2014 INTERNATIONAL OIL SPILL CONFERENCE

Three Years of Shoreline Cleanup Assessment Technique (SCAT) for the *Deepwater Horizon* Oil Spill, Gulf of Mexico, USA

Jacqueline Michel, Zachary Nixon, William Holton, and Mark White
Research Planning, Inc., 1121 Park Street, Columbia, South Carolina 29201 USA

Scott Zengel
Atkins, 2639 North Monroe Street, Building C, Tallahassee, Florida, 32303 USA

Frank Csulak, Nicolle Rutherford, and Carl Childs
National Oceanic and Atmospheric Administration, Office of Response and Restoration, 7600 Sand Point Way, NE, Seattle, Washington, 98115 USA

ABSTRACT 299884:

The oil from the 2010 *Deepwater Horizon* spill in the Gulf of Mexico was documented as stranding on 1,773 kilometers (km; 1,102 miles) of shoreline as of May 2013. Of the shorelines oiled, beaches comprised 50.8%, marshes 44.9%, and other shoreline types 4.3%. One year after the spill began, oil remained on 830 km; two years later, oil remained on 685 km and three years later, oil remained on 632 km, with 74% of the shoreline classified as trace (<1%) oiling degree. Shoreline cleanup activities were authorized on 660 km, or 73.3% of oiled beaches. Because the oil stranded over a three-month period and at a period in time when the beaches were in a relatively eroded condition, the oil became deeply buried and posed many challenges to its removal. The continued remobilization of oil buried in both intertidal and nearshore habitats resulted in the chronic re-oiling of sand beaches at trace levels for over three years, thus the slow rate of decline in the shoreline oiled lengths. Treatment of sand beaches in the first year focused on use of mechanical beach cleaners and excavation and sifting of deeply buried oil to minimize clean sediment removal. Later treatments were mostly manual except for mechanical excavation of deeply buried oil in Louisiana beaches in 2012 and 2013. Passive, manual, and mechanical treatments were authorized on 71 km, or 8.9% of oiled marshes and associated habitats, though actual treatment was conducted in smaller zones within these segments. Intensive marsh cleanup treatments were limited to ~1-2% of oiled marshes Gulf-wide and focused on areas with thick persistent marsh oiling. The Shoreline Cleanup Assessment Technique (SCAT) Program was the most complex and long lasting of any past spill. The SCAT Program evolved as needed to support the changing requirements and many challenges over the duration of the response. Many of the tools and products developed and used will be of value for future spill responses.

INTRODUCTION:

The *Deepwater Horizon* oil spill began on 20 April 2010 and was finally capped on 15 July 2010, resulting in the release of 4.09 million barrels into the Gulf of Mexico, excluding an estimated 810,000 barrels that were directly recovered from the wellhead, thus not released to the Gulf (McNutt et al. 2011). A Shoreline Cleanup Assessment Technique (SCAT) Program was established on 28 April 2010 as part of the Environmental Unit under the Planning Section and will end when all segments are moved out of the emergency response sometime in 2014. The

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

shoreline response program went through four stages of response (Michel et al. 2013), with a detailed plan for each stage that described the process for conducting shoreline inspections, issuing shoreline treatment recommendations (STRs), inspecting against habitat-specific cleanup endpoints, moving to the next stage of the response, and eventually to determining that removal actions were deemed complete.

STAGES OF THE RESPONSE:

During the *Deepwater Horizon* spill response, up to 18 SCAT teams, consisting of Federal, State, local, and BP representatives, conducted field surveys to document the location, degree, and character of shoreline oiling using standard methods and terminology (NOAA, 2013; Owens and Sergy, 2000). The shoreline response program encompassed four stages, defined primarily to recognize changes in oiling threat, oiling conditions, progression through cleanup operations, and seasonal factors as summarized below:

<u>Stages I/II Nearshore and Shoreline Response Plan</u>: The first two stages of the response (May to September 2010) covered the period during which oil continued to strand onshore. Stage I activities involved on-water recovery of floating oil slicks in nearshore waters. Stage II activities involved the initial cleaning of bulk oil from intertidal areas until the source was controlled. To minimize the impact of clean-up operations, comprehensive shoreline cleanup activities were deferred until free-floating oil on the surface waters was reduced to a minimal level and the risk of shoreline oiling was diminished. As such, SCAT shoreline surveys during this stage were rapid and focused on locating floating oil adjacent to the shoreline and stranded bulk oil for immediate removal, especially where such oil could remobilize and spread to other areas.

<u>Stage III Shoreline Treatment Implementation Framework</u>: Once source control was assured and the bulk of free-floating oil had been recovered or was stranded on shore, response activities entered the third stage of shoreline cleanup operations. During this period (September 2010 to March 2011), detailed SCAT surveys were conducted of all shorelines within the Area of Response. Site- and habitat-specific STRs generated within the SCAT Program and approved by the Unified Command were issued for each shoreline segment or group of segments where treatment was authorized, specifying the area and types of treatment operations to be conducted. Technical working groups were formed to reach consensus on appropriate cleanup methods and “2010 No Further Treatment (NFT) guidelines” for each habitat type. It was realized that additional shoreline treatment would be required over time; however, the goal was to complete the majority of active cleanup operations by Spring 2011, when shoreline use by nesting birds, sea turtles, and people increased. Treatment of amenity beaches included intensive sifting, excavation, and manual removal methods. An intensive treatment strategy was developed and refined for marsh areas with thick persistent oiling. Response actions involved raking and cutting to remove oiled vegetation mats, oiled wrack, and residual surface oiling using manual and mechanical teams (Zengel and Michel 2013).

<u>Stage IV Shoreline Response Plan</u>: This stage (March to November 2011) started with a resurvey of all affected shorelines to document Spring 2011 conditions and determine the need for further cleanup to meet “2011 NFT guidelines,” which were similar to those in Stage III. New Stage IV STRs were issued for shorelines requiring treatment. When shoreline segments

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

met the 2011 NFT guidelines, they were moved from active response into a Patrol and Maintenance status because of the risk of : exposure of buried oil by wind erosion; re-oiling from remobilization of subsurface oil as a result of beach erosion; and remobilization of oil in nearshore submerged mats and on marsh platforms. Stage IV was scheduled for completion by the end of the 2011 hurricane season in the Gulf of Mexico.

Shoreline Cleanup Completion Plan (SCCP): This final stage of the shoreline response (November 2011 and forward) defined the process whereby removal actions would be deemed complete and shoreline segments could be moved out of the response. For the first time in this response, a pathway was defined to determine that shoreline treatment was completed in a particular area. The shoreline-oiling conditions documented by SCAT teams were compared against shoreline cleanup "endpoints." Once a segment met these final criteria (Tables 1and 2; which were very similar to the prior NFT guidelines), the segment was removed from active response. The SCCP required surveys of selected shoreline segments after the 2011 Atlantic hurricane season, and multiple post-treatment surveys of segments to assure that oiling conditions continued to meet endpoints. Segments that did not meet endpoints were returned to Operations for further treatment, and the inspection process was repeated.

The SCAT Program managed all of the field data collected by SCAT teams using a Microsoft Access database linked to mapping software (ArcGIS). A large team of SCAT Data Managers conducted data entry and quality assurance, tracked the status of 4,397 shoreline segments, generated a wide range of daily to weekly products to meet the demands of the response, and supported the development of 280 STRs during Stages III and IV (exclusive of many revisions).

RESULTS:

Key metrics that are closely watched during an oil spill response include the lengths of shoreline by oiling category over time to gauge the response progress. Of the 7,044 km of shoreline surveyed as of May 2013 (Table 3), 1,773 km (1,102 miles) were oiled at some point during this incident, based on the maximum oiling (the maximum extent and heaviest oiling category recorded for each shoreline segment tracked during the response). Of this, 977.2 km (607 miles) were sand beaches and 795.8 km (494 miles) were marshes and mangroves. The majority of this oiling was in Louisiana with 1,074.5 km of oiled shoreline (60.6% of shoreline oiling in this incident). Florida had 285.6 km (16.1%); Mississippi had 258.5 km (14.6%); and Alabama had 154.5 km (8.7%) of impacted shoreline (Table 4, Figure 1). Based on maximum oiling across all states, 359.8 km (20.3%) of the shoreline oiling were classified as Heavy, 222.3 km (12.5%) as Moderate, 636.8 km (35.9%) as Light, 322.1 km (18.2%) as Very Light, and 232.2 km (13.1%) as Trace. One year after the incident, 46.8% or 830 km of the 1,773 km of impacted shoreline still had some degree of oiling; after two years, 38.6% or 685 km remained oiled; and after three years, 35.6% or 632 km remained oiled. Heavy to moderately oiled shorelines had declined by 87.8% in one year, 95.9% in two years, and 96.2% by three years, compared to maximum oiling conditions (Table 3, Figures 2 and 3).

The shorelines in Florida, Alabama, and Mississippi were moved out of the *Deepwater Horizon* response in Spring 2013, and segments within Louisiana were moved out of response as "response actions are deemed complete." New reports of oil on these shorelines are made to the National Response Center, and USCG pollution investigators respond to determine if the oil is

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

from the *Deepwater Horizon* spill. These investigators recover the oil if feasible. If there is too much oil for them to recover, USCG notifies BP to respond if the oil is determined to be from the *Deepwater Horizon* spill or a cleanup contractor if it is not.

There were interesting patterns in the types of oil observed by SCAT teams over time. A new SCAT oil type was defined for “surface oil residue balls” (SRBs) and “surface oil residue patties” (SRPs). These oil types were broken up pieces of surface oil residues, semi-cohesive oil and sand mixtures that were 80-90% sand, that originally formed as larger surface oil residue mats or smaller fields of patchy surface oil residue. It was apparent over time that it was not appropriate to call them “tarballs” because SRBs and SRPs were not tar and were mostly composed of sand rather than oil (tar balls are mostly oil). Figure 4 shows the changes in distribution in surface oil types and thickness over time on beaches and marshes. On beaches, there was very little emulsified oil or “mousse” after the first summer and very little surface oil residue after the first year (other than SRBs and SRPs). SRBs became the dominant surface oil type as buried/nearshore mats continued to break up. On marshes, the dominant oil type in the first summer was mousse on the marsh surface and tarry coatings on the vegetation. However, over time, the mousse weathered into tarry coats and thicker (cover) surface oil residues, except where it was buried, trapped under oiled vegetation mats and wrack, or mixed into thick accumulations of fine organic material such as “coffee grounds.” The lack of change in surface residue on the marsh surface over the three-year period indicates that this type of oiling is persistent.

DISCUSSION:

The vast extent of the shoreline that required survey for the *Deepwater Horizon* oil spill, the eroded nature of the beaches at the time of oiling, the three months of continuous flow of oil, the fragile nature of the Louisiana coastline, tropical storms and hurricanes with associated storm surges, and wildlife and human use of the Gulf Coast, among others factors posed many challenges to the SCAT Program and the successful completion of shoreline treatment. Key challenges included the following:

1) Oil that initially stranded onshore for over three months when beaches were in an erosional condition, which resulted in deep burial as well as stranding very high in the supratidal zone (following tropical storms) where it could be buried by wind accretion. Over 100,000 pits, trenches, and augers holes were used to search for and delineate buried oil for removal through the end of 2013. Augers were mounted onto small tracked vehicles that could rapidly excavate sediment borings to 2.5 m depths for inspection.

2) Oil that mixed with sediments in the nearshore zone, which resulted in the accumulation of submerged oil mats (SOMs) that were difficult to locate and remove and caused chronic re-oiling as they were buried/exposed and broken up by wave action. These SOMs generated the evolution of what was called “Snorkel SCAT,” where teams worked in waist-deep water and used narrow spades (“sharp shooter” shovels) to excavate sediments to depths of up to 50 cm in a grid pattern to delineate areas for removal by long-arm excavators working from the shoreline. These Snorkel SCAT teams worked closely with Operations to refine areas for removal and confirm that all recoverable oil was removed.

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

3) Restrictions on use of mechanical treatment methods along some sand beaches, which limited the depth of removal actions and resulted in persistence of deeply buried oil for several years. The shoreline erosion and remobilization of oil on sand beaches after Hurricane Isaac crossed Louisiana in August 2012 led to the development of a renewed augering program to identify and removal buried oil from all tidal zones, resulting in the removal of 6.1 million pounds of oiled materials in Louisiana in 2013.

4) Cleanup endpoints on amenity beaches that specified “no visible oil” on the surface or in the subsurface sediments These endpoints, and the widely scattered distribution of oil residues in the beach sediments, led to the extensive use of mechanical equipment to excavate and sift sediments to depths of nearly 1.25 m during operations called “Deep Clean” and “Big Dig” in Florida and Alabama. All cleanup endpoints for a habitat also included “or as low as reasonably practicable considering the allowable treatment methods and net environmental benefit,” which was often used when removal amounts reached very low levels on amenity beaches.

5) Cessation of both cleanup operations and SCAT surveys during environmental stand-downs in 2011, 2012, and 2013 to avoid disturbance to nesting birds and sea turtles.

6) The need for multiple re-surveys of affected shorelines because of trigger points, such as the end of hurricane season or after environmental stand-downs or during the SCCP process.

7) Concerns about re-oiling from buried oil or SOMs resulted in a four-step final inspection process under the SCCP that included a pre-inspection to be scheduled at least 48 hours after treatment operations were terminated, a Shoreline Inspection Report-1 (SIR-1) scheduled at least 48 hours after the pre-inspection, a SCAT Monitoring survey within about 25 days later, and a final SIR-2 scheduled within 30 days of the SIR-1. However, weather and sea conditions often delayed completion of these surveys within the specified time periods, particularly in Louisiana where many segments had to be accessed by boat. If a segment failed any of these surveys or inspections and was returned to Operations for further treatment, the process was started over again. Eventually, SCAT teams were allowed, and even required, to “mitigate” oil that did not meet cleanup endpoints when feasible (or within certain limits); and Operations crews were assigned to the SCAT teams to assist in mitigation, again particularly in Louisiana where the amounts of oil removed during mitigation could involve hundreds of pounds of oiled materials. In contrast, in the Eastern states, the amounts of oil mitigated by SCAT teams were in the range of pounds or fractions of pounds during the SCCP inspection process.

One result of the challenges defined above was that reaching the defined cleanup endpoints was, in many places, extremely difficult. The degree of oiling rapidly declined over the first year of the response. Greater than 50% of the oiled shorelines had no oil observed one year after the response, and shorelines classified as having heavy to moderate oiling had declined by nearly 88%. However, over the next two years of the response, the decline in reported length of oiled shoreline slowed significantly with nearly 36% of the surveyed shorelines remaining in an oiled status three years after the spill. Cleanup efforts had not been reduced in the remaining oiled areas; rather the many challenges associated with the cleanup prevented the response from rapidly meeting the cleanup endpoints.

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

The SCAT program evolved as needed to support the changing requirements and many challenges over the nearly four years of the *Deepwater Horizon* response. Many of the tools and products developed and used in the response will be of value for future spill responses. However, it is important to recognize that each spill is unique, and SCAT need to remain flexible in scale and complexity according to the shoreline oiling conditions and response needs encountered during each incident.

ACKNOWLEDGMENTS:

The BP SCAT Program Managers over time included Richard Santner, Mary Cocklan-Vendl, Bea Stong, and Gary Hayward. The BP technical advisors/SCAT Coordinators included Ed Owens, Gary Mauseth, Andy Graham, Elliott Taylor, Greg Challenger, and Mike LaTorre. The BP SCAT data managers included Teresa Allard, Doug Reimer, and Alain Lamarche. All of them were key members of the SCAT Program and contributed to its success. BP SCAT team leaders and logistics personnel, state agency personnel from each state (LA, FL, AL, MS), and federal and state agency field representatives from USCG, NOAA, California Department of Fish and Game, other federal agencies, and federal contractors were all key members of the SCAT program.

REFERENCES:

McNutt, M., R. Camilli, G. Guthrie, P. Hsieh, V. Labson, B. Lehr, D. Maclay, A. Ratzel, and M. Sogge. 2011. Assessment of Flow Rate Estimates for the Deepwater Horizon / Macondo Well Oil Spill. Flow Rate Technical Group report to the National Incident Command, Interagency Solutions Group, March 10, 2011. Available at: http://www.doi.gov/deepwaterhorizon/loader.cfm?csModule=security/getfile&PageID=237763. Accessed 10 December 2013.

Michel, J., E.H. Owens, S. Zengel, A. Graham, Z. Nixon, T. Allard, W. Holton, P.D. Reimer, A. Lamarche, M. White, N. Rutherford, C. Childs, G. Mauseth, G. Challenger, and E. Taylor. 2013. Extent and degree of shoreline oiling: *Deepwater Horizon* oil spill, Gulf of Mexico, USA. PLoS ONE 8(6):e65087.

National Oceanic and Atmospheric Administration (NOAA). 2013. Shoreline Assessment Manual. 4th Edition. Seattle: NOAA Emergency Response Division. 65 pp. + appendices.

Owens, E.H. and G.A. Sergy. 2000. The SCAT Manual – A Field Guide to the Documentation

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

and Description of Oiled Shorelines (Second Edition). Edmonton, AB: Environment Canada. 108 pp.

Zengel, S. and J. Michel. 2013. *Deepwater Horizon* oil spill: salt marsh oiling conditions, treatment testing, and treatment history in northern Barataria Bay, Louisiana. U.S. Department of Commerce, NOAA Technical Memorandum NOS OR&R 42. 74 pp.

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

Table 1. Shoreline Cleanup Completion Program Cleanup Endpoints for the *Deepwater Horizon* Oil Spill for the Eastern States (Mississippi, Alabama, Florida).

<table>
<tr><th colspan="3">EASTERN STATES</th></tr>
<tr><th>Shoreline Type</th><th>Surface Oil</th><th>Subsurface Oil</th></tr>
<tr><td>Residential and Amenity Sand Beaches</td><td>No visible MC-252 oil,
<u>or</u>
as low as reasonably practicable, considering the allowed treatment methods and net environmental benefit</td><td>No visible MC-252 oil,
<u>or</u>
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
<tr><td>Non-Residential or Non-Amenity Sand Beaches</td><td>< 1% visible surface oil and oiled debris, and no surface residue balls >5 cm (~2 inches)
<u>or</u>
as low as reasonably practicable, considering the allowed treatment methods and net environmental benefit</td><td>No subsurface oil exceeding 3 cm (~1¼ inch) in thickness and patchy (<50%) distribution that is greater than Oil Residue,
<u>or</u>
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
<tr><td>Beaches in Special Management Areas (state and federal wildlife refuges, parks, wilderness areas)</td><td><u>Subject to direction of Special Area Managers</u>: <1% surface oil and oiled debris, and no surface residue balls >2.5 cm (~1 inch)
<u>or</u>
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td><td><u>Subject to direction of Special Area Managers</u>: No subsurface oil exceeding 3 cm (~1¼ inch) in thickness and patchy (<50%) distribution that is greater than Oil Residue,
<u>or</u>
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
<tr><td>USFWS Breton National Wildlife Refuge</td><td><1% surface oil and oiled debris,
<u>or</u>
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td><td>No removal of subsurface oil</td></tr>
<tr><td>Coastal Marshes and Mangroves</td><td colspan="2">- No flushable oil on the vegetation or soils
- No release of sheens that can affect sensitive resources
- No thick oil (TO = >1 cm) residues:
o at the edge of the marsh
o on beach/shell berm/overwash areas
o in the marsh interior, including isolated patches within the marsh
- No thick or pooled oil (TO) in the marsh interior or below the vegetation that cannot be accessed by other means
<u>or</u>
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
<tr><td>Man-made Structural Shorelines</td><td colspan="2">− No accessible oiled debris
− For non-amenity areas, no surface oil greater than Stain or Coat (>20 %) distribution
− No oil on surfaces that rubs off on contact
− In high public use or high visibility areas, no surface oil greater than Stain or 10% Coat distribution on solid surfaces
− In inaccessible or remote areas where oil removal was not possible because of safety restrictions or ecological/cultural restraints, oil no longer generates petrogenic sheens that can affect sensitive resources under all weather conditions
<u>or</u>
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
</table>

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

Table 2. Shoreline Cleanup Completion Program Cleanup Endpoints for the *Deepwater Horizon* Oil Spill for Louisiana.

<table>
<tr><th>Beach Type</th><th>Surface Oil</th><th>Subsurface Oil</th></tr>
<tr><td>Residential Beaches (e.g. Grand Isle and 100 yards on either side of the public access point on Elmers Island)</td><td>No visible oil that is MC-252,
or
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td><td>No visible MC-252 subsurface oil above stain,
or
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
<tr><td>Non-Residential Beaches (e.g. Grand Terre(s), East Timbalier) and Non-Federal Special Management Areas (e.g. South Pass, Whiskey Island)</td><td>< 1% distribution of oil and oiled debris,
or
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td><td>No subsurface oil exceeding 2.54 cm in thickness and patchy (<50% distribution) that is greater than Oil Residue,
or
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
<tr><td>Beaches in Federal Special Management Areas (e.g. Chandeleur Islands)</td><td>< 1% surface oil and oiled debris,
or
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td><td>No attempt to remove subsurface oil</td></tr>
<tr><td>Coastal Marshes and Mangroves</td><td colspan="2">No flushable oil on the vegetation or soils
No release of heavy, persistent sheen that can affect sensitive resources
No thick oil residues at the edges of: The marsh or The beach/shell berm/overwash areas
No thick or pooled oil in the marsh interior, including isolated oiling patches within the marsh
No more thick or pooled oil in the marsh interior or below the vegetation
No oil that is sticky to fur and feathers
or
as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
<tr><td>Man-made Structural Shorelines</td><td colspan="2">No accessible oiled debris
For non-amenity areas, no surface oil greater than Stain or Coat >20 % distribution
No oil on surfaces that rubs off on contact
In high public use or high visibility areas, no surface oil greater than Stain or 10% Coat distribution on solid surfaces
In inaccessible or remote areas where oil removal was not possible because of safety restrictions or ecological/cultural restraints, no longer generates petrogenic sheens that can affect sensitive resources under all weather conditions
Or as low as reasonably practicable considering the allowed treatment methods and net environmental benefit</td></tr>
</table>

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

Table 3. Summary lengths (kilometers) of oiled shoreline by time period and oiling descriptor.

Length (km)	Total Surveyed[1]	Heavy	Moderate	Light	Very Light	Trace	Total Oiled	No Oil Observed
Max. Oiling	7,058	360	222	637	322	232	1773	5,285
One Year	6,948	24.7	59.3	170	141	461	855	6,093
Two Years	7,039	6.4	17.4	91.9	83.1	486	685	6,355
Three Years	7,044	7.5	14.9	63.9	79.9	466	632	6,412

[1] Changes in lengths reflect both revisions to the shoreline and additional surveys over time

[2] "No oil observed" means, based on the SCAT surveys, the shoreline was never oiled.

Table 4. Detailed shoreline oiling lengths (kilometers) by state, habitat, date, and oiling category. "No oil observed" means that, as of the last survey date within the period the shoreline was not oiled. For these later periods, the shoreline might have been previously oiled and the oil subsequently removed by cleanup actions and/or natural processes.[1]

State	Habitat	Time	Total Surveyed	Heavy	Mod-erate	Light	Very Light	Trace	Total Oiled	No Oil Observed
LA	Beaches	Maximum	425.2	86.4	33.2	90.9	42.9	42.8	296.2	129.1
		May-2011	497.0	2.4	5.3	44.9	9.9	92.5	154.9	342.1
		May-2012	521.1	0.5	0.5	8.9	3.9	124.2	137.9	383.1
		May-2013	530.2	0.6	0.4	9.1	3.8	129.7	143.6	386.7
	Wetlands	Maximum	4697.7	134.7	169.1	202.8	222.8	24.9	754.2	3943.5
		Mar-2011	4424.2	17.7	38.1	69.4	107.8	25.3	258.4	4165.8
		May-2012	4494.3	1.8	3.6	58.2	64.0	34.2	161.9	4332.4
		May-2013	4522.6	2.8	2.8	39.2	60.8	35.0	140.6	4382.0
	Other	Maximum	174.6	8.6	4.5	3.0	5.8	2.2	24.1	150.5
		May-2011	114.1	0.0	0.3	2.3	1.1	3.9	7.7	106.5
		May-2012	117.5	0.0	0.0	1.1	0.5	0.8	2.4	115.2
		May-2013	83.8	0.0	0.0	1.1	0.5	0.0	1.5	82.2
	All	Maximum	5297.5	229.7	206.8	296.7	271.5	69.9	1074.5	4223.0
		May-2011	5035.3	20.2	43.8	116.5	118.8	121.7	420.9	4614.4
		May-2012	5132.9	2.3	4.1	68.2	68.3	159.3	302.2	4830.7
		May-2013	5136.7	3.4	3.2	49.4	65.1	164.7	285.8	4850.9
MS	Beaches	Maximum	220.2	17.8	9.4	127.9	15.2	19.3	189.6	30.6
		May-2011	101.0	0.0	0.0	3.2	0.2	52.0	55.5	45.5
		May-2012	101.7	0.0	0.0	1.3	0.0	48.7	50.0	51.7
		May-2013	102.3	0.0	0.0	0.0	0.0	35.5	35.5	66.8
	Wetlands	Maximum	129.9	0.1	1.5	20.4	8.5	1.0	31.5	98.3
		May-2011	198.0	0.0	0.0	1.2	0.5	7.0	8.7	189.3
		May-2012	198.0	0.0	0.0	0.0	0.0	6.8	6.9	191.1
		May-2013	187.4	0.0	0.0	0.0	0.0	4.9	4.9	182.5
	Other	Maximum	127.2	0.5	2.9	11.1	17.7	5.1	37.3	89.9
		May-2011	67.5	0.0	0.0	0.2	1.7	4.0	5.9	61.7
		May-2012	67.5	0.0	0.0	0.2	0.9	3.9	4.9	62.6
		May-2013	75.6	0.0	0.0	0.2	0.9	2.3	3.4	72.2

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

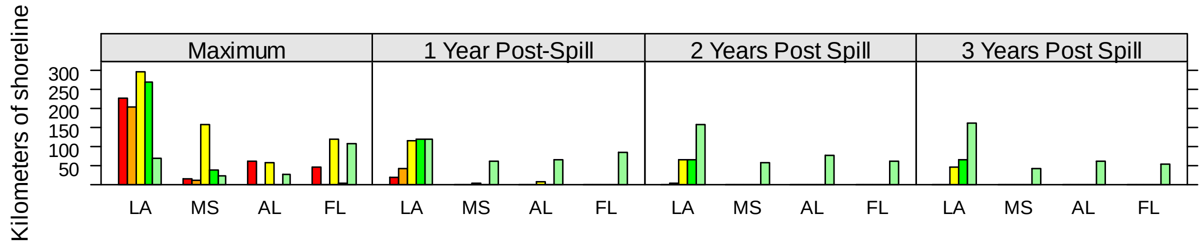
State	Habitat	Time	Total Surveyed	Heavy	Mod-erate	Light	Very Light	Trace	Total Oiled	No Oil Observed
	All	Maximum	477.3	18.4	13.9	159.4	41.4	25.4	258.5	218.8
		May-2011	366.5	0.0	0.0	4.7	2.4	63.0	70.0	296.5
		May-2012	367.2	0.0	0.0	1.5	0.9	59.4	61.8	305.4
		May-2013	365.3	0.0	0.0	0.2	0.9	42.8	43.9	321.5
AL	Beaches	Maximum	141.8	61.7	0.7	46.6	0.0	23.2	132.3	9.5
		May-2011	132.5	0.0	0.0	8.8	0.0	61.5	70.4	62.1
		May-2012	132.5	0.0	0.0	0.9	0.0	66.7	67.6	64.9
		May-2013	129.6	0.0	0.0	0.0	0.0	59.4	59.4	70.2
	Wetlands	Maximum	101.6	0.0	0.4	4.0	1.4	4.4	10.1	91.5
		May-2011	177.0	0.0	0.0	1.3	0.2	0.9	2.4	174.6
		May-2012	168.1	0.0	0.0	0.0	0.0	3.8	3.8	164.3
		May-2013	156.8	0.0	0.0	0.0	0.0	2.8	2.9	153.9
	Other	Maximum	198.1	0.5	0.6	8.4	1.4	1.2	12.1	186.0
		May-2011	83.1	0.0	0.0	0.5	1.4	5.4	7.4	75.7
		May-2012	83.1	0.0	0.0	0.0	0.0	6.6	6.6	76.5
		May-2013	97.4	0.0	0.0	0.0	0.0	2.3	2.3	95.1
	All	Maximum	441.5	62.2	1.7	59.0	2.7	28.9	154.5	287.0
		May-2011	392.6	0.0	0.0	10.6	1.6	67.8	80.2	312.4
		May-2012	383.7	0.0	0.0	0.9	0.0	77.0	77.9	305.7
		May-2013	383.8	0.0	0.0	0.0	0.0	64.5	64.5	319.3
FL	Beaches	Maximum	615.4	49.3	0.0	121.0	5.6	106.4	282.2	333.2
		May-2011	473.9	0.0	0.0	0.0	0.2	80.4	80.6	393.3
		May-2012	473.9	0.0	0.0	0.0	0.0	61.2	61.2	412.7
		May-2013	483.7	0.0	0.0	0.0	0.0	50.9	50.9	432.8
	Wetlands	Maximum	138.3	0.0	0.0	0.0	0.0	0.0	0.0	138.3
		May-2011	184.8	0.0	0.0	0.0	0.0	0.0	0.0	184.8
		May-2012	184.8	0.0	0.0	0.0	0.0	0.0	0.0	184.8
		May-2013	158.4	0.0	0.0	0.0	0.0	0.0	0.0	158.4
	Other	Maximum	87.6	0.1	0.0	0.8	1.0	1.5	3.4	84.2
		May-2011	113.1	0.0	0.0	0.0	0.0	4.4	4.5	108.7
		May-2012	113.1	0.0	0.0	0.0	0.0	3.4	3.4	109.7
		May-2013	129.7	0.0	0.0	0.0	0.0	4.0	4.0	125.8
	All	Maximum	841.3	49.4	0.0	121.8	6.5	107.9	285.6	555.7
		May-2011	771.8	0.0	0.0	0.0	0.2	84.8	85.1	686.8
		May-2012	771.8	0.0	0.0	0.0	0.0	64.6	64.6	707.2
		May-2013	771.9	0.0	0.0	0.0	0.0	54.9	54.9	717.0
ALL[2]	Beaches	Maximum	1402.7	215.3	43.3	386.3	63.7	191.7	900.3	502.4
		May-2011	1442.4	6.9	20.6	93.6	26.6	405.6	553.2	889.2
		May-2012	1469.3	4.5	13.8	32.1	17.7	423.9	492.1	977.3
		May-2013	1483.1	4.7	12.1	23.4	17.6	410.9	468.8	1014.3

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

State	Habitat	Time	Total Surveyed	Heavy	Mod-erate	Light	Very Light	Trace	Total Oiled	No Oil Observed
	Wetlands	Maximum	5067.5	134.8	171.0	227.2	232.6	30.3	795.9	4271.6
		May-2011	5125.9	17.7	38.4	73.3	110.0	36.5	276.1	4849.8
		May-2012	5187.1	1.9	3.7	58.5	64.0	47.7	175.8	5011.3
		May-2013	5172.1	2.8	2.8	39.2	60.9	45.8	151.5	5020.6
	Other	Maximum	587.5	9.7	8.0	23.4	25.8	10.1	76.9	510.5
		May-2011	379.9	0.0	0.3	3.0	4.2	17.9	25.6	354.3
		May-2012	383.3	0.0	0.0	1.3	1.4	14.7	17.3	366.0
		May-2013	388.6	0.0	0.0	1.2	1.4	9.1	11.7	376.9
	All	Maximum	7057.7	359.8	222.3	636.8	322.1	232.1	1773.1	5284.5
		May-2011	6948.2	24.7	59.3	170.0	140.9	460.0	854.9	6093.3
		May-2012	7039.7	6.4	17.4	91.9	83.1	486.3	685.2	6354.6
		May-2013	7043.8	7.5	14.9	63.9	79.9	465.8	632.0	6411.8

[1]Shoreline oiling along the Texas coast was surveyed only once and using a slightly different approach, with a reported 58 km of trace oiling.
[2] All state totals include Federal lands not included in state subtotals.

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023



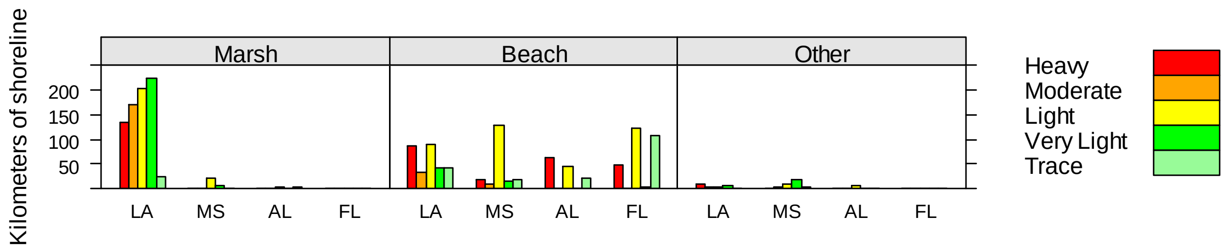


Figure 1. Length of oiled shoreline by maximum oiling and years 1, 2, and 3 post spill, by state and degree of oiling for the *Deepwater Horizon* oil spill (top); length of oiled shoreline under maximum oiling by shoreline habitat type, state, and degree of oiling (bottom)

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

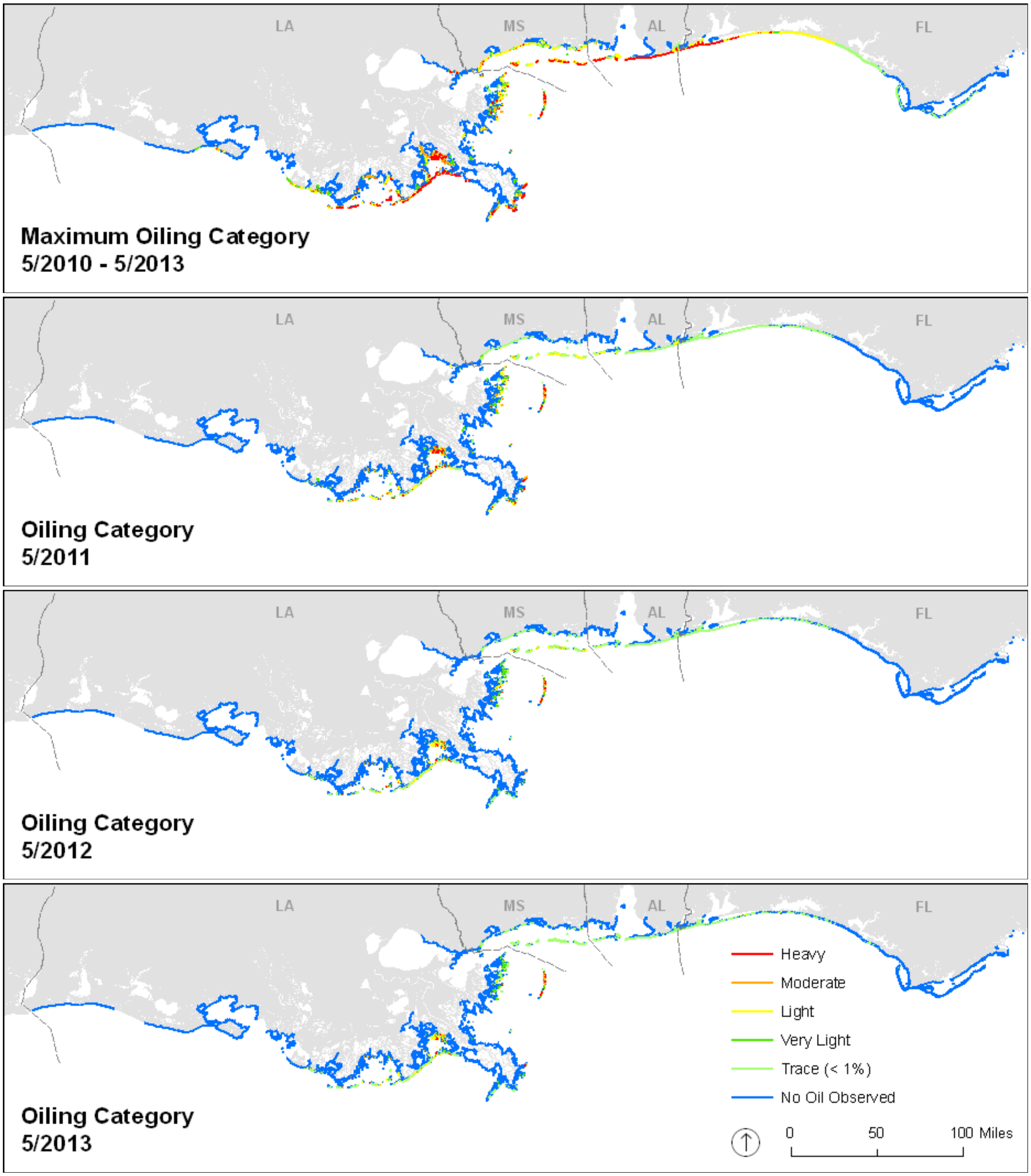


Figure 2. Maps showing the extent of oiled shoreline by maximum oiling and 1, 2, and 3 years post spill, by degree of oiling for the *Deepwater Horizon* oil spill. "No oil observed" means that, as of the last survey date within the period the shoreline was not oiled. For these later periods, the shoreline might have been previously oiled and the oil subsequently removed by cleanup actions and/or natural processes.

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

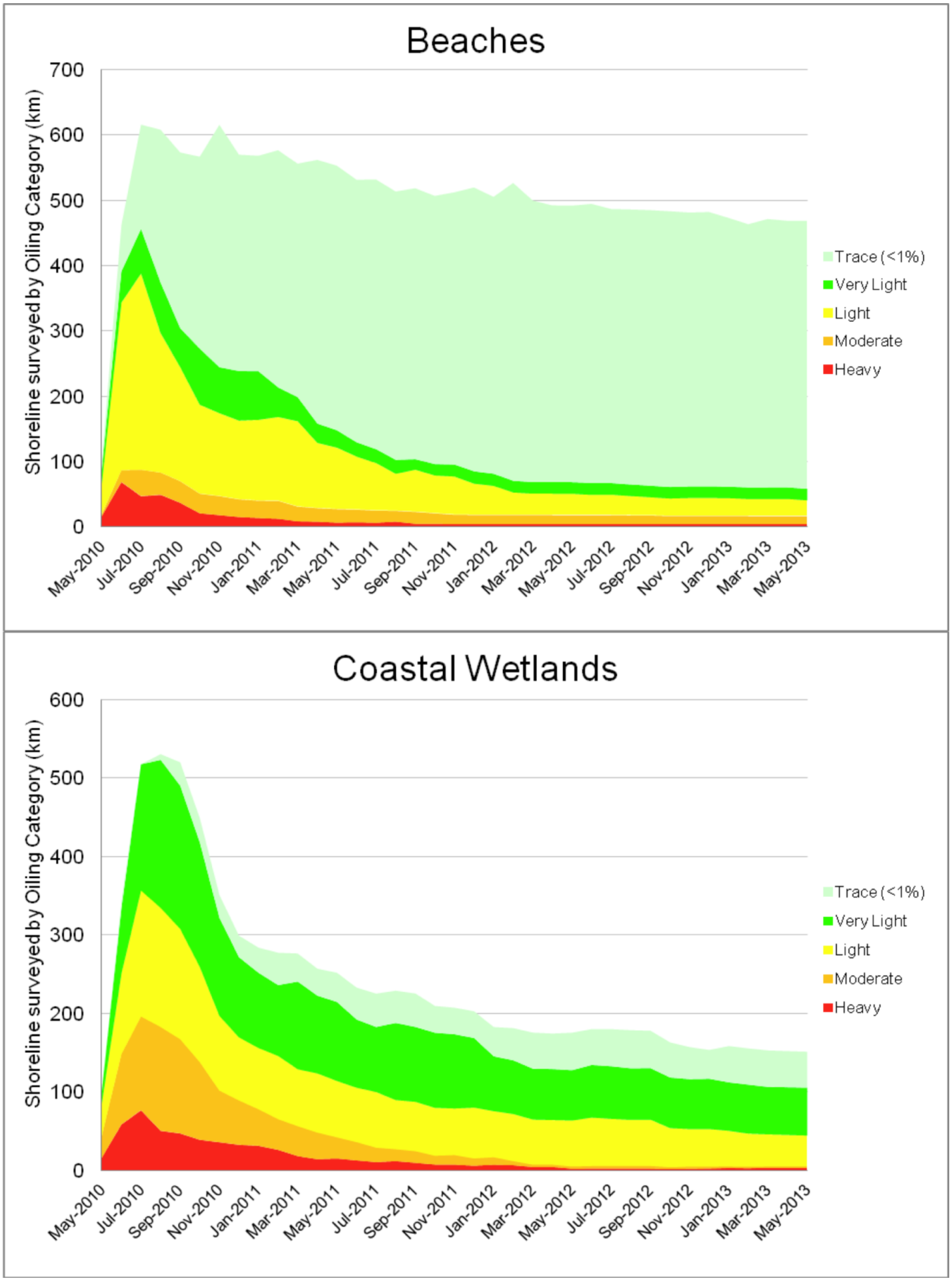


Figure 3. Times-series plot of the kilometers of oiled shoreline by oiling category and habitat type for the *Deepwater Horizon* oil spill.

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023

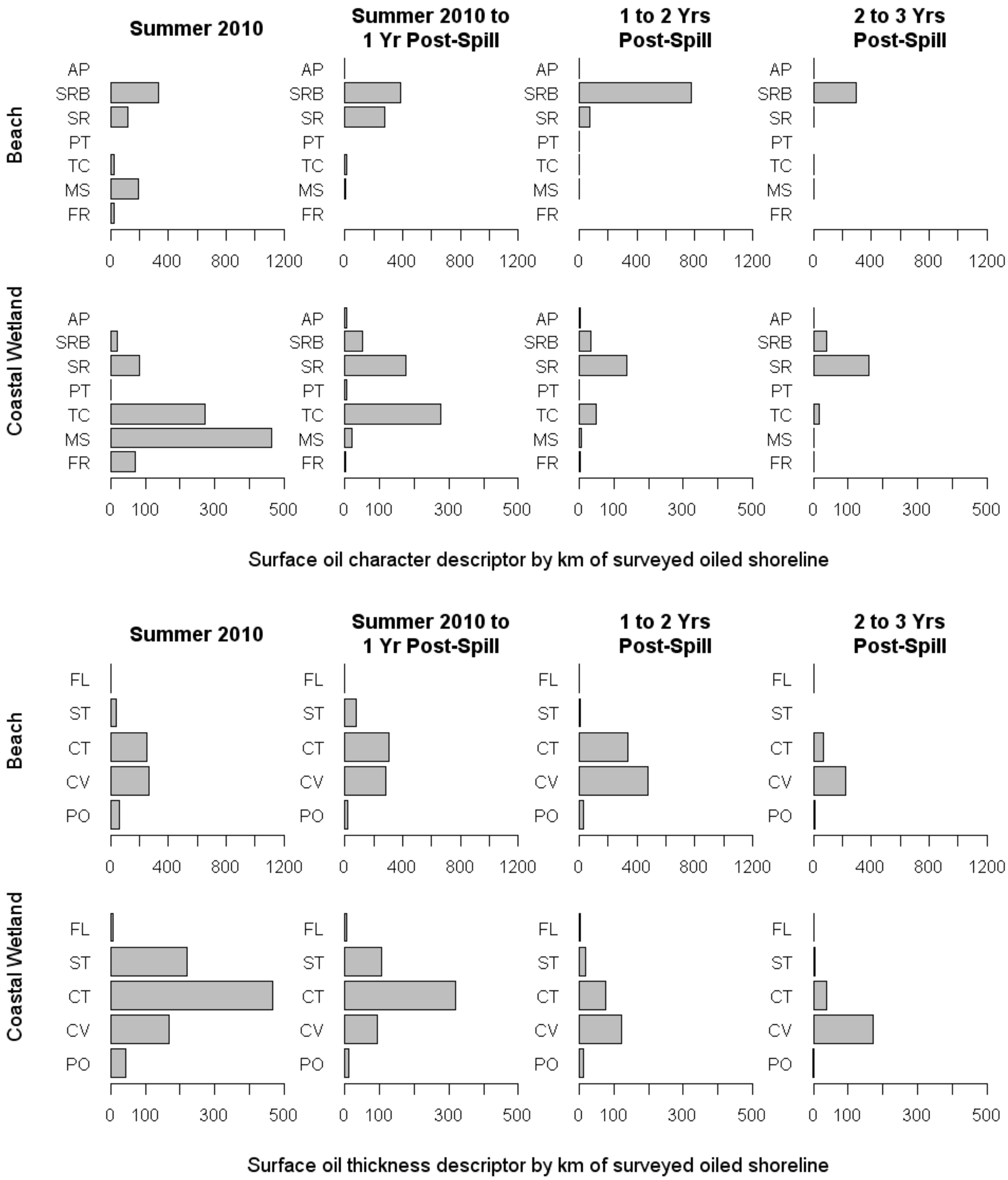


Figure 4. Temporal changes in oil type and thickness on beaches and marshes affected by the *Deepwater Horizon* oil spill. Surface oil character abbreviations: AP = asphalt pavement; SRB = surface residue balls; SR = surface residue; TB = tarballs; PT = patties; TC = tar; MS = mousse; FR = fresh oil. Surface oil thickness abbreviations: PO = pooled or thick oil (> 1cm); CV = cover (≤1 to 0.1 cm); CT = coat (visible oil <0.1 cm, can be scrapped off with fingernail); ST = stain (visible oil, cannot be scrapped off with fingernail); FL = film (transparent or iridescent sheen, or oily film).

Downloaded from http://meridian.allenpress.com/iosc/article-pdf/2014/1/1251/1754258/2169-3358-2014_1_1251.pdf by guest on 09 June 2023