MC252/*DEEPWATER HORIZON* QUANTIFICATION OF PHYSICAL RESPONSE INJURY TO SUBMERGED AQUATIC VEGETATION

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SAV TWG

NOAA Office of Response and Restoration

Assessment and Restoration Division

prepared by:

Sean Meehan

NOAA Restoration Center

St. Petersburg, Florida

Restoring injured seagrass is an important step in reducing the cumulative adverse impact to seagrasses throughout nearshore waters and in preserving this important ecosystem. Over the last few decades, restoration efforts have used different techniques with varying successes (Fourqurean et al. 1995; Fonseca et al. 1998; Fonseca et al 2000; Kenworthy et al. 2000; Kenworthy et al. 2002; Hall et al. 2006; Kenworthy et al. 2006; Hammerstrom et al. 2007; Gutiérrez 2009). These techniques include one or a combination of the following: sediment fill; planting (through transplant); bird staking to provide direct fertilization to promote faster growth; and no-action alternatives (natural recovery). The restoration technique employed is dependent on the characteristics (e.g., depth and width of scars/blowout; species of seagrass; substrate composition) and location (e.g., nutrient limitation; wind and wave climate) of injury.

During the Mississippi Canyon 252/ *Deepwater Horizon* oil spill, seagrasses were injured as a result of response efforts to protect shorelines and wildlife from oiling. The majority of these injuries were propeller scars and blowholes from response vessels placing booms (temporary floating barrier used to contain oil) in shallow coastal areas. Boom curtains and anchors used to hold booms in place in very shallow water were pulled over the seagrass beds with the rising and falling tides and with wind or vessel waves/wakes or currents, scouring the seagrass beds. These types of seagrass injuries did not only occur in boom placement areas, but in areas of shallow water with underlying seagrass during the transportation of booms.

A major goal of the Oil Pollution Act of 1990 (OPA) is to make the environment and the public "whole" again after injury to or loss of natural resources and associated ecological and economic services as a result of oil discharge. This goal is achieved by returning injured natural resources and services to the condition they would have maintained if the incident had not occurred. As part of the Natural Resource Damage Assessment (NRDA) under the OPA regulations, the trustees (State and Federal) chose to pursue emergency restoration actions to minimize continuing, or prevent additional, injury to seagrass beds.

In order to rapidly assess injury and restore the affected seagrass beds, an aerial imagery and on-ground rapid assessment process was developed to identify and quantify areas in need of restoration, identify characteristics of the injury, and decide on the most appropriate restoration techniques.

Methods

Geographic Information Systems (GIS) and Aerial Imagery Analysis

GIS was used document and map potential and known areas of seagrass beds impacted from response vessels placing booms. Data layers of mapped seagrass areas, bathymetry, and boom locations were collected from State, Federal, and Responsible Party sources. These layers were overlaid and queried to locate boom polyline features that were over known seagrass beds at depth contours less than or equal to 1 meter (m) at mean low water level. This information was also cross-referenced with observational reports of vessel and boom impacts to seagrass beds. A total of thirteen impacted or potentially impacted bay, lagoon, and/or offshore island systems were identified from the Chandeleur Islands, Louisiana to Apalachee Bay, Florida.

Focused assessment efforts were conducted around known boom placement locations to address boom related damages to seagrass systems. In this methodological approach, a 50 m buffer was placed around boom polylines that fit the query described above to create an area (polygon) in which reconnaissance for boom damage would be conducted (NOAA 2011). 189 polygons were originally identified for reconnaissance, totaling 3,455 acres.

Aerial imagery site identification

Aerial imagery was captured in October 2010 as part of the NRDA effort by the aerial imagery, submerged aquatic vegetation and shoreline technical workgroups (TWGs). To further refine the GIS analysis, aerial imagery was utilized to identify seagrass injuries present before and after response activities, as well as to assist in reconnaissance and identification of areas for restoration in the established polygons (NOAA 2011). The high altitude imagery covered all of the identified seagrass areas from the Chandeleur Islands, LA to Apalachee Bay, FL at the 1:2,400 scale required for reconnaissance activities. Technical experts (D. Field and W. J. Kenworthy) determined the quality to be high enough for damage assessment planning. Pre-oil spill aerial imagery available for all seagrass locations was compared to October 2010 imagery depending on quality (e.g., Florida Department of Environmental Protection 8-bit imagery for northern Gulf of Mexico and USGS – USACE – NOAA individual frames of Alabama and Mississippi). Sites without available pre-spill imagery were assessed for injury during field assessment.

Detailed aerial imagery analysis was conducted manually by D. Field and W. J. Kenworthy on all of the buffered polygon areas (50 m buffer around boom polyline in less than or equal to 1 m depth) that were identified in the GIS exercise. The results indicated either little or no visible damage in any of the areas in the Chandeleur Islands, LA and the Mississippi barrier islands, deeming reconnaissance in these polygons unnecessary. Based on imagery analysis, many locations in Florida bays and lagoons were also removed from survey.

Overall, as a result of the imagery analysis, the original 189 polygons established for reconnaissance was reduced to 88 polygons (66 polygons with potential damage and 22 error-correction polygons) for survey by field teams. Error-correction polygons did not show signs of seagrass injury, and were utilized as a control to verify imagery analysis.

Reconnaissance

Field surveys were conducted in the summer of 2011 to verify imagery analysis and to collect necessary data such as scar depth, scar width, species composition, and other data needed for emergency restoration planning and implementation. A pilot study was conducted to develop and test field reconnaissance methods, including safety protocols, mapping and Trimble protocols, and *in situ* site characterization. Where pre-spill imagery was not available, field teams collected information on the age of the scar where appropriate (e.g., scars within *T. testudinum* were determined to be over a year old if rhizomes were running across the scar) and orientation (e.g., typical of boom placement injury).

Maps for reconnaissance were created by placing transects at 20 m intervals across the buffered polygons. During the pilot survey, this 20 m distance was deemed the best for identifying seagrass injuries from a spotter vessel. Field teams had the option of reducing the distance to 10 m transect width intervals if water clarity was poor. GPS points for transect endpoints were preloaded in the Trimble/Mapping GPS system as shapefiles. Trimble units were used to navigate along the length of each transect.

Field teams navigated to the assigned coordinates and then along the predetermined transect lines within each polygon. These transects were marked at endpoints with stakes or buoys to help with systematic coverage of the assigned polygon. The Trimble operator was positioned in the bow of the vessel as it was driven along the length of the transect at a slow speed. The Trimble operator simultaneously collected a trackline for recording and filing purposes. Another team member stood by with a stake or buoy to mark any injury considered for potential restoration.

Using a survey–grade, differential global positioning system (DGPS; Trimble ® Geo XT handheld or similar equipment), each seagrass injury was mapped by physically tracing the foot print of the damage and recording its total length (m). The physical features obtained from mapping were then downloaded to ArcGIS (ESRI 2011, using XTools Pro®, (projection: GCSNorth America_1993; Datum: D_North America_1983).

Once all transects were complete and the polygon area had been surveyed, the field team examined the seagrass injury characteristics. In order to be evaluated for restoration, candidate seagrass injuries initially had to meet the following criteria: a) the injury occurred within the predetermined area around the oil boom location (polygon), and b) the injury was devoid of any significant seagrass re-growth, suggesting that it was less than 6 months in age.

In areas already heavily scarred, field teams looked for signs that the damage was caused by boom deployment rather than typical recreational boating traffic. Decisions were then left to field representatives (Federal, State and Responsible Party) to determine eligibility of scars/blowholes as candidates for restoration. In all cases, all field reconnaissance team representatives conferred and agreed upon the status of such injuries.

Once candidate scars were established, the following data describing the seagrass injuries were collected: injury depth (>15 centimeters (cm) indicates a candidate site for sediment fill); seagrass species (injuries mapped in *Thalassia testudinum* dominated seagrass would require different restoration techniques compared to fast-growing species such as *Halodule wrightii* / *Ruppia maritima* dominated beds); injury length; sediment characteristics; seagrass percent cover (Braun-Blanquet); proximity to other injuries; and surrounding site attributes.

Seagrass injury widths were obtained every 5 m along the length of the injury for a total of at least three measurements ($\geq$ 15 m) to determine average width. If an injury was greater than

50 m in length, the length of the injury was divided by 10, and widths were measured at the resulting product interval to provide a total of at least 10 measurements. If the injury was less than 15 m in total length, the field team took a minimum of three width measurements – one at each endpoint and one in the middle. Measurements at the endpoints were taken 1 m from the visible edge of the injury. The field team used a PVC L-shaped device marked with 10 cm increments along both the vertical and horizontal axes. These measuring devices were constructed of at least one-inch schedule 40 PVC and were at least two meters along the vertical axis and half a meter along the horizontal axis. This allowed for measurement from both the vessel and *in situ*. Widths were easily measured by direct placement of the horizontal end of the "L" across the injury.

Injury depth was measured by recording depth in the center of the injury and subtracting it from the depth measured in the undisturbed seagrass immediately adjacent to the injury at the same measurement location. Depth and habitat data for each injury as well as other notable features were recorded within the 'comments' section of the Trimble file. However, the data were also recorded on hard copy data sheets.

All of the injury data and characteristics described above were identified to allow for more precise and informed decision making regarding alternatives for restoration and prioritization of sites. Examples of data collected from the scars and blowholes are provided in the supporting/supplemental table.

Post reconnaissance imagery analysis verification

Locations of candidate scars for restoration were re-analyzed to confirm that those injuries were not present before response activities were initiated.

Results

Originally, 189 polygons (3,455 acres) were identified as candidate sites for boat survey. After review of available high-quality imagery, 88 polygons (66 with observed damage and 22 control or error-correction) were surveyed, covering 554 acres, which reduced survey efforts (84% reduction), saving time and money.

The data collected on scar characteristics (e.g., age of scar and location) during reconnaissance identified a total of 73 candidate scars and/or blowholes across the northern Gulf of Mexico. The total injured area for scars and/or blowholes across the impacted area totaled 876 square meters (Table 1). Of those 73 scars and/or blowholes, 16 were recommended for restoration based on the criteria above (see supplemental data for individual scar/blowhole data). The remaining injuries did not fit our criteria for restoration (e.g., scars less than or equal to 15cm deep and sites dominated by *H. wrightii*, which are assumed to recover quickly without intervention), and were considered no-action injuries.

Reconnaissance of error-correction polygons verified the accuracy of the aerial imagery analysis to identify candidate sites of seagrass scarring, for none of the 22 error-correction polygons showed any signs of scarring or blowholes. Pre-oil spill imagery, where available and of high enough quality, verified that the injuries of the candidate scars were not present prior to DWH oil spill response activities with one exception in St. Andrews Bay, Florida, where a polygon was previously highly scarred. It was agreed that the best action for this polygon was staking the complete area to reduce impacts from boating and allow natural recovery of seagrass.

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Tables

Table 1. Summary of scar and blowhole injury by location attributed to *Deepwater Horizon* oil spill response action

Location	State	Total Scar Area (m^2)	Total Blowhole Area (m^2)	Total injured Area (m^2)
Grand Bay	Mississippi/Alabama	4	-	4
Big Lagoon	Florida	54.3	87.2	141.5
Perdido Bay	Alabama	8.3	11.8	20.1
Santa Rosa Sound	Florida	335.6	27.7	363.3
Choctawhatchee Bay	Florida	56.6	4.8	61.4
St. Andrews Bay	Florida	157.6	13.7	171.3
Apalachee Bay	Florida	68.2	24.2	92.4
St. George Sound	Florida	15.3	5.4	20.7
St. Joseph Bay	Florda	1.3	-	1.3
	Total Area (m^2)	701.2	174.8	876