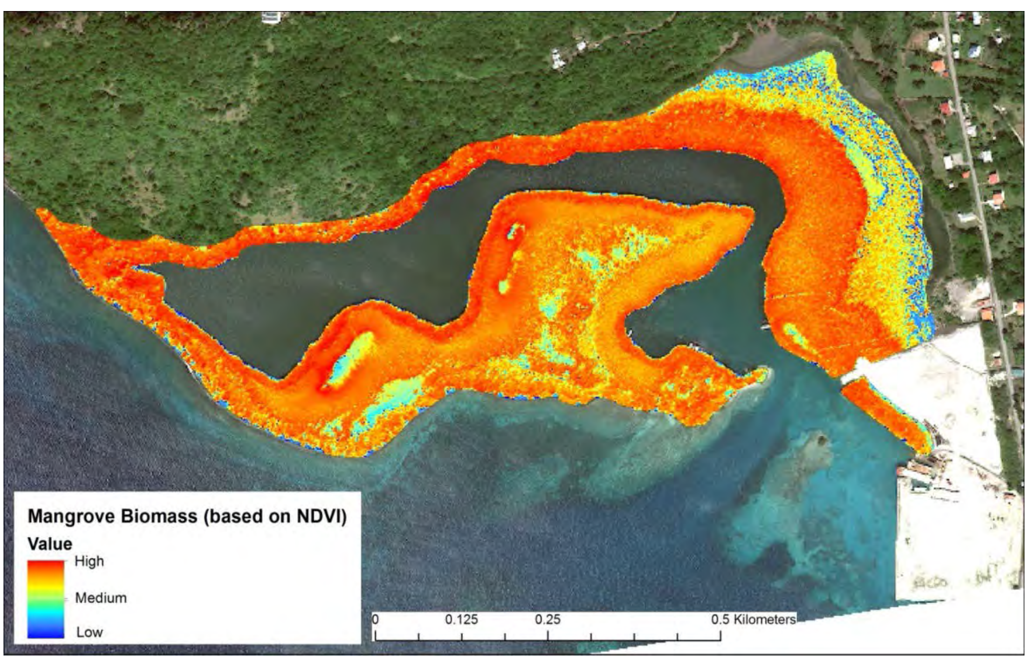


Figure 8. Modeled mangrove biomass based on the Normalized Difference Vegetation Index (NDVI) from imagery acquired November 12, 2014.

CARACOL AND FORT LIBERTE, THREE BAYS NATIONAL PARK, HAITI

Field surveys were carried by a research consultant in June and November 2015 to document existing conditions within the mangrove and coastal wetland habitats of Three Bays National Park. Site visits were conducted in Caracol Bay (including the outlet of Riviere du Nord at Bord de la Mer de Limonade), Forte Liberté, and Lagon aux Boeufs. The type of field data collected include those mentioned under "DATA COLLECTION: Field Surveys" section of this report. The total mangrove area mapped within 3BNP using the Quickbird 2002/2003 images equals 4,146.27 hectares. Using the WorldView-2 2014 imagery, a total of 4,257.42 hectares for a net increase of 111.15 hectares was seen. Total loss of mangrove areas that were detected from 2003-2014 was estimated to be 91.48 hectares however mangrove growth into new areas was calculated to be 202.63 ha. A breakdown of the classification results and maps by geography are found in Table 1 and Figures 9-10- below.

Table 1. Mangrove Change detection table showing results of 3BNP mangrove change from 2003-2014 in hectares.

	3BNP	**Caracol**	**Fort Liberté**	**Lagon aux Boeufs**
New growth (hectares)2003 -2014	202.63	107.55	55.82	39.26
Mangrove loss (hectares) 2003-2014	91.48	43.01	33.45	15.01
No change (hectares) 2003-2014	4,054.79	3,818.03	178	58.76

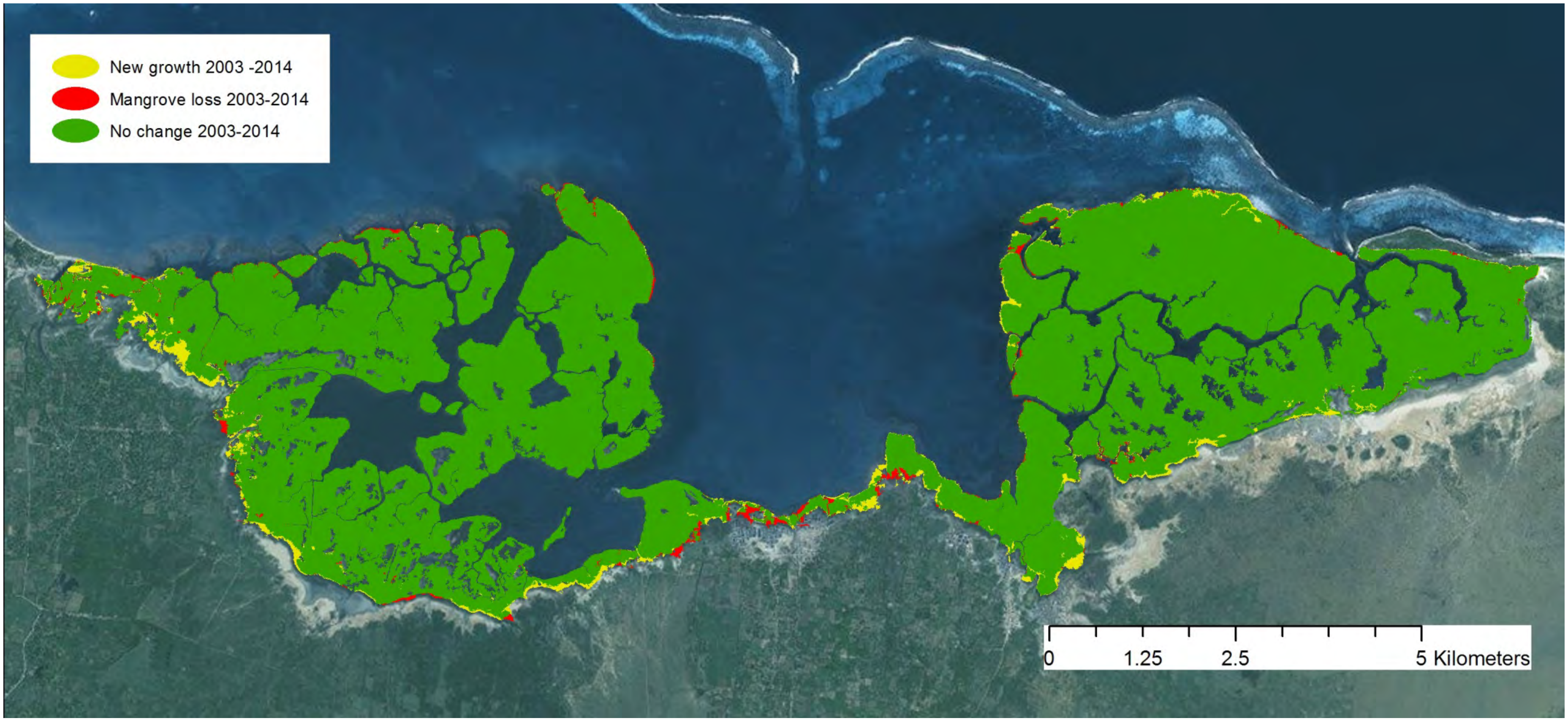


Figure 9. Mangrove change detection for Caracol Bay from 2003-2014.

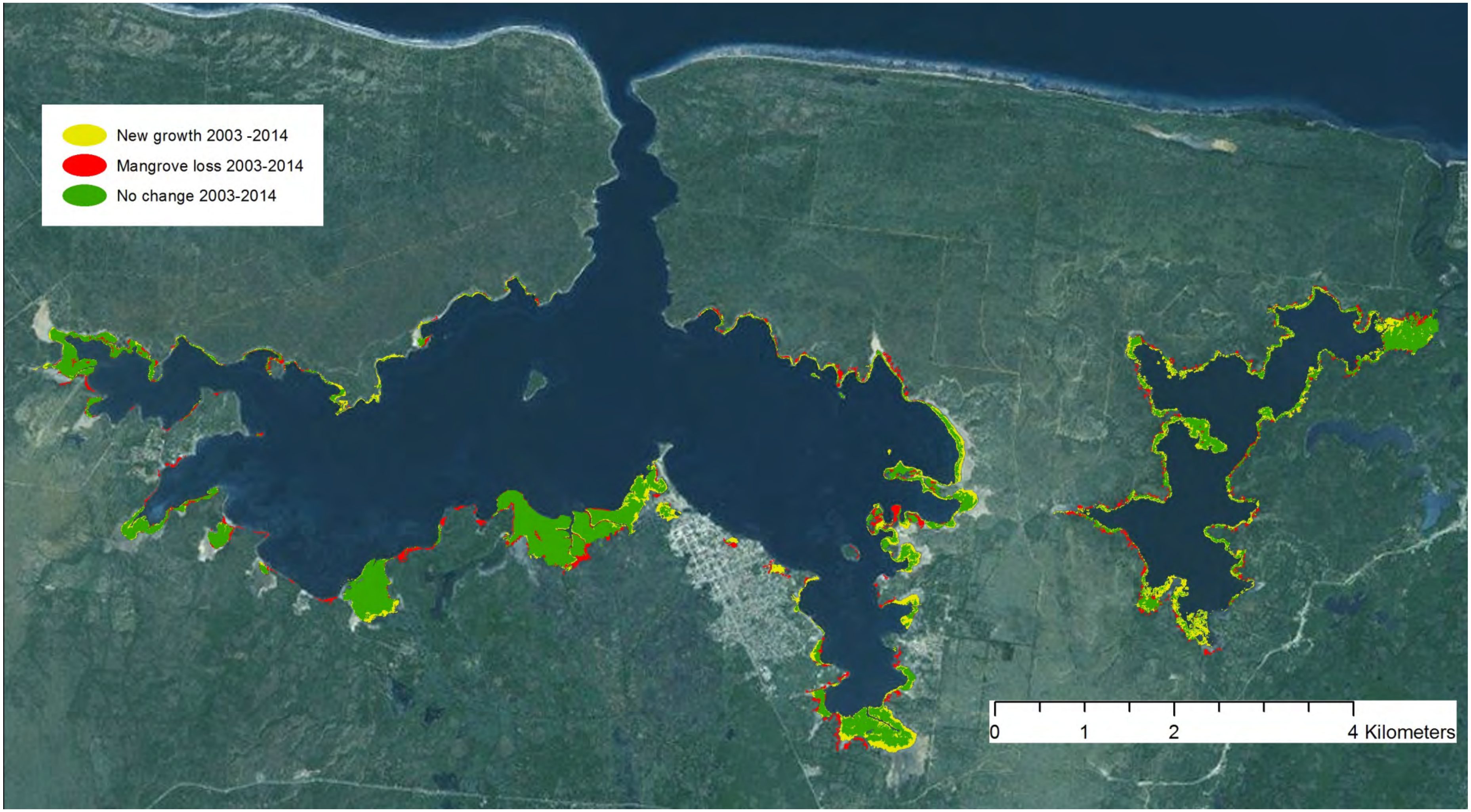
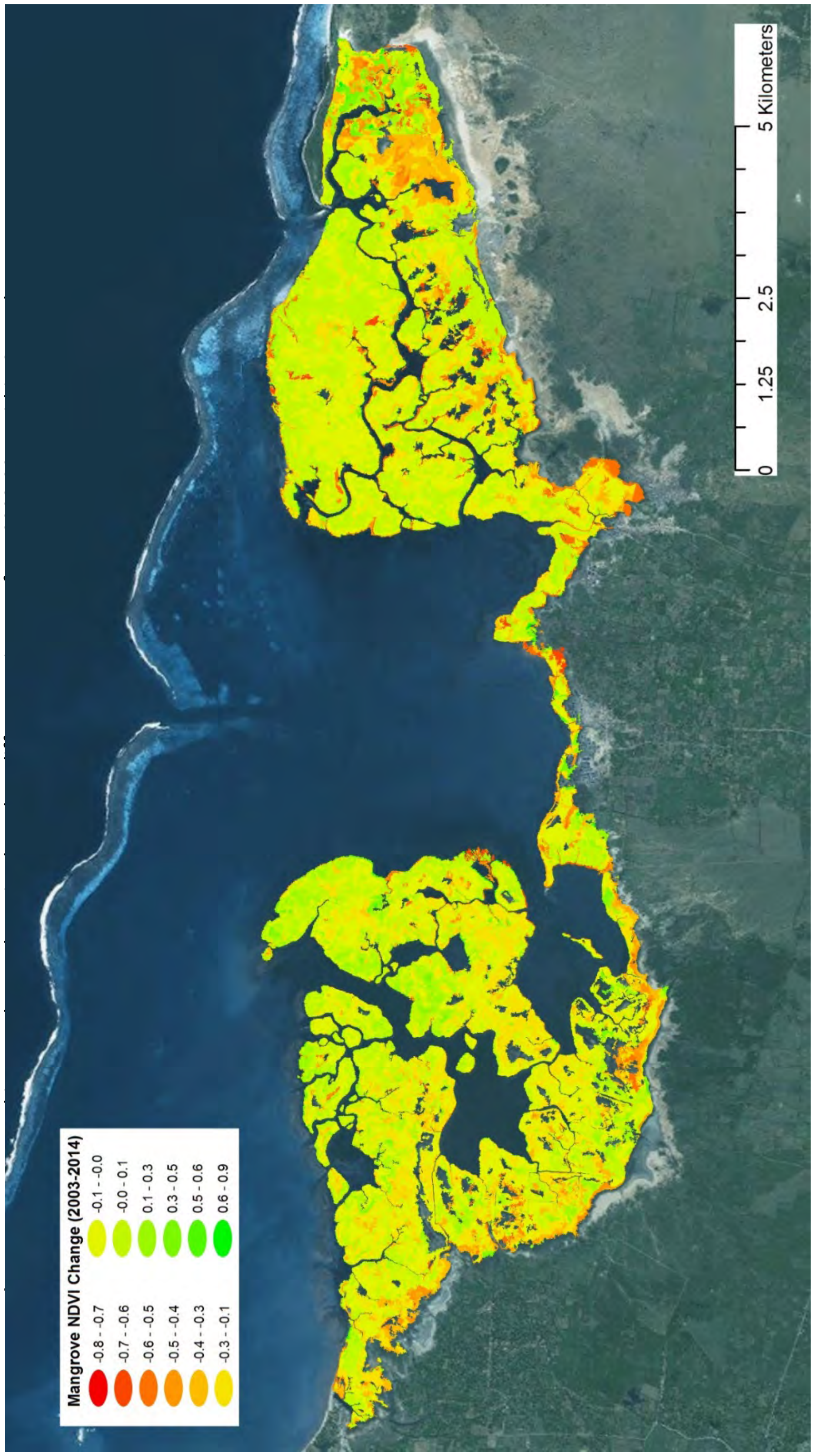


Figure 10. Mangrove change detection for Fort Liberte Bay and Lagon aux Boeufs from 2003-2014.

Figures 11and 12 show the results of the change detection of the mean Normalized Vegetation Difference Index (NDVI) value that was calculated for each mangrove image segment using the Quickbird and WorldView-2 imagery. Some differences result from cloud shadow so care should be taken when deciphering results. Areas where mangroves have been removed show the highest change in NDVI value.



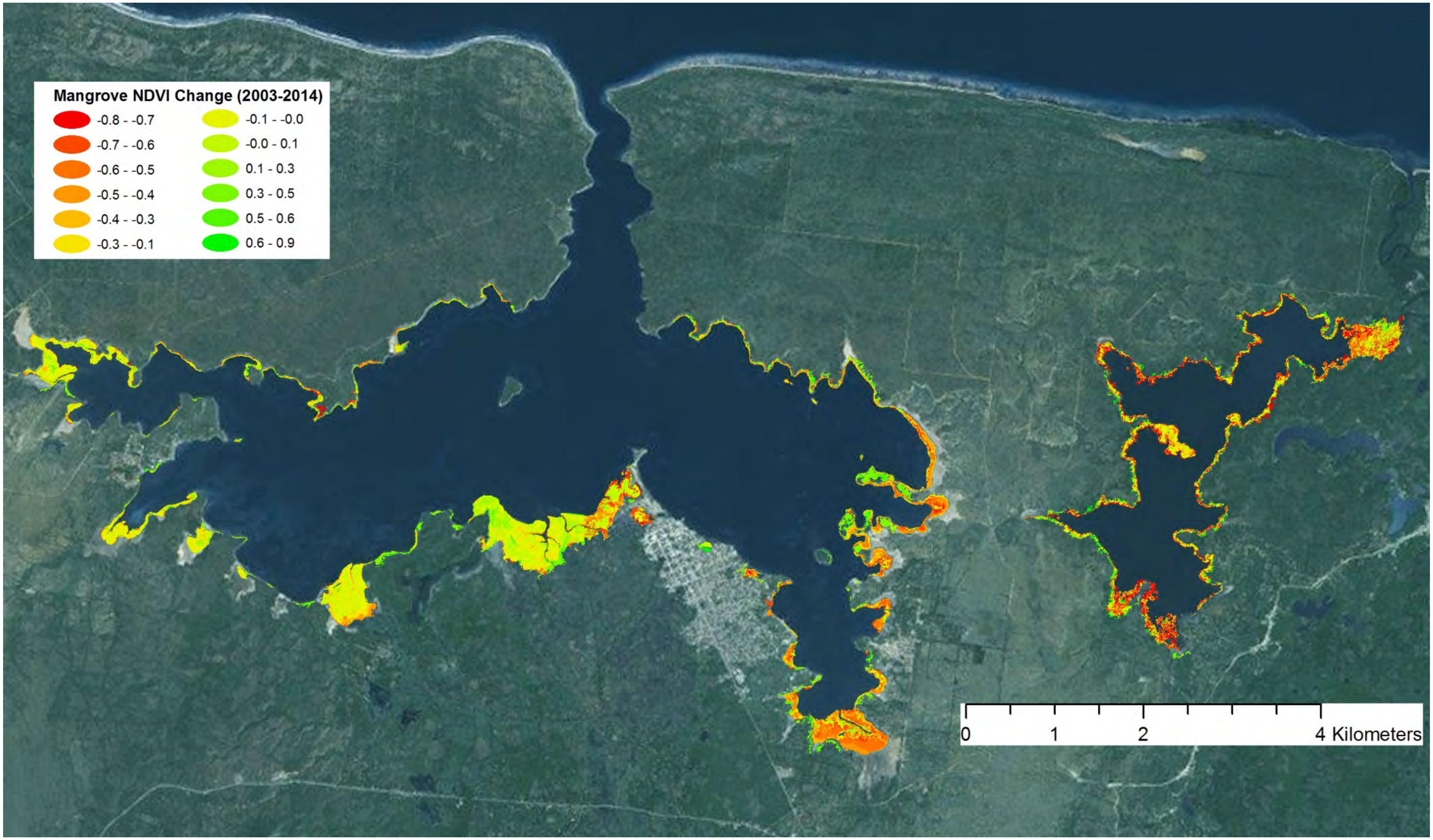


Figure 12. Mangrove biomass change detection based on differences in NDVI from 2003-2014 within Fort Liberte Bay and Lagon aux Boeufs.

ASHTON LAGOON, UNION ISLAND, ST VINCENT AND THE GRENADINES

To determine the health status of mangroves in this area, field surveys were first conducted by TNC in December 2015 and March 2016. The type of field data collected include those mentioned under "DATA COLLECTION: Field Surveys" section of this report. IKONOS imagery attained in March 2009 and from WorldView-2 imagery acquired in June 2012 revealed a total of 18.09 hectares of mangrove and 19.81 hectares respectively (Figure 13). One major threat that negatively impacted the mangrove system was a 300 berth marina project which started in 1994. A year after the project's inception, the project became non-operational. Nonetheless massive dredging and causeway construction had already occurred and modified the natural circulation in the Bay impacting the mangrove system located there by reducing nutrient inflow stunting mangrove growth. Though a steady mangrove die-off can be seen in the central part of the wetlands, mangrove growth continues along the causeways and a slow expansion to the north of the wetland.

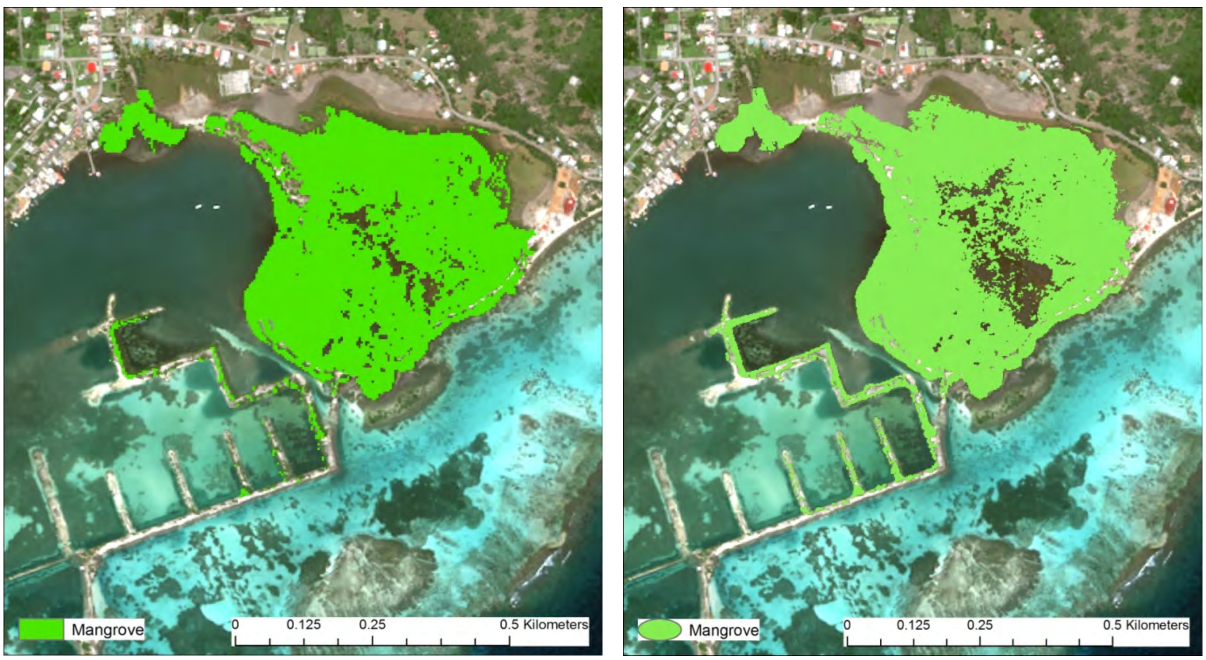
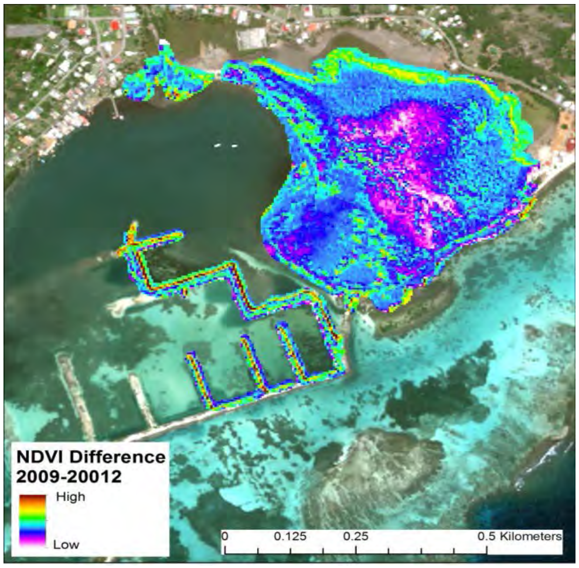


Figure 13. Mapped mangrove extent from IKONOS imagery in March 2009 (left) and mangrove extent from WorldView-2 imagery in June 2012 (right).



Changes in mangrove extent over three years, from 2009 to 2012 can be seen in Figure 14. The dark blues and purple shades indicate mangrove die off, while the greens, yellows, and browns indicate mangrove growth. Note signs of die off in the center of the forest, but large growth along the causeways and expansion of the mangrove in the north.

Figure 14. Comparison of changes in mangrove extent in Ashton Lagoon over three years, from 2009 to 2012.

The Normalized Vegetation Difference Index (NDVI) was also calculated for both 2009 and 2012 to demonstrate changes in mangrove biomass over time (Figure 15). As stated earlier in the report, areas of higher biomass are shown in the orange and red shades and lower biomass in the blue and yellow shades.

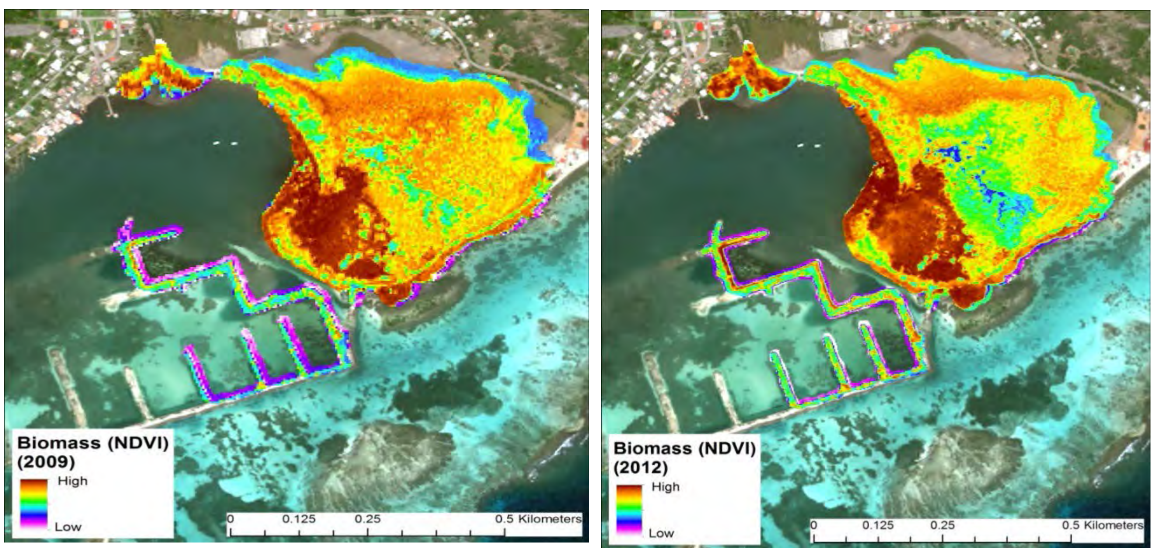


Figure 15. Results of the Normalized Vegetation Difference Index (NDVI) calculated using the 2009 IKONOS imagery (left) and the 2012 WorldView-2 imagery (right).

Figure 16 shows where mangrove biomass has been reduced in Ashton Lagoon between 2009-2012 (i.e. 3.01 hectares) while the map on right shows areas where mangrove biomass was increased between 2009-2012 (by 1.1 hectares).

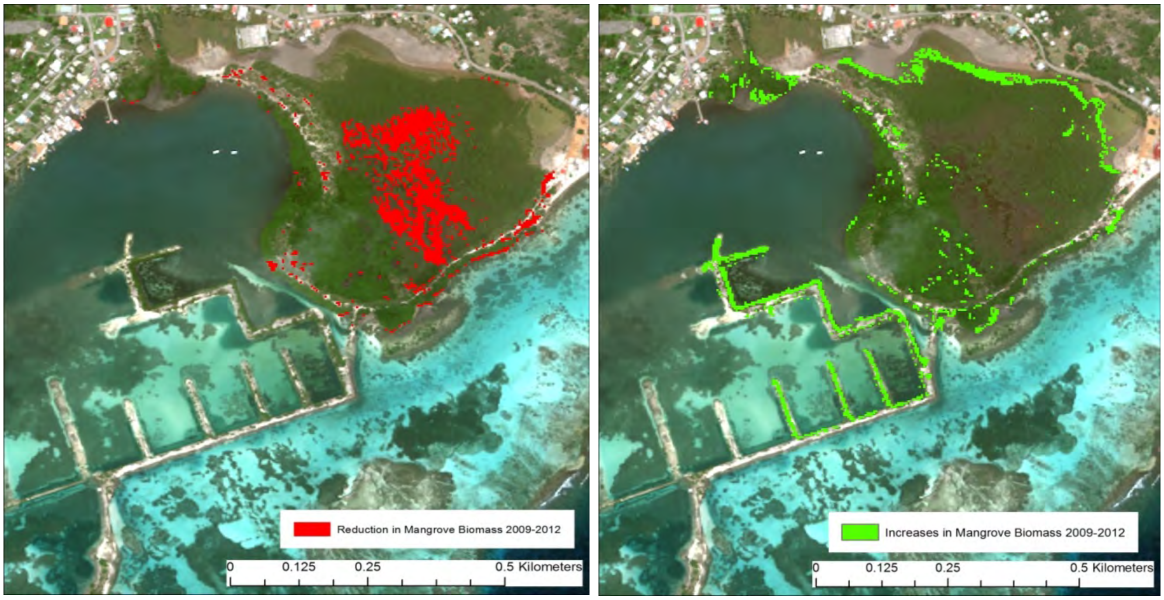


Figure 16. The left map shows areas where mangrove biomass was reduced in Ashton Lagoon between 2009-2012 (3.01 ha) while the map on the right shows areas where mangrove biomass was increased between 2009-2012 (1.1 ha).

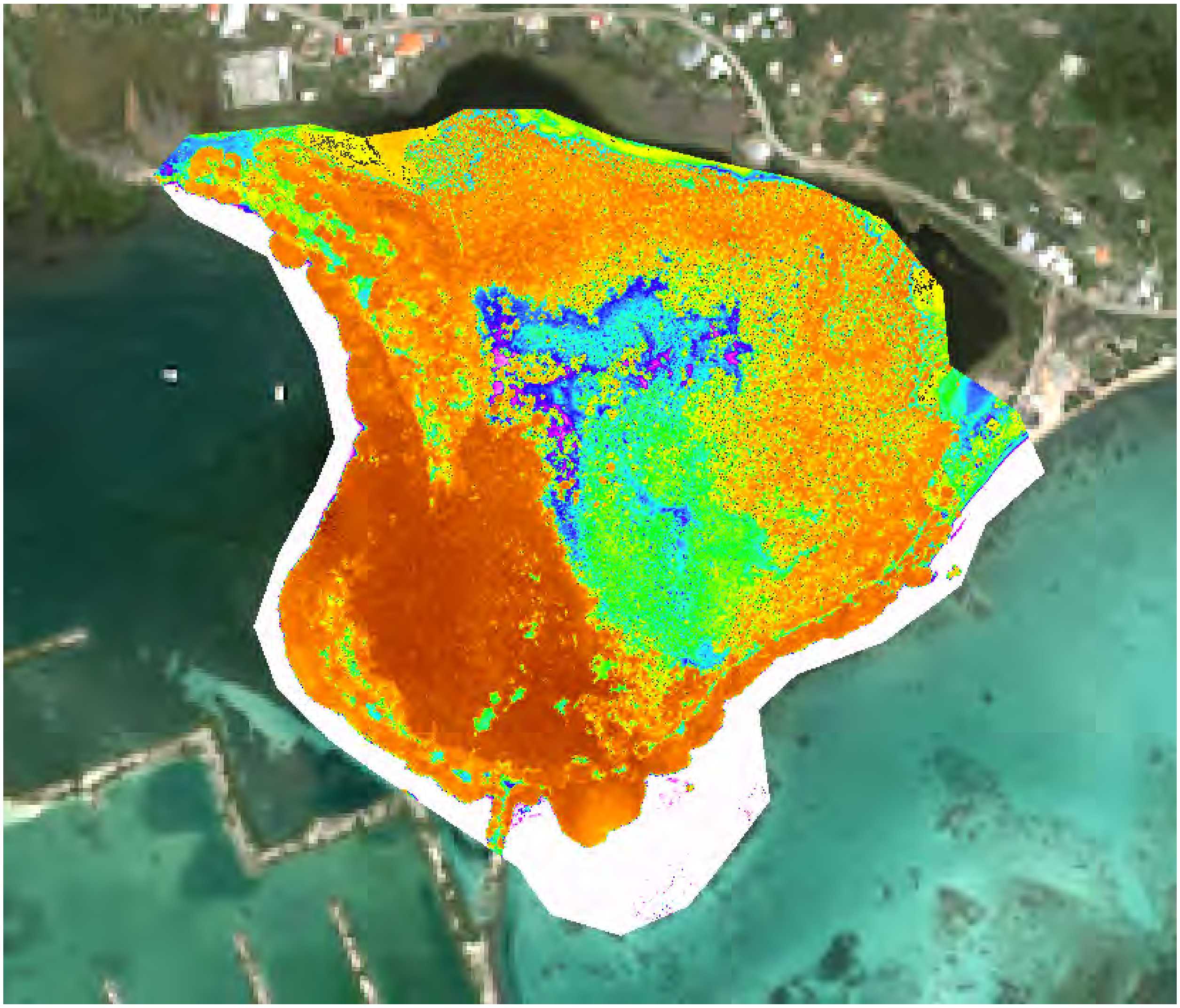


Figure 17. Results of the Normalized Vegetation Difference Index (NDVI) that was calculated using the drone imagery collected at a 2cm resolution (flying at 400ft) in November 2015.