

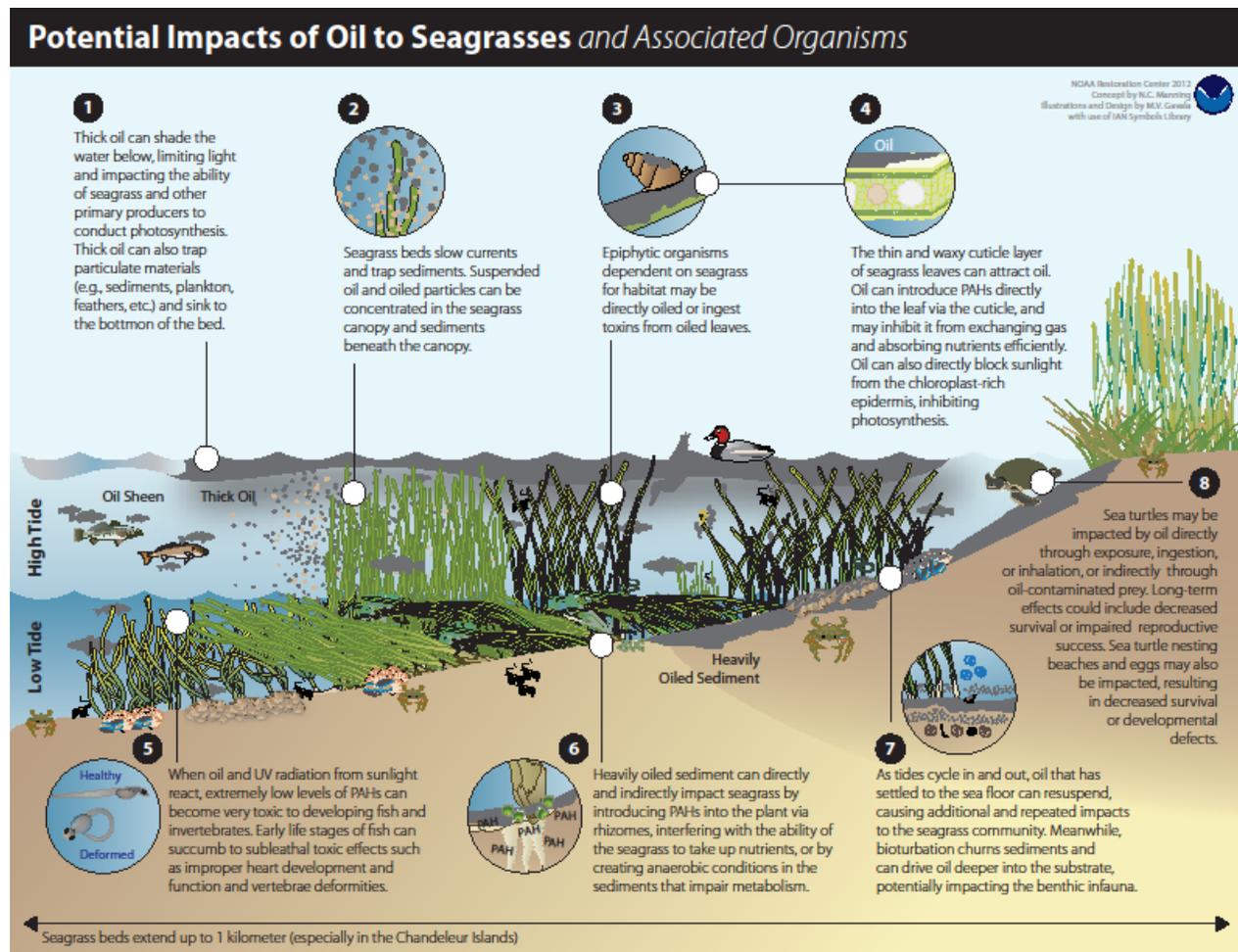
# Seagrass response following exposure to *Deepwater Horizon* oil in the Chandeleur Islands, Louisiana (USA)

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**Supplement 1.** Conceptual model illustrating the potential impacts of oil on seagrass and associated organisms.



## Supplement 2. Polycyclic Aromatic Hydrocarbon Analytes

<i>Acenaphthene</i>	<b>C1-Naphthalenes</b>	<b>C4-Dibenzothiophenes</b>
<i>Acenaphthylene</i>	<b>C1-Naphthobenzothiophenes</b>	<b>C4-Fluoranthenes/pyrenes</b>
<i>Anthracene</i>	<b>C1-Phenanthrenes/anthracenes</b>	<b>C4-Naphthalenes</b>
<i>Benzo(a)anthracene</i>	<b>C2-Chrysenes</b>	<b>C4-Naphthobenzothiophenes</b>
<i>Benzo(a)fluoranthene</i>	<b>C2-Dibenzothiophenes</b>	<b>C4-Phenanthrenes/anthracenes</b>
<i>Benzo(a)pyrene</i>	<b>C2-Fluoranthenes/pyrenes</b>	<i>Chrysene</i>
<i>Benzo(b)fluoranthene</i>	<b>C2-Fluorenes</b>	<i>Chrysene+Triphenylene</i>
<i>Benzo(b)fluorene*</i>	<b>C2-Naphthalenes</b>	<i>Dibenzo(a,h)anthracene</i>
<i>Benzo(b)fluoranthene+</i>	<b>C2-Naphthobenzothiophenes</b>	<i>Dibenzo(a,h+a,c)anthracene</i>
<i>Benzo(j)fluoranthene+</i>	<b>C2-Phenanthrenes/anthracenes</b>	<i>Dibenzofuran</i>
<i>Benzo(k)fluoranthene+</i>	<b>C3-Chrysenes</b>	<i>Dibenzothiophene</i>
<i>Benzo(e)pyrene</i>	<b>C3-Dibenzothiophenes</b>	<i>Fluoranthene</i>
<i>Benzo(g,h,i)perylene</i>	<b>C3-Fluoranthenes/pyrenes</b>	<i>Fluorene</i>
<i>Biphenyl</i>	<b>C3-Fluorenes</b>	<i>Indeno(1,2,3-c,d)pyrene</i>
<b>C1-Chrysenes</b>	<b>C3-Naphthalenes</b>	<i>Naphthalene</i>
<b>C1-Dibenzothiophenes</b>	<b>C3-Naphthobenzothiophenes</b>	<i>Naphthobenzothiophene</i>
<b>C1-Fluoranthenes/pyrenes</b>	<b>C3-Phenanthrenes/anthracenes</b>	<i>Phenanthrene</i>
<b>C1-Fluorenes</b>	<b>C4-Chrysenes</b>	<i>Pyrene</i>

*Italicized* PAHs are pyrogenic and **bold** are petrogenic compounds

\* Co-elutes with C1-fluoranthenes/pyrenes

+ Benzofluoranthenes can co-elute in various combinations with one another

## Supplement 3. Detailed Description of Image Interpretation and Change Analyses Methods

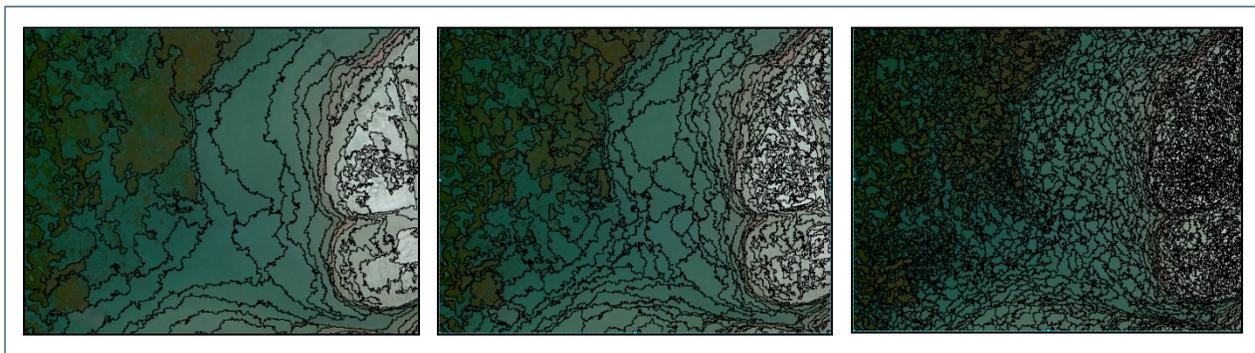
### SAV Mapping

The purpose of the mapping was to delineate the aerial extent of submerged aquatic vegetation (SAV) along the length of the Chandeleur Islands using advanced imagery analysis techniques. This proposed SAV Imagery Analysis/Interpretation activity was considered a “hybrid” approach between automated object-based imagery analysis (OBIA) and the traditional photo interpretation methods of all previous Gulf of Mexico seagrass mapping projects (Handley *et.al.*, 2007). The hybrid OBIA/interpretation activity was agreed upon collaboratively by the AITWG. Products resulting from the OBIA effort were reviewed by USGS photo interpretation team with any uncertain SAV determinations noted and potentially corrected. It was anticipated that any systematic issues present in SAV classification would be worked through due to ongoing collaboration with the USGS lead throughout the SAV classification process. Any further attribution by USGS, such as species level determinations (if deemed necessary and possible), would be performed by USGS photo interpretation team. Initially, the developed protocol required a minimum target mapping unit of 0.01 of an acre, far greater than most mapping efforts previously conducted, however as the hybrid classification progressed the minimum target mapping unit was reduced in size to 0.001 acre (43 square feet) as the ability to discriminate seagrass from background sediment over the greatest part of the area was possible.

An advanced image analysis technique called Object-Based Image Analysis (OBIA) image segmentation was used to generate image objects which are polygons consisting of areas of similar spectral and textural characteristics in the imagery. Image segmentation was done using Trimble’s eCognition Developer software. The aerial imagery and principal components images derived from the aerial imagery were input into eCognition. The input images were then segmented based on parameters of scale and homogeneity specified by the analyst. The homogeneity parameters are based on color properties and shape properties of smoothness and compactness. The blue and green input bands were

weighted heavier during the segmentation process because these shorter wavelengths penetrate the water better than longer wavelengths.

Nested image objects were produced at several scales as shown in Figure S3.1. Objects from the coarser scales of segmentation (i.e., larger objects) were used to classify and mask out the land areas, including the marshes. Water bodies in the interior of the islands and the ocean waters on the Gulf side of the islands, where little or no SAV is present, were also masked out. The remaining area, consisting of the ocean and tidal flats on the interior side of the islands, was then segmented again in eCognition at a finer scale for mapping the SAV. The process of selecting appropriate scale and homogeneity parameters was done by the remote sensing analyst in collaboration with the AITWG chair from the USGS who has years of experience photo interpreting and mapping SAV. This collaboration ensured that the final objects were of a scale and level of detail to appropriately discriminate discrete units of submerged aquatic vegetation for mapping.



**Figure S3.1.** Nested image objects generated by the image segmentation.

Initially intent on mapping the presence of all seagrass in the meadows at the Chandeleurs, it became apparent that the hybrid mapping effort had high accuracy to delineate seagrass beds/patches with a density over an estimated 30% cover of seagrass shoots and leaves that present a distinct edge to the bed/patch. However, at less than approximately 30% seagrass vegetative cover, the photointerpretation signature is slight discoloration of the sediment/sand without the development of a distinct edge. Therefore, the delineation of sparse (less than 30%) seagrass areas had limitations in the object based classification process. As a result, it was determined that the products of the OBIA process for seagrass mapping at the Chandeleurs present only those seagrass beds/patches with distinct edges, which we have called “discrete units of seagrass.”

Once the final set of image objects was generated, various attribute values were calculated for each object. These attribute values were based on spectral and textural properties of the imagery within each object, as well as geometric properties of the objects themselves. A total of fifty-two attributes were derived for each image object. The image objects, along with their calculated attributes, were exported from eCognition as shapefiles which were then imported into an ArcGIS geodatabase.

The fine scale image objects were classified using Classification and Regression Tree (CART) statistical analysis (Breiman et al., 1984). The attributes from the objects generated for each image frame were used as input to the CART. Each image frame was processed separately because of spectral differences caused by sun glint and other environmental factors.

The classification scheme was binary, consisting of two classes: SAV and NOT SAV. Training samples of each class were identified throughout each image frame. The analysts worked collaboratively with the USGS team member to identify numerous training samples representing the range of conditions observed in the imagery, including variations in illumination, water depth, substrate, turbidity, and surface disturbance. Although the classification scheme was binary (presence/absence of SAV), samples of many other features were identified in order to be discriminated and removed from consideration as SAV,

in particular the NOT SAV training samples consisted primarily of sand substrate sites, but other non-SAV features were included. The training samples were input to the CART analysis and used to develop a classification model based on Random Forest decision tree logic (Breiman, 2001). The model was then applied to all objects in the image frame. Each object was assigned a class label and a probability value from the CART analysis. The probability values were based on the number of votes a class received from all the decision trees that went into the Random Forest model development. This initial classification was evaluated and a probability threshold was determined above which objects were classified with high confidence. All objects with probability values below this threshold were masked out and a second round of CART analysis was run using new sample sites selected from among the objects being reclassified. After the second round of CART, the probability values from round 2 were compared with the probability values from round 1 on an object-by-object basis. The final class label was determined from the round with the higher probability value.

The results of the CART classification were inspected and edited using traditional photointerpretation methods to refine the classification. The classified image objects were overlaid on the imagery and photo interpretation was performed to identify image objects (polygons) representing errors of omission and commission. Corrections were made by editing the class label for these polygons. Only the class labels were edited; object geometry was not altered from the initial object shapes derived from image segmentation.

The review and editing was an iterative and in-depth process involving the mapping staff and outside review by USGS experts. Several rounds of review and editing were made by the NewFields remote sensing staff with each round of edits subsequently quality checked by the USGS expert (AITWG chair) in SAV mapping and the Chandeleurs. Once the USGS expert signed off on the draft maps, they were sent to the National Wetlands Research Center where they were reviewed by a USGS photo interpreter who noted any additional edits to be made. This review was also quality checked by the USGS expert. The edits suggested by the USGS were made by NewFields staff and a final review and quality check was made by the USGS expert before the maps were finalized.

After the review process was completed, the SAV maps representing all of the image frames from each year were joined into a single map and a minimum mapping unit was enforced. To do this, all adjoining polygons of the same class were merged. Next, any polygons less than 0.001 acre (four square meters) were eliminated by dissolving them into the surrounding polygon, resulting in a standard minimum mapping unit.

### **Change Detection**

The change detection analysis consisted of two parts: 1) change between 2010 and 2011 along the full length of the Chandeleurs, and 2) change between all three dates of mapping (2010, 2011, and 2012) within the five Areas of Concern.

For the initial change detection along the full length of the Chandeleurs, the minimum mapping unit SAV maps for 2010 and 2011 were overlaid and the polygons intersected. The output was clipped to the maximum common area of the two maps. Change in SAV between 2010 and 2011 was then calculated for each polygon and the acres of gains, losses, and no change were summarized.

For the second stage of change detection, the 2012 SAV map, consisting of the five Areas of Concern, was overlaid and intersected with the 2010/2011 data and clipped to the boundaries of the five Areas of Concern. Changes in SAV between the three dates were then determined by querying the dataset.

The objective of the change detection analysis was to identify areas of SAV loss resulting from exposure to oil. Thus it was necessary to discriminate between natural losses and those potentially related to oil. To refine the analysis, Core Areas were identified and delineated within each of the Areas of Concern by the AI TWG chair who has mapped and studied the Chandeleurs for many years and is familiar with the natural processes of the islands. These Core Areas represent areas where interpretation of the imagery

suggested that natural forces between 2010 and 2012 cannot explain the total SAV losses within the Core Areas.

Areas that were excluded from the Core Areas included outer edges of SAV meadows where natural erosion or burial may have occurred, areas adjacent to channels where scouring and sedimentation may have caused losses, areas where water column turbidity obscured the bottom, and overwash fans where significant sediment deposits were made by storms. In particular, we wanted to exclude massive overwash fans created by Hurricane Isaac which occurred a few weeks before the 2012 imagery was collected. By eliminating these areas of potential natural losses from consideration, the Core Areas focused the analysis on areas where losses were more likely to be due to the effects of oil exposure documented by the 2010 May NAIP imagery and SCAT surveys.

The delineation of the Core Areas was an iterative process. Initially, they were determined solely based on interpretation of the 2010 and 2011 imagery. When the 2012 post-Hurricane Isaac imagery became available, the Core Areas were refined to exclude overwash fan deposits from the hurricane. The final versions of the Core Areas were delineated after obtaining pre-Hurricane Isaac imagery from August 26, 2012. This imagery provided additional detail that helped further discriminate areas of loss due to the hurricane from those potentially due to oil exposure.

After the Core Areas were overlaid and intersected with the combined 2010, 2011, and 2012 dataset, the change in SAV within the Core Areas between the three years was calculated and summarized.

### **Bibliography**

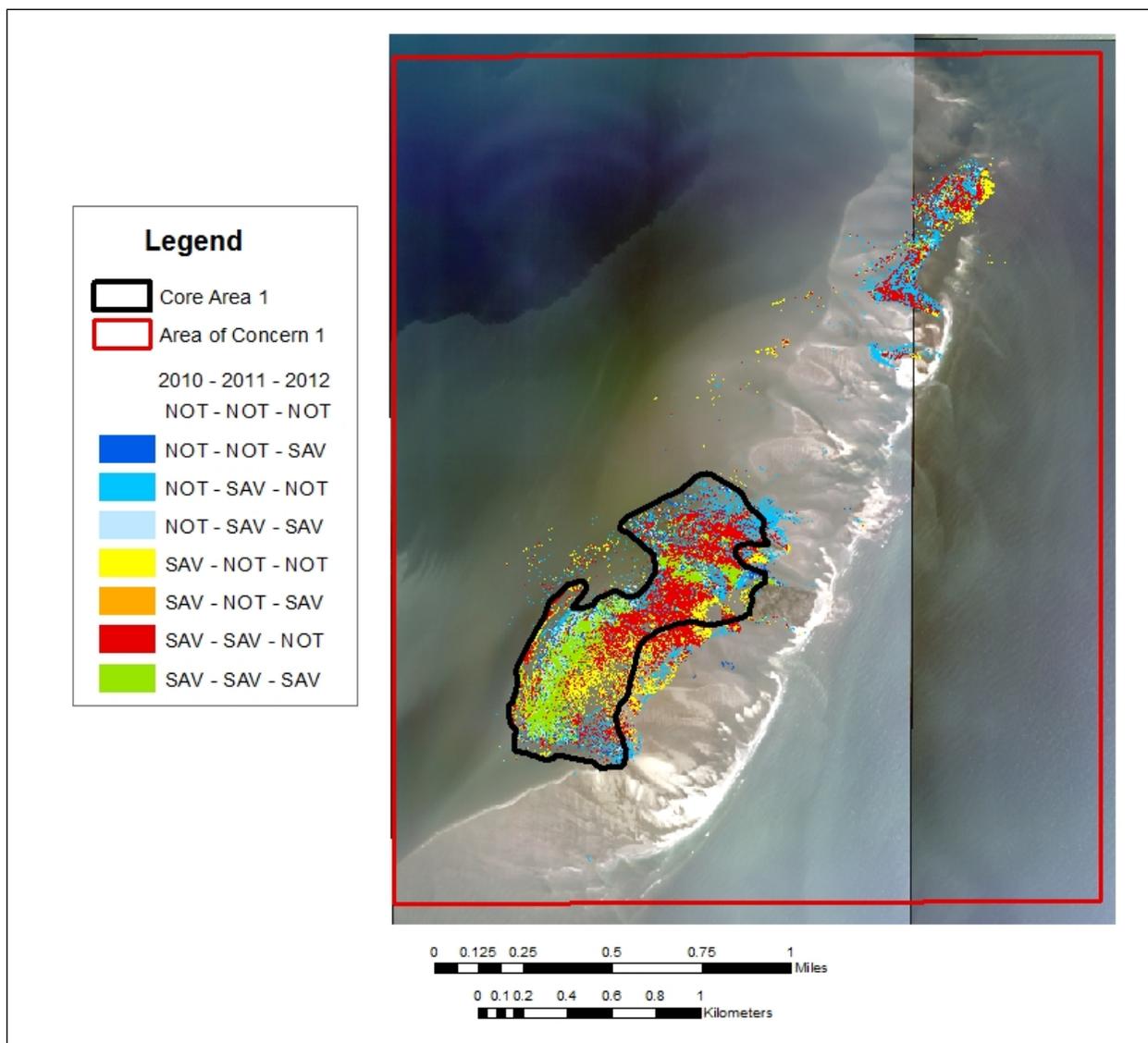
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Breiman L, Friedman JH, Olshen RA, Stone CJ (1984) *Classification and Regression Trees*. Wadsworth, Belmont, CA

Handley L, Altsman D, DeMay R (2007) *Seagrass Status and Trends in the Northern Gulf of Mexico: 1940–2002*: U.S. Geological Survey Scientific Investigations Report 2006–5287.

### **Supplement 4. Figures (S4.1, S4.2, S4.3, S4.4, and S4.5) and corresponding tabulated results below (Tables S4.1, S4.2, S4.3, S4.4, and S4.5) for the change analysis in Core Areas 1, 2, 3, 4 and 5.**

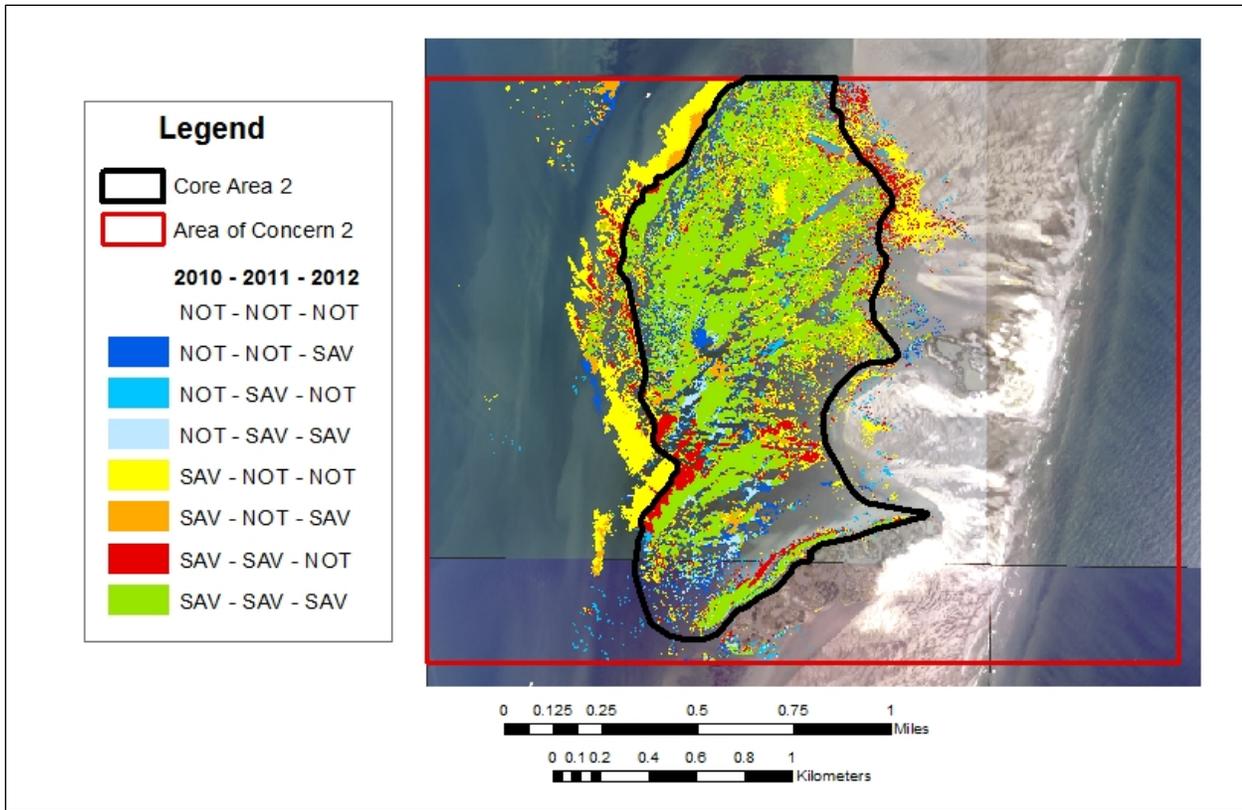
In the figures green symbolizes areas that were mapped as seagrass (SAV) on all three dates. These areas, therefore, experienced no change in seagrass cover. Similarly, the areas with no coloration and the underlying imagery visibly represent areas that were mapped as NOT SEAGRASS (NOT) on all three dates. The yellow class represents areas where seagrass was present (SAV) in 2010, absent (NOT) in 2011, and still absent (NOT) in 2012. For the purposes of this analysis, the areas without seagrass in 2011 and 2012 mapping events are referred to as “persistent loss”. In other words, there was an initial loss of SEAGRASS between 2010 and 2011, with continued absence (no recovery) in 2012. The red class, referred to as “delayed loss”, indicates that seagrass was present (SAV) in 2010, still present (SAV) in 2011, but absent (NOT) in 2012. Orange represents areas where seagrass was present (SAV) in 2010, absent (NOT) in 2011, and present again (SAV) in 2012. Thus, these orange areas represent initial losses that subsequently revegetated. The three blue colors indicate areas that were not seagrass (NOT) in 2010 and therefore are not candidates for seagrass loss or gain from the base year 2010.



**Figure S4.1.** Change in SAV (seagrass) in Area of Concern 1. Legend indicates the presence or absence of SAV (seagrass) over 3 years (2010, 2011, and 2012). Core Area is outlined in black.

**Table S4.1.** Results of the change analysis during three years in Core Area 1 for eight change class categories; SAV = seagrass present; NOT SAV = no seagrass present. All values are in acres.

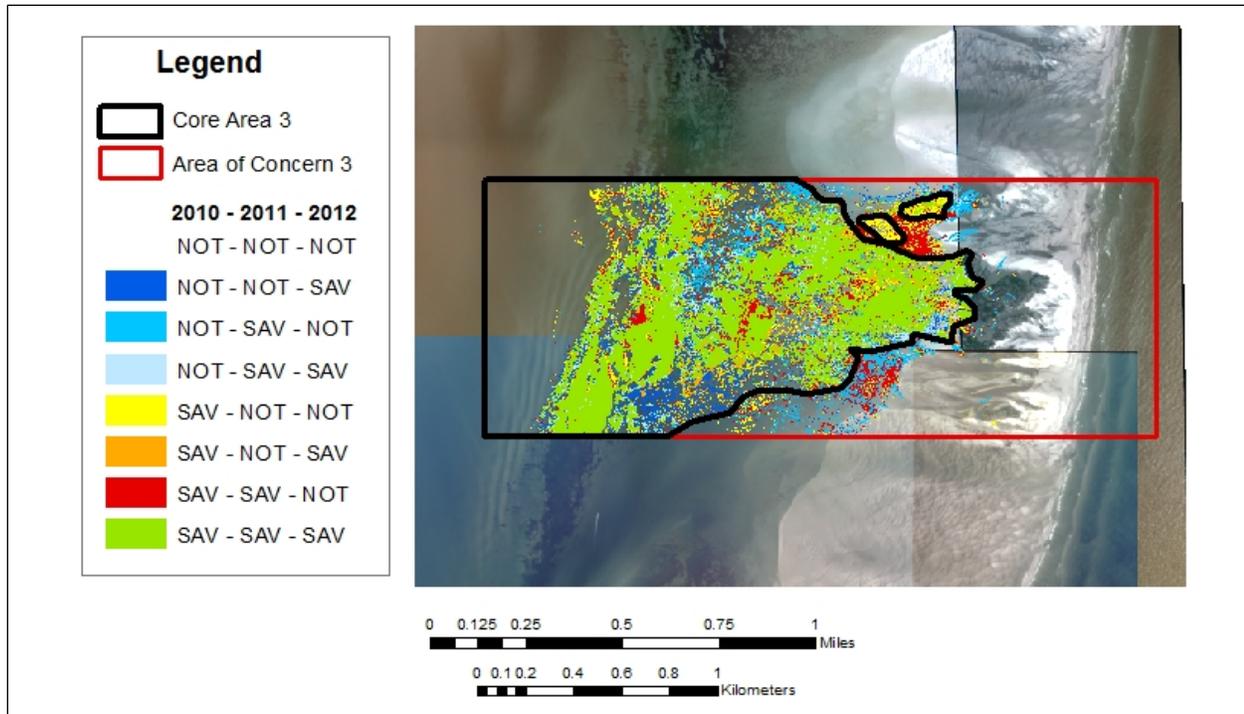
Core Area 1				
2010	2011	2012	Acres	Change Classes
SAV	SAV	SAV	25.37	No Net Change
SAV	SAV	NOT SAV	41.17	Delayed Loss
SAV	NOT SAV	SAV	0.99	No Net Change
SAV	NOT SAV	NOT SAV	13.73	Persistent Loss
NOT SAV	SAV	SAV	7.31	Gain
NOT SAV	SAV	NOT SAV	19.99	No Net Change
NOT SAV	NOT SAV	SAV	3.69	Gain
NOT SAV	NOT SAV	NOT SAV	53.69	No Net Change



**Figure S4.2.** Change in SAV (seagrass) in Area of Concern 2. Legend indicates the presence or absence of SAV over 3 years (2010, 2011, and 2012). Core Area is outlined in black.

**Table S4.2.** Results of the change analysis during three years in Core Area 2 for eight change class categories; SAV = seagrass present; NOT SAV = no seagrass present. All values are in acres.

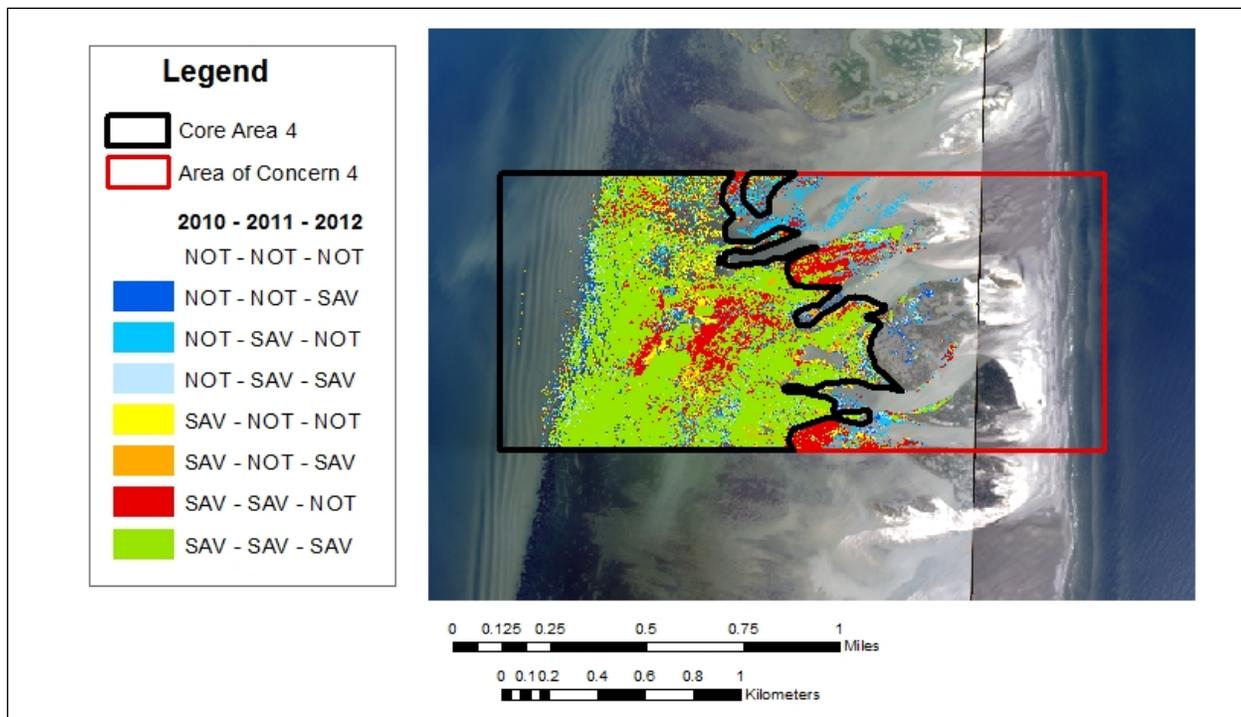
Core Area 2				
SAV	SAV	SAV	176.44	No Net Change
SAV	SAV	NOT SAV	28.68	Delayed Loss
SAV	NOT SAV	SAV	21.98	No Net Change
SAV	NOT SAV	NOT SAV	35.76	Persistent Loss
NOT SAV	SAV	SAV	13.28	Gain
NOT SAV	SAV	NOT SAV	9.84	No Net Change
NOT SAV	NOT SAV	SAV	22.59	Gain
NOT SAV	NOT SAV	NOT SAV	156.41	No Net Change



**Figure S4.3.** Change in SAV in Area of Concern 3. Legend indicates the presence or absence of SAV over 3 years (2010, 2011, and 2012). Core Area is outlined in black.

**Table S4.3.** Results of the change analysis during three years in Core Area 2 for eight change class categories; SAV = seagrass present; NOT SAV = no seagrass present. All values are in acres.

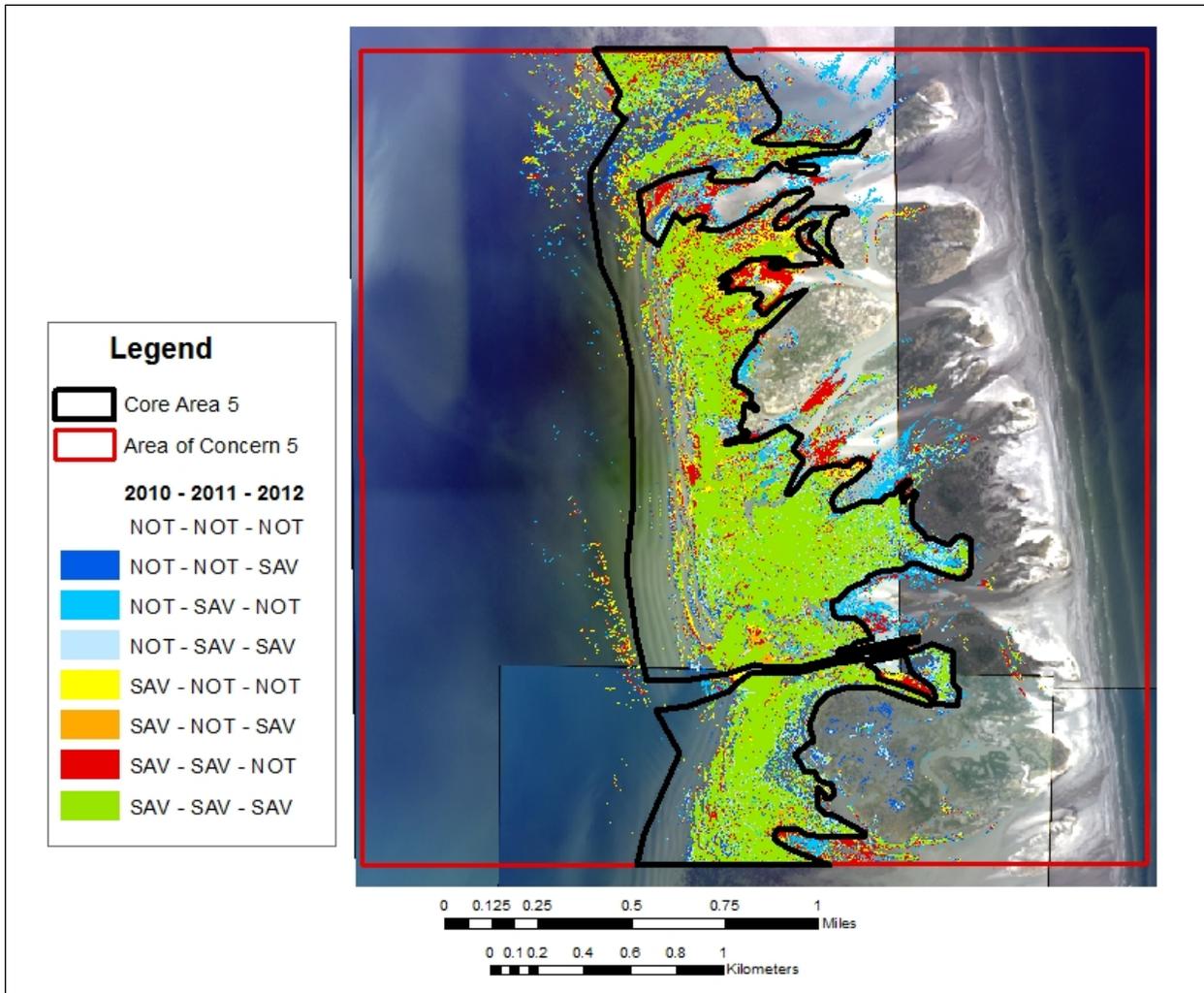
Core Area 3				
SAV	SAV	SAV	149.39	No Net Change
SAV	SAV	NOT SAV	19.26	Delayed Loss
SAV	NOT SAV	SAV	12.84	No Net Change
SAV	NOT SAV	NOT SAV	17.35	Persistent Loss
NOT SAV	SAV	SAV	17.81	Gain
NOT SAV	SAV	NOT SAV	16.05	No Net Change
NOT SAV	NOT SAV	SAV	21.17	Gain



**Figure S4.4.** Change in SAV in Area of Concern 4. Legend indicates the presence or absence of SAV over 3 years (2010, 2011, and 2012). Core Area is outlined in black.

**Table S4.4.** Results of the change analysis during three years in Core Area 2 for eight change class categories; SAV = seagrass present; NOT SAV = no seagrass present. All values are in acres.

<b>Core Area 4</b>				
<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>Acres</b>	<b>Change Classes</b>
SAV	SAV	SAV	159.12	No Net Change
SAV	SAV	NOT SAV	32.74	Delayed Loss
SAV	NOT SAV	SAV	9.1	No Net Change
SAV	NOT SAV	NOT SAV	14.8	Persistent Loss
NOT SAV	SAV	SAV	11.66	Gain
NOT SAV	SAV	NOT SAV	10.61	No Net Change
NOT SAV	NOT SAV	SAV	9.33	Gain
NOT SAV	NOT SAV	NOT SAV	123.27	No Net Change



**Figure S4.5.** Change in SAV in Area of Concern 5. Legend indicates the presence or absence of SAV over 3 years (2010, 2011, and 2012). Core Area is outlined in black.

**Table S4.5.** Results of the change analysis during three years in Core Area 2 for eight change class categories; SAV = seagrass present; NOT SAV = no seagrass present. All values are in acres.

Core Area 5				
SAV	SAV	SAV	277.88	No Net Change
SAV	SAV	NOT SAV	37.64	Delayed Loss
SAV	NOT SAV	SAV	14.8	No Net Change
SAV	NOT SAV	NOT SAV	30.06	Persistent Loss
NOT SAV	SAV	SAV	35.79	Gain
NOT SAV	SAV	NOT SAV	23.6	No Net Change
NOT SAV	NOT SAV	SAV	24.34	Gain
NOT SAV	NOT SAV	NOT SAV	210.31	No Net Change

**Supplement 5.** Conceptual illustration of the oiling scenario in the Chandeleur Islands showing the general bio-physical characteristics of the shallow shelf and the heterogeneous distribution of surface (top panel) and subsurface oiling (bottom panel).

