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Deepwater Horizon/Mississippi Canyon 252 Oil Spill Natural Resource Damage Assessment Technical Report:

Quantification of Nearshore Avian Mortality using the Shoreline Deposition Model and Lost at Sea Factor

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1. INTRODUCTION

The *Deepwater Horizon* / Mississippi Canyon (MC 252) Oil Spill began in late April 2010 in the northern Gulf of Mexico. The Natural Resource Trustees for the management and protection of avian resources, including the Department of the Interior, U.S. Fish and Wildlife Service and National Park Service, and the states of Florida, Alabama, Mississippi, Louisiana, and Texas implemented a number of studies to evaluate oil spill-related injuries to birds.

The Trustees used various methodologies to quantify avian injury resulting from the DWH spill, such as methods to specifically quantify fledgling losses (USFWS 2015a, USFWS 2015b), losses after September 30, 2010 (USFWS 2015c), and offshore avian injuries (IEc 2015a). This report describes the methodologies used to estimate avian mortality in the nearshore environment of the northern Gulf of Mexico (nGOM), that the Trustees were able to quantify. Oil was continually released into the nGOM from the DWH spill beginning on April 20, 2010 and until the well was capped on July 15, 2010. Oil remained in the nGOM and impacted shorelines after the well was capped. During this time, birds were exposed to, and killed by, DWH oil.

Both live and dead birds were collected during DWH spill response and Natural Resource Damage Assessment (NRDA) wildlife search efforts. Dead birds were collected to document avian injury resulting from the DWH spill, and live birds were collected for the purpose of cleaning and rehabilitation. Bird searches began on April 20 and continued through September 30, 2010, the date when wildlife response activities began to curtail.

The number of birds collected during any spill response is usually less than the total number of birds that died, and such is true for the DWH spill. There are several reasons the number of birds collected during a spill does not represent the total number of birds that died, including: 1) wildlife searchers cannot find every carcass or injured bird along the shoreline (i.e., *searcher efficiency* is not 100%); 2) not all of the birds remained on the shorelines to be found by searchers because, for example, they may have been scavenged by predators (i.e., *carcass persistence* is not 100%); 3) not all birds that may have died out at sea are pushed by wind and water currents to the shoreline to be found by searchers (i.e., *carcass drift* and decomposition impact the number of birds deposited on shorelines); and 4) wildlife searchers are unable to search the entire length of shoreline every day of a spill (i.e., *search effort* coverage spatially and temporally is not 100%).

The Shoreline Deposition Model (SDM) uses information on the number of dead and live debilitated birds collected, along with area-specific information on searcher efficiency, carcass persistence, and search effort to estimate the total number of spill-impacted birds that deposited on beach and marsh edge shoreline in the nGOM. A Lost at Sea Factor (that adjusts for carcass drift and the likelihood that a dead or dying bird on open water would deposit on a shoreline) is applied to SDM results to estimate the total mortality occurring in the nGOM nearshore environment. Together, the SDM and Lost at Sea Factor were used to estimate the quantifiable nearshore avian mortality from the time the spill began through September 30, 2010.

This report explains how the SDM and Lost at Sea Factor were applied to the DWH spill. Section 2 below describes background information, Section 3 provides additional information on the SDM data inputs, Section 4 provides information on various parameters used in the SDM, Section 5 describes the SDM analysis, Section 6 describes the birds lost at sea analysis, and Section 7 provides the results and discussion.

2. BACKGROUND

The Trustees used the SDM and Lost at Sea Factor to estimate the quantifiable avian mortality in the nearshore environment of the nGOM. "Nearshore" was defined as the area that begins at the beach or marsh edge and extends 40 km from the shore. The mortality that occurred further than 40 km from the shoreline (i.e., offshore) was estimated using different methodology (IEc 2015a). Additional exposure to oil and potential mortality occurred within the interior marsh (Wallace and Ritter 2015) and within colonies (Baker *et al.* 2015). The Trustees recognize that, while not quantified, this additional mortality is potentially significant and necessitates additional restoration.

The calculation of total quantifiable nearshore avian mortality includes both, a) the total number of birds deposited along nGOM shorelines, which is estimated using bird deposition rates (carcasses/km) modeled by the SDM, as well as, b) the total number of birds lost at sea in nearshore waters of the nGOM, which is estimated using a Lost at Sea Factor. The nearshore avian mortality estimate described in this report covers April 20 through September 30, 2010 across the nGOM shoreline from the southernmost tip of Texas to the southernmost tip of Florida.[1]

To estimate the number of carcasses depositing per km (i.e., carcass deposition rate), the SDM applies the standard equations published in Ford *et al.* 1987, Page *et al.* 1990 and Ford *et al.* 2009. It also relies on site-specific data on the dead and live birds collected between April 20 and September 30, 2010 as part of NRDA and spill response efforts (*DWH Collected Birds Dataset*) as well as information on the associated wildlife searches that occurred during that timeframe (*DWH Wildlife Search Effort Dataset*). In order to organize the search and bird collection data geographically for analysis in the SDM, the nGOM shoreline within the model area was delineated into discrete segments, each segment consisting of a section of shoreline with the same habitat type (*DWH SDM Segment Dataset*).

To estimate birds lost at sea, the Trustees used information from a carcass drift study conducted as part of the NRDA (Ford *et al.* 2014). Specifically, the Trustees used information on how bird carcasses drifted in the nearshore waters and the likelihood of a carcass stranding along the nGOM shoreline (IEc 2015b). The SDM data inputs, parameters, drift analysis, and deposition rate calculations are described in more detail below.

[1] The area modeled by the SDM covers the nGOM shoreline from approximately Galveston Bay, Texas to Apalachicola Bay, Florida but birds found further south in Texas and Florida on the GOM side are added to the total to calculate the total avian nearshore mortality.

3. SDM DATA INPUTS

This section discusses the primary data inputs for the SDM, including, birds collected, shoreline segments, and search effort.

BIRDS COLLECTED

Data on the birds collected during spill response efforts is one of the primary data inputs used by the SDM. The Trustees collected birds through two separate efforts across the nGOM: 1) searches conducted by Wildlife Operations personnel operating under the Unified Command; and 2) searches conducted as part of NRDA bird studies specifically geared towards estimating mortality using techniques such as the SDM. Both dead and live birds were collected during these searches and are included in the *DWH Collected Birds Dataset*.

The Trustees verified and validated the *DWH Collected Birds Dataset* according to the guidelines provided in the *U.S. Department of the Interior Deepwater Horizon Natural Resource Damage Assessment Procedures for Cooperative Data Verification and Validation* (USDOI 2013). Additional information regarding the *DWH Collected Birds Dataset* and the data review process is provided in the Data Verification and Validation Report (IEc 2015c).

After the data review process was completed, there were 8,905 birds in the dataset (5,810 dead birds and 3,095 birds collected alive). A number of birds were excluded from the SDM for the reasons described below, and after these exclusions, the SDM relied on data from 7,508 of the collected birds (4,660 dead and 2,848 birds collected alive).

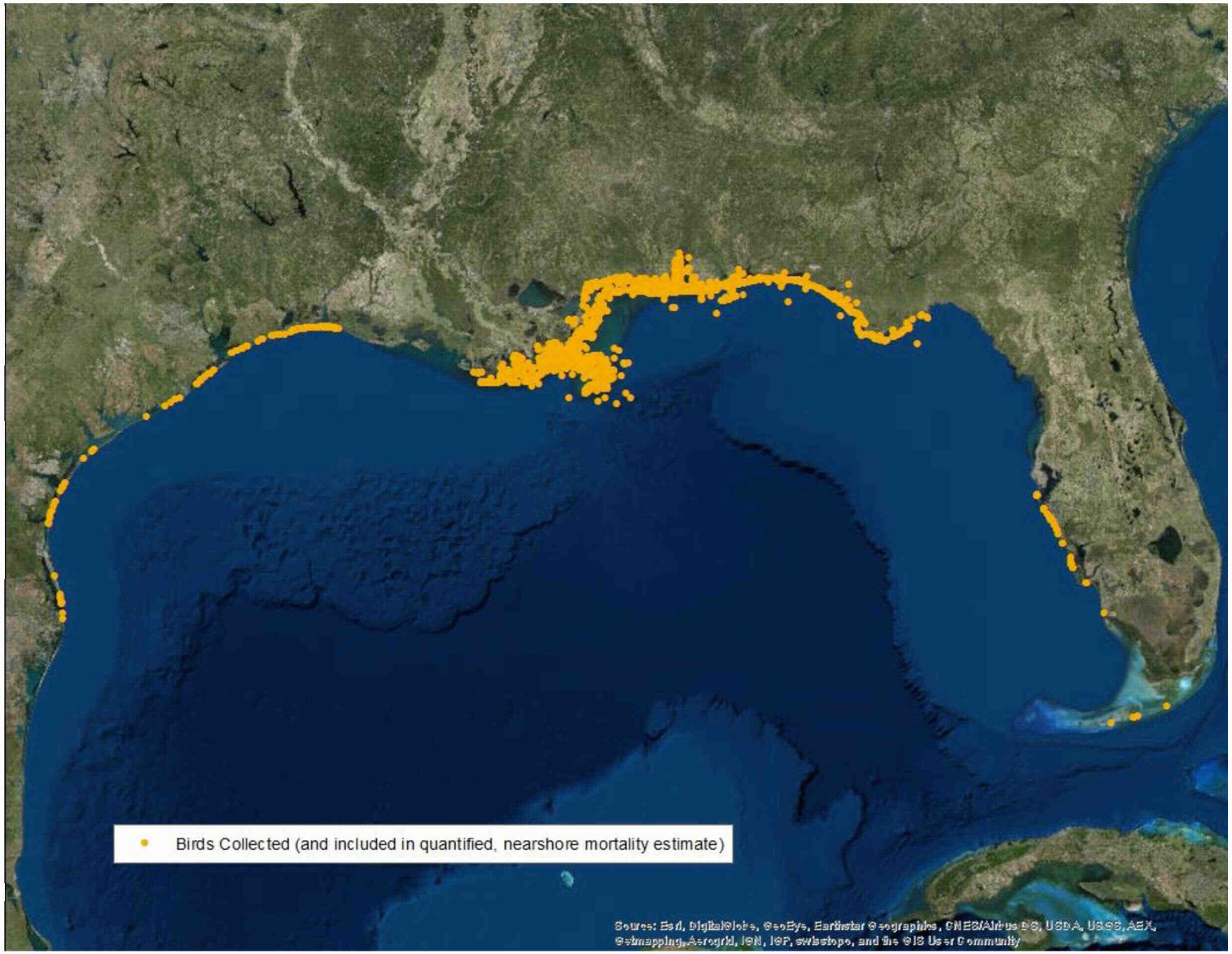
- 99 birds were excluded from the SDM because they were assumed to have died or been captured due to non-spill related reasons (48 dead and 51 live collected birds). For example, some birds were collected after being hit by a car. Since these birds were not killed due to the DWH oil spill, it is inappropriate to include them in the SDM.
- 45 dead birds were excluded from the SDM because they were not found as part of any of the wildlife searches described above, but were captured as part of specific DWH NRDA studies that attached radio transmitters to the birds, released them back into the wild, and tracked their subsequent survival. Since these birds were collected using the radio signals and searcher efficiency was very high, it is inappropriate to include them in the deposition rate calculations. These birds are simply added to the total avian mortality results from the SDM since they represent spill related mortalities (see Section 5, SDM Analysis).
- 219 birds were excluded from the SDM because they were collected after September 30, 2010 (208 dead and 11 live collected birds). The SDM is used to estimate avian mortality only through September 30, 2010 since search effort data is limited after this date. The Trustees used other methods to estimate mortality after September 30, 2010 (USFWS 2015c).
- 215 birds were excluded from the SDM because they were collected from outside of the SDM area (181 dead and 34 live collected birds), such as the east coast of

Florida. Because these birds were collected from areas far away from the spill-impacted area, the birds are less likely to have been associated with the DWH oil spill and are therefore excluded from modeling.

- 637 dead birds were excluded from the SDM because they were collected from colonies during the time "colony sweep" efforts occurred. Wildlife Operations conducted a number of searches specific to colonies (referred to as "colony sweeps") between August 28 and September 13, 2010, during which carcasses from the interior areas of colonies were collected. Because these carcasses were collected during searches that were conducted in the *interior* of colony islands, rather than along the shoreline, they do not fit a requisite of the SDM and were excluded. Searcher efficiency and carcass persistence values specific to the interior of breeding colonies, necessary for the SDM, were also unavailable. More information on the "colony sweeps" is provided in USFWS 2015d.
- 35 birds were excluded from the SDM because they were collected from offshore waters, greater than 40 km from the shoreline (9 dead and 26 live collected birds). The DOI has quantified injury to offshore birds using a separate methodology, as described in IEc 2015a. Therefore, these birds are excluded to avoid double counting.
- 147 birds had no associated location information (22 dead birds and 125 birds collected alive). Without information on where these birds were collected, they were unable to be included in the model. These birds are simply added to the total avian mortality results from the SDM since they represent spill related mortalities (see Section 5, SDM Analysis).

As summarized above, approximately 87 percent of the birds collected are utilized in the SDM. A map illustrating the collection locations of the 7,508 birds relied on for the SDM is provided in Figure 1.

FIGURE 1. DEAD AND LIVE, IMPAIRED BIRDS COLLECTED (AND INCLUDED IN QUANTIFIED, NEARSHORE MORTALITY ESTIMATE)



SHORELINE SEGMENTS

During spill response, the shoreline of the nGOM was divided into small stretches of land for response activities. NRDA wildlife searches, referred to as beached bird surveys, were conducted regularly along identified segments of the shoreline to collect dead birds. These NRDA searches were organized with the intention of collecting bird deposition information from samples of shoreline segments and using the bird collection data in a model to help estimate avian mortality. The NRDA shoreline segments were originally located along barrier islands, colony islands, and the mainland, and extended across much of the nGOM from south Texas to eastern Florida. As the spill and the NRDA beached bird surveys progressed, search teams were directed to avoid colony islands (to avoid disturbing nesting birds) and the segments in eastern Florida were abandoned (as it became apparent that DWH oil was not impacting this area). Concurrent with NRDA searches, Wildlife Operations personnel operating under the Unified Command for response efforts also conducted searches during which live and dead birds were collected. Wildlife Operations searches were not confined to a certain suite of shoreline segments like the NRDA teams. Searches in the marsh habitat were conducted by boat, and almost exclusively by Wildlife Operations personnel. Often, but not always, Wildlife Operations teams searched and collected dead birds on the same NRDA segments as the NRDA teams.

Shoreline segments are used by the SDM to organize bird collection and search data geographically. The *DWH SDM Segment Dataset* contains information on each of the shoreline segments used in the SDM. This includes segments defined as part of the NRDA wildlife searches described above, segments searched by Wildlife Operations personnel as well as additional segments that were delineated to ensure the shoreline in the nGOM relevant to the SDM was included in the model. Shoreline segments were delineated regardless of whether a specific segment was ever searched for birds, to enable the SDM to address spatial data gaps (further explained in Section 5, SDM Analysis). The *DWH SDM Segment Dataset* contains 7,342 segments, representing a total of 12,507 km of shoreline (Table 1). The development of the *DWH SDM Segment Dataset*, how segments were delineated, and the verification and validation of the dataset are described in the associated Data Verification and Validation Report (IEc 2015d).

Because searcher efficiency and carcass persistence vary with habitat, the segments were delineated such that they include only one habitat type. All beach segments are assigned "beach" as the habitat type (a total of 1,784 km), and marsh segments were assigned either "*Phragmites*" (998 km) or "*Spartina*" (8,093 km), depending on the dominant vegetation type. If an area of marsh habitat could not be identified as either "*Phragmites*" or "*Spartina*", the segment was assigned a generic "marsh" as the habitat type (1,214 km). These designations allow the SDM to apply the habitat-specific searcher efficiency and carcass persistence values, listed in Tables 2 through 5 below, to the birds collected from a given segment and to estimate a segment-specific carcass deposition rate. Shoreline areas that are comprised of riprap or other manmade structures were assigned the habitat type of "clad." Approximately 418 km of shoreline, or 3.3 percent of the total shoreline delineated, was classified as "clad" (Table 1). Because searcher efficiency and carcass persistence values were not available for clad, these segments are not analyzed in

the SDM. Birds collected on clad segments were treated the same way as birds that could not be geographically assigned to an SDM segment; this situation is described in more detail in Section 7, Model Results and Discussion (Birds Covered by the SDM).

Carcass deposition rates are estimated in the SDM over time intervals where consecutive searches of a segment occur on dates less than or equal to seven days apart (see Section 5, Usable Search Data discussion below for an explanation of this decision). During spill response efforts, there were segments that were searched infrequently (e.g., greater than seven days between searches) or not searched at all. In order to address some of these gaps in search effort information, the SDM extrapolated deposition data from modeled segments to nearby segments for which data were lacking (see Figure 3 and Section 5, SDM Analysis). To facilitate this process, segments were organized into 161 different Extrapolation Areas, contained within 20 Regions (Table 1).

SDM Regions designated as "offshore" (including Texas Offshore, Louisiana Offshore, Mississippi Offshore, Alabama Offshore, Florida Offshore, and Federal Offshore Waters) extend from the near shoreline to up to 40 km from the shore. These regions do not contain any shoreline segments (they contain only water) and are therefore not modeled in the SDM. They are however included as part of the nearshore avian injury quantification and any birds collected from these regions are added to the final SDM results. Mortality occurring further out to sea than 40 km from the shore was assessed using different methodology (IEc 2015a). Exposure and potential mortality occurring within the interior marshes was also assessed using additional methodologies (Wallace and Ritter 2015), as was exposure and additional mortality in colonies (Baker *et al.* 2015).

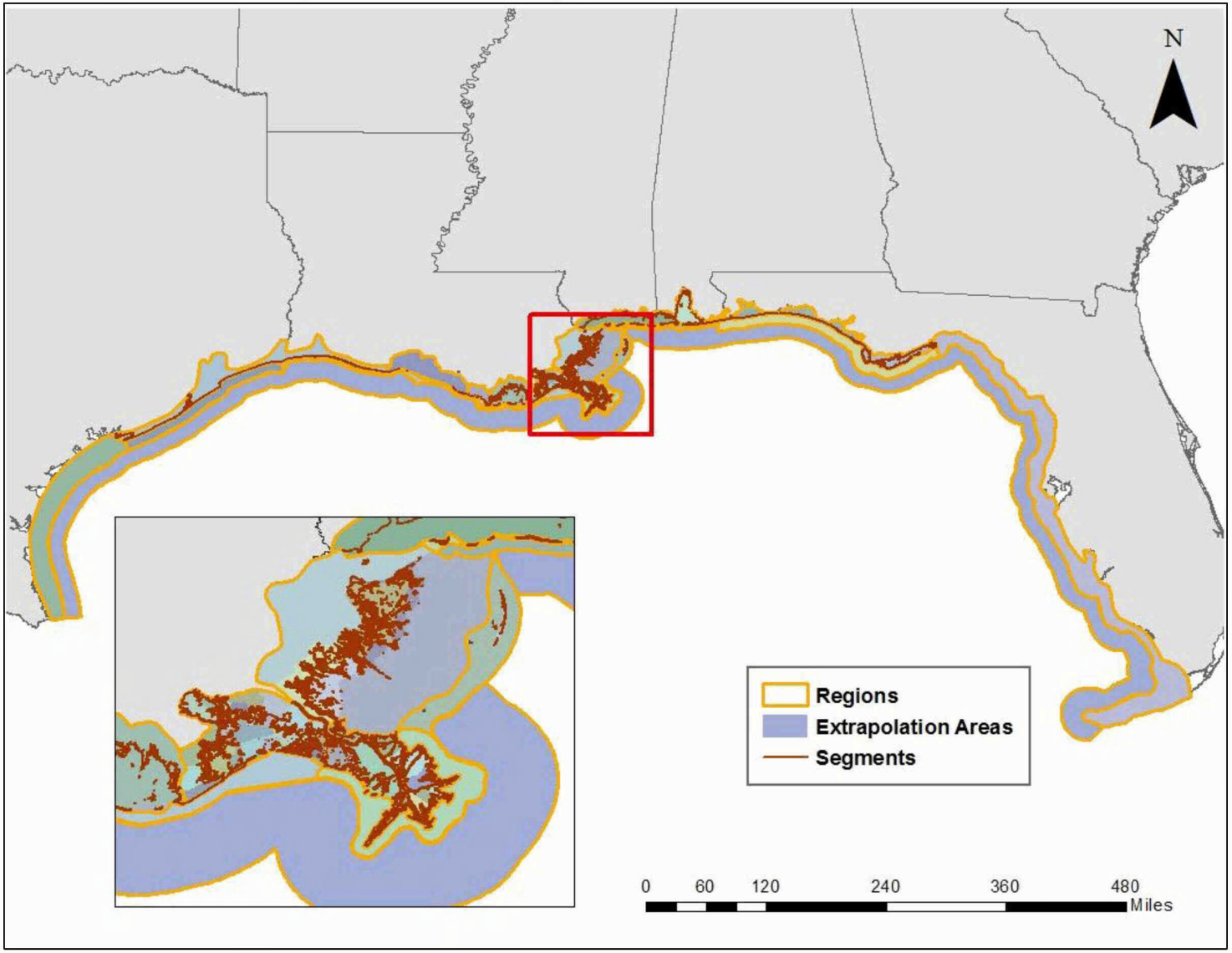
Table 1 presents the total length of shoreline segments from the *DWH SDM Segment Dataset* in each habitat type in each Region used in the SDM, and Figure 2 illustrates how the segments, Extrapolation Areas, and Regions are arranged across the nGOM. Additional information regarding the *DWH SDM Segment Dataset* is provided in the Data Verification and Validation Report (IEc 2015d).

TABLE 1. TOTAL LENGTH OF SHORELINE SEGMENTS BY HABITAT WITHIN EACH SDM REGION (KM)

SDM REGION	CLAD	BEACH	MARSH	PHRAGMITES	SPARTINA
TEXAS OFFSHORE	N/A	N/A	N/A	N/A	N/A
NORTH TEXAS-WEST LOUISIANA	30.84	405.38	273.66	0	24.34
LAKE MECHANT	0.32	2.46	0	0	22.42
TERREBONNE BAY	0	43.55	0	0	1408.88
BARATARIA BAY	22.23	76.02	0	0.21	2680.63
LOUISIANA OFFSHORE	N/A	N/A	N/A	N/A	N/A
BIRDSFOOT WEST	19.59	268.85	268.06	0	0
BIRDSFOOT EAST	14.22	42.57	0	701.67	666.33
BIRDSFOOT OUTER	220.33	20.73	0	295.25	478.88
BILOXI MARSH	26.48	16.86	0	0.4	2779.67
MISSISSIPPI-ALABAMA COAST	51.48	83.55	182.17	0	28.36
MISSISSIPPI-ALABAMA GULF ISLANDS	0	116.5	14.16	0	3.84
MISSISSIPPI OFFSHORE	N/A	N/A	N/A	N/A	N/A
MOBILE BAY SEASHORE	4.97	89.37	8.33	0	0
MOBILE BAY INTERIOR	7.92	82.75	167.36	0	0
ALABAMA OFFSHORE	N/A	N/A	N/A	N/A	N/A
PENSACOLA	0	101.59	0	0	0
APALACHICOLA WEST	0	165.01	32.68	0	0
APALACHICOLA EAST	19.59	268.85	268.06	0	0
FLORIDA OFFSHORE	N/A	N/A	N/A	N/A	N/A
FEDERAL OFFSHORE WATERS	N/A	N/A	N/A	N/A	N/A

Notes:
1) The following Regions are not included in the table above because data were insufficient to model them: South Florida, South Texas, Vermilion Bay and Breton-Chandeleur Islands. Vermilion Bay, Breton-Chandeleur Islands and part of Lake Mechant Regions are addressed separately in USFWS 2015e.
2) N/A means that there are no segments in that Region because there is no land in the Region (i.e., "offshore" Regions that include only water).

FIGURE 2. SDM SEGMENTS, EXTRAPOLATION AREAS, AND REGIONS ACROSS NORTHERN GULF OF MEXICO



Note: South Texas, Texas Offshore, and South Florida Regions are shown in the map above for completeness, but these regions have insufficient data to model using the SDM; instead birds found in these regions are simply added to the total. See Section 7, Model Results and Discussion.

SEARCH EFFORT

NRDA beached bird surveys and Wildlife Operations searches were conducted across the nGOM during the spill. These searches are documented in the *DWH Wildlife Search Effort Dataset* including the date, location, and length of the shoreline searched. The *DWH Wildlife Search Effort Dataset* was verified and validated according to the guidelines provided in the *U.S. Department of the Interior Deepwater Horizon Natural Resource Damage Assessment Procedures for Cooperative Data Verification and Validation* (USFWS 2013).

During the data review process, the location of each search was matched with segments of the nGOM shoreline. Different search teams sometimes referred to the shoreline they searched using different names, and sometimes search teams used only general descriptions to document the locations searched (i.e., rather than providing specific information on the segments searched). Therefore, determining which segments were covered by each documented search in the *DWH Wildlife Search Effort Dataset* required making various assumptions. For example, when a wildlife search team described searching "Dauphin Island", it was assumed that all shoreline segments comprising the perimeter of Dauphin Island were searched unless information was available to further define the specific search location.

In order to systematically determine the segments associated with each search, polygons were drawn in Google Earth software to define the boundary of each unique search location described by search teams. Boundaries for locations were drawn to best characterize the location described. For example, when a wildlife search team described searching "western Dauphin Island", a polygon covering only the western side of the island was drawn and therefore only the western segments were included. In general, this process likely overestimated searched locations more than underestimated. Because search teams sometimes recorded search locations only generally and additional information to help refine the search area was unavailable, all of the segments in the area described on field datasheets were assumed to have been searched (and the *DWH Wildlife Search Effort Dataset* contains one record for each segment assumed searched). This conservative approach may underestimate avian mortality because collected bird information could be attributed to more shoreline than was truly searched, as further described in Section 7, Uncertainties and Assumptions.

After assigning all applicable segments to each documented search, the *DWH Wildlife Search Effort Dataset* contained a total of 623,599 segment-searches (a "segment-search" is defined as one search of one segment on one day). After removing duplicates (i.e., multiple records of searches of the same segment on the same day), unidentified searches (i.e., searches in locations that could not be identified), and searches conducted during colony sweeps, there were 261,125 unique segment-searches that were included in in the SDM. Duplication accounted for most of this reduction and was largely due to the process described above for identifying the segments covered by a specific search as well as because searches were often described generally by the search teams, leading to significant overlap in the segments assigned to each search term.

Additional information regarding the *DWH Wildlife Search Effort Dataset* is provided in the Data Verification and Validation Report (IEc 2015e).

4. SDM PARAMETERS

This section discusses the searcher efficiency and carcass persistence parameters required to model mortality along shorelines and the application of these parameters in the SDM.

SEARCHER EFFICIENCY CONSIDERATIONS

An important factor influencing the number of carcasses or live birds collected on a given wildlife search is searcher efficiency. Searcher efficiency is the probability that a wildlife searcher would find a carcass or live bird on the shoreline where they are conducting a search (Byrd *et al.* 2009). There are a number of reasons a searcher may not see a dead or impaired live bird along a shoreline. For example, a bird's coloration may make it difficult to see along beaches due to shadowing or being caught up in the wrack line. Searchers in boats looking along a marsh edge may miss birds that are mixed in with the marsh vegetation or that are just under the surface of the water.

Searcher efficiency rates are inherently variable and depend upon a range of local factors, such as the degree of debris on the beach or the texture of the beach substrate (Van Pelt and Piatt 1995, Fowler and Flint 1997, Ford 2006, Byrd *et al.* 2009). Therefore, as part of the NRDA, the Trustees conducted studies in both marsh and beach habitats (Donlan *et al.* 2013a and Donlan *et al.* 2013b, respectively) to estimate DWH spill-specific searcher efficiency values by habitat. The Trustees placed bird carcasses along transects in beach and marsh habitat and documented the number of carcasses searchers were able to find. Searcher efficiency calculations are described in Varela *et al.* 2015a.

Searcher efficiency was different for the different habitat types (Varela *et al.* 2015a). It was easier for searchers to find bird carcasses on sandy beaches than along marsh edges (Tables 2 and 3). Similarly, in marshes, it was easier for searchers to find birds in *Phragmites*-dominated habitat as compared to *Spartina*-dominated habitat. As a result, searcher efficiency values are highest for beaches and lowest for *Spartina*-dominated habitat. The size and condition of the bird also had an impact on searcher efficiency; larger birds were easier to find than smaller birds, and intact or slightly scavenged birds were easier to find than heavily scavenged birds (Varela *et al.* 2015a).

Searcher Efficiency Values used in the SDM

For beach habitat, searcher efficiency values were calculated for two scavenging states and three size classes (Varela *et al.* 2015a). The scavenging states were: "Heavily scavenged", which included birds that were mummified or highly decomposed and "No/light scavenged", which included birds that were intact or lightly disturbed. The three size classes were: Small (<200g), Medium (200-500g), and Extra Large (>1000g) (Varela *et al.* 2015a). Because there were no large carcasses (>500g-1000g) used in the sandy beach searcher efficiency study, an average of the searcher efficiency values for extra large and medium carcass sizes was taken to calculate the searcher efficiency value for large carcasses.

A statistical analysis was completed on the searcher efficiency values and a standard error range was generated (discussed in detail in Varela *et al.* 2015a). We used the standard error range to calculate a high and low searcher efficiency estimate for each scavenging state and size combination (i.e., we added the standard error to the estimate for a high searcher efficiency value and subtracted the standard error from the estimate for a low searcher efficiency value). For the purposes of the SDM, a weighted average searcher efficiency value for beach was calculated for both high and low estimates using the proportion of birds collected in the various scavenged states and size classes along beaches from the *DWH Collected Birds Dataset*.[2] This provided low and high searcher efficiency estimates for sandy beach habitats.

A similar process was used to develop the searcher efficiency values used in *Spartina* and *Phragmites* marsh habitats. For both *Spartina* and *Phragmites* marsh habitats, searcher efficiency values were provided by the four size classes. Again, high and low estimates for searcher efficiency were calculated for each marsh habitat type and size combination by adding and subtracting the standard error from the estimate. A weighted average was then calculated using the proportion of birds collected in each size class from both marsh habitat types (using information from the *DWH Collected Birds Dataset* and *DWH SDM Segments Dataset*). This provided low and high searcher efficiency estimates for both *Spartina* and *Phragmites* habitat types. For areas where the habitat in the SDM could only be identified as marsh, an average of the *Phragmites* and *Spartina* values was used.

Searcher efficiency data for live birds were not available. The searcher efficiency rate for live birds is likely higher than that of dead birds since live birds are likely to have more of a vertical profile than dead birds and may still be able to move, catching the eye of a searcher. However, perfect searcher efficiency is unlikely. Therefore, for the purposes of the SDM, we assumed the searcher efficiency rates for live birds are half-way between 100% and the dead bird searcher efficiency values for each habitat type.

The high and low end searcher efficiency values used in the SDM are provided in the tables below.

[2] The *DWH Collected Birds Dataset* contains a data field that facilitates the identification of bird records associated with each size class and scavenged state, as well as which records were used in the SDM. Only those records pertaining to birds used in the SDM were relied on to determine the proportion of birds in various sizes and scavenging states. See the "data dictionary" for the *DWH Collected Birds Dataset* for additional information (IEc 2015c). The *DWH SDM Segments Dataset* was used to determine which records were found on beach segments.

TABLE 2. HIGH END ESTIMATES OF SEARCHER EFFICIENCY

	HABITAT TYPE			
	BEACH	MARSH	SPARTINA	PHRAGMITES
DEAD BIRDS	0.93	0.52	0.31	0.73
LIVE BIRDS	0.96	0.76	0.66	0.87
Values represent the weighted average of values specific to bird sizes and carcass conditions.				

TABLE 3. LOW END ESTIMATES OF SEARCHER EFFICIENCY

	HABITAT TYPE			
	BEACH	MARSH	SPARTINA	PHRAGMITES
DEAD BIRDS	0.79	0.33	0.18	0.48
LIVE BIRDS	0.90	0.67	0.59	0.74
Values represent the weighted average of values specific to bird sizes and carcass conditions.				

CARCASS PERSISTENCE CONSIDERATIONS

Another important factor influencing the number of carcasses collected on wildlife searches is the carcass persistence rate. Carcass persistence represents the probability a carcass will remain on a shoreline segment for a given period of time (Byrd *et al.* 2009). In order for a bird to be found, it must remain on a beach or along a marsh edge long enough for a person to find it. Bird carcasses disappear for a number of reasons, such as scavenging by other animals; burial by accumulations of marine debris, vegetation, or sand; or rewash back into the water. For example, on a beach, a dead bird may be taken away and eaten by a coyote; while in a marsh, a dead bird might be consumed by an alligator. Similarly, insects and other creatures such as crabs may consume the flesh from a bird carcass causing the bird to be less visible to a person trying to find it.

Because carcass persistence rates are variable and depend upon a range of local factors (Byrd *et al.* 2009, Ford and Zafonte 2009, Ford 2006, Fowler and Flint 1997), the Trustees conducted site-specific carcass persistence studies in beach and marsh habitats (Donlan *et al.* 2016 and Donlan *et al.* 2013a respectively). During these studies, the Trustees placed carcasses along the shoreline and revisited the carcass each day for up to 14 days to document the number of days before the carcass disappeared (i.e., no longer persisted).

Persistence rates varied over time, and bird carcasses were most likely available for a searcher to find on the first day it washed up on a beach or marsh edge. If a carcass remained on a beach for several days, only skeletal remains were often left, making it harder for searches to recognize the carcass. Bird carcasses disappeared at a faster rate soon after the bird was deposited for both sandy beaches and marsh edges, likely because

the carcasses are fresher (i.e., less scavenged) closer to the time the carcass is first deposited (Varela *et al.* 2015b). Bird carcasses also disappeared at a faster rate in marshes than on sandy beaches, and disappeared more quickly in *Phragmites*-dominated marsh habitat than *Spartina*-dominated marsh habitat (Varela *et al.* 2015b).

The likelihood that a carcass persists across the time period between two subsequent searches of a segment is a product of the probabilities that it persists for any given day after it was deposited. This persistence factor is then combined with the efficiency factor to calculate the likely number of deposited birds on a specific search, given the number of birds collected on that search. Since persistence values varied daily, the persistence to "Day X" was calculated as a function of the probabilities for each day.

Carcass Persistence Values used in the SDM

For beach habitat, daily carcass persistence values were calculated for each bird size class (Varela *et al.* 2015b). The size classes included the same Small, Medium, Large, and Extra Large size classes described above for searcher efficiency values. A similar statistical analysis was completed on the carcass persistence values and a standard error range was generated, as discussed in more detail in Varela *et al.* 2015b. We used the standard error range to calculate high and low carcass persistence values for each day after deposition for each size class (i.e., we added the standard error to the estimate for a high carcass persistence value and subtracted the standard error from the estimate for a low carcass persistence value). For purposes of the SDM, one weighted average value was calculated using the proportion of birds collected in each size class along beaches from the *DWH Collected Birds Dataset*.

For both *Spartina* and *Phragmites* habitats, carcass persistence values were calculated using the same approach as described above for beach habitats. For habitats defined generically as "marsh", daily persistence values were defined as the average value of *Spartina* and *Phragmites*.

Persistence values specific to live birds were not available. However, it is likely that a live bird could only be captured by response searchers if it was impaired and weakened due to oiling. Although still alive, it is unlikely that such a weakened bird would be able to successfully defend itself against predators. Therefore, it was assumed that a live, but impaired, bird would succumb to predators at the same rate as carcasses would succumb to scavengers, and that captured live birds would have soon died due to the spill had they not been captured for rehabilitation. Hence, the same carcass persistence values were used for dead and live birds in the SDM. The daily probability values of a carcass persisting on the shoreline after it has deposited are provided in Tables 4 and 5 below.

TABLE 4. HIGH END ESTIMATES OF CARCASS PERSISTENCE TO DAY X

	DAY	HABITAT TYPE			
		BEACH	MARSH	SPARTINA	PHRAGMITES
DEAD AND LIVE BIRDS	0	1.00	1.00	1.00	1.00
	1	0.81	0.59	0.63	0.56
	2	0.71	0.44	0.48	0.41
	3	0.65	0.37	0.40	0.34
	4	0.61	0.32	0.35	0.30
	5	0.57	0.29	0.32	0.27
	6	0.55	0.27	0.30	0.25
	7	0.53	0.26	0.28	0.24

TABLE 5. LOW END ESTIMATES OF CARCASS PERSISTENCE TO DAY X

	DAY	HABITAT TYPE			
		BEACH	MARSH	SPARTINA	PHRAGMITES
DEAD AND LIVE BIRDS	0	1.00	1.00	1.00	1.00
	1	0.64	0.33	0.42	0.24
	2	0.50	0.18	0.26	0.10
	3	0.43	0.11	0.18	0.05
	4	0.38	0.08	0.13	0.03
	5	0.34	0.06	0.10	0.02
	6	0.31	0.05	0.08	0.01
	7	0.29	0.04	0.07	0.01

5. SDM ANALYSIS

The underlying equations and methodology utilized by the SDM have been applied to multiple oil spills to estimate avian mortality, such as the *Apex Houston*, the *Jacob Luckenbach*, and the *Cosco Busan* (Page *et al.* 1990, Ford *et al.* 2006, Ford *et al.* 2009). The SDM was developed based on these previous efforts and utilized site-specific data collected as part of the DWH NRDA and response efforts.

Inherent in the SDM calculations are a number of assumptions, including the assumption that the dead birds collected from shorelines deposit on those shorelines because they died along the shoreline or died in the water and washed ashore. The SDM also assumes that these carcasses persist on the shoreline for a period of time and at a rate equal to the carcass persistence rates. Further it assumes that wildlife searchers have a probability of finding a bird on the shoreline that is equal to the searcher efficiency rate. Finally the

SDM assumes that the daily deposition rate of carcasses and injured birds is constant between searches.

The sections below describe the following steps utilized in the SDM:

1. Define the spatial (e.g., nGOM as defined by the *DWH SDM Segment* dataset) and temporal (e.g. April 20 to September 30) scope of the model.
2. Analyze the *DWH Wildlife Search Effort* dataset to identify the number of usable search intervals (within all of the Extrapolation Areas) for each segment.
3. Identify the number of carcasses and live birds collected from the corresponding segment during each usable search interval.
4. Estimate the daily carcass and live bird deposition rate (carcasses/km) for each useable search interval using the number of carcass or live birds collected and the appropriate searcher efficiency and carcass persistence values.
5. For each day of the model period, calculate an average deposition rate for each habitat type in each Extrapolation Area using the daily deposition rates calculated for segments within useable search intervals. Any days without model coverage receive a value of 0.
6. For each day, multiply the average deposition rate per habitat by the total length of segments of that habitat type in each Extrapolation Area to determine the total daily carcass/live bird deposition for that day.
7. Aggregate these daily Extrapolation Area values to determine the total deposition over the model time period.

GEOGRAPHIC AND TEMPORAL SCOPE

The SDM estimates the total number of birds that died in the nearshore environment of the nGOM from April 20 to September 30, 2010. The nGOM encompasses over 10,000 kilometers of shoreline (beach and marsh edge). Any of these areas might be a location where a sick or impaired bird lands or a dead bird washes up. The SDM models the area from approximately Galveston Bay, Texas to Apalachicola, Florida. Birds collected farther west to the southernmost tip of Texas and farther east to the southernmost tip of Florida are not modeled, due to insufficient data, but are included in the total avian mortality estimate (as shown in Figure 2). A number of offshore Regions are shown in Figure 2; however, since these Regions do not contain any shoreline (i.e., are all water, with no land), they are not modeled in the SDM and instead any dead or live impaired birds collected from these Regions are simply added to the SDM results. Additionally, due to insufficient data, the Vermilion Bay and Breton-Chandeleur Islands Regions are not modeled in the SDM, but are addressed using a different methodology (USFWS 2015e).

The SDM covers a time period of 163 days, starting when the spill began on April 20, 2010 through the 87 days when oil was spilling into the nGOM (July 15, 2010), and until NRDA searches ceased (September 30, 3010). The SDM only estimates mortality over time periods for which there is sufficient data on wildlife searches (see Usable Search

Data discussion below). After September 30, 2010, there is insufficient search data to accurately determine avian mortality using the SDM.

USABLE SEARCH DATA

The more frequently searches were conducted in a given area, the more information is available to the SDM related to the number of birds depositing along the shoreline. Long time intervals between searches can result in an inaccurate estimation of the deposition rate (number carcasses deposited/km on a given day). For example, as the time interval between searches increases, it becomes more likely that carcasses could have beached and been removed between subsequent shoreline searches leading to an underestimation of the deposition rate, which assumes all carcasses that deposited between subsequent searches are available to be found. Therefore, the SDM includes data only for searches that are seven days or less apart to allow for a more accurate estimation of the deposition rate (Ford *et al.* 2009).

The SDM also requires three sequential search dates that are each less than or equal to seven days apart to create one "usable search interval." For example, if searches of a segment were conducted on June 1, June 6, and June 12, the SDM considers these searches as one "usable search interval" since June 1 and June 6 are less than or equal to seven days apart and June 6 and June 12 are less than or equal to seven days apart. The SDM requires three search dates in order to more accurately estimate the number of birds that deposited on the shoreline between searches. Because not all birds deposited on the shoreline will be found by wildlife searchers, and because these un-found birds have some likelihood of persisting and being found on a subsequent search, the SDM uses searcher efficiency and carcass persistence values from Tables 2 through 5 above to determine the number of birds that a searcher missed during the first part of the useable search interval (e.g., June 1 to June 6) that were found during the second portion of the useable search interval (e.g., June 6 and June 12). This estimated number of birds is then subtracted from the number of birds collected on June 12 before the model estimates the deposition rate over the time interval between June 6 and June 12. If the SDM did not account for this phenomenon, it would overestimate the deposition rate between June 6 and June 12.

ESTIMATING THE TOTAL CARCASS DEPOSITION (SPATIAL EXTRAPOLATION)

As noted previously, the deposition rate calculations in the SDM are based on published equations (Ford *et al.* 1987, Page *et al.* 1990 and Ford *et al.* 2009) and used to calculate the deposition rate for all dates in the second half of useable search intervals. The deposition rate equation takes into account: 1) the number of birds collected from a segment that was searched; 2) the number of birds that were missed during the previous search of the same segment; 3) the persistence of bird carcasses over the length of time between consecutive searches; and, 4) the searcher efficiency value associated with the segment's habitat type.

A daily deposition rate is calculated for each segment on each day that is covered by a usable search interval. The average daily deposition rate (carcasses/km) across segments of the same habitat within each Extrapolation Area is then spatially extrapolated to all

segments of that habitat in the same Extrapolation Area to estimate total number of birds deposited in that Extrapolation Area on that day for the specific habitat (see Figure 3 below). The SDM aggregates the daily estimates of mortality within Extrapolation Areas to reach a total estimate of mortality over the modeled time period.

For example, if on May 11 there is a calculated deposition rate for three beach segments in the North Texas-West Louisiana Extrapolation Area, the daily deposition rates (carcasses/km) for the beach segments are added together and divided by 3. That average beach deposition rate is then applied to the length of all beach segments in the North Texas-West Louisiana Extrapolation Area for May 11. The same is done for the *Phragmites*, *Spartina*, and marsh segments, as applicable, using the associated average deposition rates per km. Once this calculation has been done for each habitat type within each Extrapolation Area for each day of the model period (April 20 to September 30), the modeled number of birds deposited on each day in each Extrapolation Area can be summed to generate an estimate of total avian mortality within a region (*SDM Results*, Tables 6 and 7).

FIGURE 3. EXAMPLE OF AN SDM EXTRAPOLATION AREA CALCULATION

Example of an SDM extrapolation calculation for the Mississippi-Alabama Gulf Islands extrapolation area on August 7, 2010.

The Mississippi-Alabama Gulf Islands Extrapolation Area illustrated above contains a total of 114 segments; 101 of the segments are dominated by beach habitat, 3 are dominated by *Spartina* habitat, and 10 are dominated by marsh habitat. Based on available search effort data, the SDM calculated deposition rates (carcasses/km) for 27 of the 114 shoreline segments in the Mississippi-Alabama Gulf Islands Extrapolation Area for August 7, 2010 (the segments highlighted in pink above).

Of these 27 segments, 25 were classified as beach habitat. To calculate the total number of birds that deposited on beach habitat in the Mississippi-Alabama Gulf Islands Extrapolation Area on August 7, the average of these 25 deposition rates was calculated (0.13 carcasses/km) and then multiplied by the total beach habitat length for that extrapolation area (116.5 km). As such, the SDM estimates that a total of 15.15 birds were deposited across the entire beach shoreline of the Mississippi-Alabama Gulf Islands Extrapolation Area on August 7.

Two segments (out of the 27 segments with usable search data) were classified as *Spartina* habitat. The average of their deposition rates was 0 (because no birds were collected from those segments during the associated shoreline searches). As such the SDM estimates that no birds were deposited on *Spartina* shoreline in the Mississippi-Alabama Gulf Islands Extrapolation Area on August 7.

Due to a lack of search effort data, the SDM did not calculate deposition rates for any of the marsh-dominated segments, and a value of 0 was assigned by default. These gaps in available data are one of the primary sources of underestimation in the SDM.

6. LOST AT SEA FACTOR

CARCASS DRIFT - LOST AT SEA FACTOR

The SDM estimates nearshore avian injury based on the number of birds deposited along shorelines. However, a number of nearshore birds were injured due to oiling and never deposited on the shoreline to be found; these can be considered "lost at sea." The number of birds lost at sea is an important part of the total avian mortality, and has been estimated in past spills including *Exxon Valdez* (Ford *et al.* 1996).

As part of the total nearshore avian mortality, we estimate and apply a lost at sea factor to account for those birds that were killed by the oil spill and never made it to the beach or marsh shoreline in the SDM area. The lost at sea factor is the probability of a dead bird becoming lost at sea versus washing ashore. In order to estimate the probability of a bird being lost at sea, the Trustees conducted a Carcass Drift Study (Ford *et al.* 2014). During this study, bird carcasses were deployed across the nGOM via planes and boats, and were tracked using radio telemetry to determine whether the carcasses washed ashore or were lost at sea. The likelihood that birds dying on the water would drift to shore was generally calculated as the total number of birds lost at sea divided by the total number of birds deployed. For this study, the probability of a bird lost at sea was calculated as 0.1551, and the lost at sea factor was calculated as 6.45 (1/0.1551). In other words, for every one bird that successfully drifted to shore, another 6.45 birds were lost at sea. This calculation is described in more detail in IEc 2015b.

In order to apply the Lost at Sea Factor to the SDM results, the portion of the SDM results that represents birds that died in open water and drifted ashore must be identified. During bird collection activities, live birds were collected from both the water and on land, and the location of the bird prior to capture was documented on field datasheets and recorded in the *DWH Birds Collected Dataset*. Since captured live birds represent birds that were so sick that they could not evade capture, it can be assumed that, had these birds not been captured for rehabilitation, they would have died at sea. For lack of better information, the proportion of live birds that were captured at sea, as opposed to captured on land, was used as a surrogate for the proportion of the SDM results that represents birds that originated at sea and were subject to potential at sea loss. Approximately 32 percent of the live-captured birds were captured in open water. Thus, 32 percent of the carcasses generated by the SDM were assumed to have originated in open water, and the Lost at Sea Factor was applied to this portion to identify the number of additional birds that likely died on the water but did not wash ashore.

After the SDM calculates the nearshore avian mortality estimate (*SDM Results*, Tables 6 and 7), we apply the lost at sea factor to the appropriate proportion of model results (as described above) to estimate the total number of additional birds that died on the water and did not wash ashore (*Birds Lost at Sea*, Tables 6 and 7).

7. MODEL RESULTS AND DISCUSSION

The total nearshore avian mortality estimate, able to be quantified by the Trustees, ranges from 39,763 to 59,634 birds. This range incorporates the SDM results, the estimated

number of birds lost at sea, and birds that were collected but not able to be modeled (Tables 6 and 7). The range does not include additional mortality associated with exposure to oil within the interior marshes (Wallace and Ritter 2015) or exposure to oil within some colonies (Baker *et al.* 2015). The range in results is based on using the low and high searcher efficiency and carcass persistence values as described in Section 4, SDM Parameters.

The results were translated into species-specific mortality estimates using the bird collections from the *DWH Collected Birds Dataset*. The proportion of birds collected in each species was calculated as described in USFWS 2015f. However, the species collected during wildlife searches includes species DOI is not including in their injury quantification (e.g., European starling). After excluding those species, bird injury quantification results are estimated as 38,923 to 58,414 birds (Table 8).

For summary purposes, we provide the results by region in Tables 6 and 7 and by species in Table 8. The list of species in Table 8 also excludes those species not included in DOI injury quantification. A discussion of the results and description of the data in Tables 6 and 7 is provided below.

BIRDS COVERED BY THE SDM

The *Birds Covered by the SDM* field in Tables 6 and 7 provides the total number of birds collected in Extrapolation Areas and on days that are being modeled. This includes both birds used by the SDM to calculate a deposition rate (i.e., birds collected on days and on segments in Extrapolation Areas for which there is sufficient search data to calculate a deposition rate) and birds that were collected in an Extrapolation Area and on a day that is being modeled but are not contributing to the deposition rate calculation.

In summary, all birds collected in an Extrapolation Area on a day that is modeled are considered covered by the SDM (and included in *Birds Covered by the SDM*, Tables 6 and 7). Birds that are covered by the SDM but do not contribute to a deposition rate includes those birds collected on an segment that did not have a usable search interval for that day, or from an area not utilized by the SDM (e.g., birds collected from inland or offshore areas not covered by a shoreline segment or birds collected from segments with a habitat type of "clad"). Since the SDM calculates total carcass deposition across all of the shoreline in each Extrapolation Area, all birds collected from the Extrapolation Area on a day that is modeled must be considered part of the birds modeled in the SDM to avoid any double counting.

SDM RESULTS

The SDM Results in Tables 6 and 7 provide the total number of modeled birds per Region, using the birds collected, searcher efficiency, carcass persistence, and search effort data. In essence this includes the sum of the SDM spatial extrapolation within each Extrapolation Area and day that has sufficient search data to model, as described in Section 5, Estimating the Total Carcass Deposition (Spatial Extrapolation).

BIRDS LOST AT SEA

The Birds Lost at Sea field in Tables 6 and 7 provides the total estimated number of birds lost at sea per Region calculated using the Lost at Sea Factor, as described in Section 5.

REGIONAL CORRECTION FACTOR (TEMPORAL EXTRAPOLATION)

As described above, in the Estimating the Total Carcass Deposition section, spatial extrapolation occurs within each Extrapolation Area defined as part of the SDM. However, a number of birds were collected within areas covered by the SDM, but were not modeled (*Birds Not Covered by the SDM*). This occurs because the birds were collected in an area and on a day that is not being modeled (i.e., on a day when there are no usable search intervals for a given habitat type within an Extrapolation Area). The SDM estimates mortality over time periods for which there is sufficient data on wildlife searches (see Usable Search Data discussion above). When usable search data is unavailable for a particular Extrapolation Area on a specific date, the Extrapolation Area is not modeled on that day. For example, if no usable search intervals cover beach habitat in Apalachicola East on June 17, then beach habitat in Apalachicola East is not modeled for June 17. There may have been searches where wildlife teams collected birds but did not record the search on a data form or there was not enough information from the search team to include the search in the *DWH Wildlife Search Effort Dataset*.

In order to fill in these gaps in search effort data, an average regional correction factor was calculated and applied to the birds that are not modeled. The average regional correction factor is calculated as the sum of *SDM Results* and *Birds Lost at Sea* divided by *Birds Covered by the SDM* (Tables 6 and 7). For example, for the low estimate in Apalachicola East, the correction factor is the *SDM Results* (221) + *Birds Lost at Sea* (383) divided by the number of *Birds Covered by the SDM* (66), or (221+383)/66 = 9.1. The number of *Birds Not Covered by the SDM* in Apalachicola East (15) was then multiplied by 9.1 to estimate additional birds that likely died in this region (15 x 9.1 = 137) (*Birds with Regional Correction Factor*).

NRDA STUDY BIRDS

As described above, 45 NRDA Study Birds were excluded from the SDM because they were collected as part of certain DWH NRDA telemetry studies (Cooper *et al.* 2010, NRDA Bird Study #3 and Evers *et al.* 2010, NRDA Bird Study #4). These birds included oiled birds that were deployed with transmitters to track their fates, and later died and were collected. Since these birds were collected by using the transmitters to hone in on their locations (i.e., were not collected on wildlife searches), the associated searcher efficiency was essentially 100 percent and not representative of other birds. Thus, it is inappropriate to include them in the deposition rate calculation. However, these birds died as a result of the DWH spill, and therefore, are added into the total mortality estimate for each region (*NRDA Study Birds*, Tables 6 and 7).

TOTAL BIRDS BY REGION

The total number of birds that the Trustees were able to quantify, and that were expected to have died because of the spill during the model period per Region, was calculated

using the total number of birds estimated by the SDM (*SDM Results*, Table 6 and 7), birds lost at sea (*Birds Lost at Sea*, Table 6 and 7), and any birds not modeled (including birds that are applied a regional correction factor and NRDA Study Birds). For Regions where carcass deposition could be estimated by the SDM, the *Total Birds by Region* is equal to the sum of *SDM Results*, *Birds Lost at Sea*, *Birds with Regional Correction Factor*, and *NRDA Study Birds* (Table 6 and 7). For Regions that could not be addressed with the SDM, the *Total Birds by Region* is equal to the sum of *Birds Not Modeled* and *NRDA Study Birds* (Table 6 and 7).

UNCERTAINTIES AND ASSUMPTIONS

There are some uncertainties and assumptions inherent in the SDM calculations that may result in either an over or underestimate of avian mortality. For instance, a number of birds die each year, unrelated to the DWH spill due to disease, predation, or other reasons. While birds identified as having died due to non-spill related reasons were excluded from the SDM, the background level of avian mortality is not accounted for in the SDM results, which may result in an overestimate of spill-related avian mortality. Additionally, a number of the birds collected alive and taken to rehabilitation centers may have survived. For instance, 1,588 birds collected alive were documented as being rehabilitated and released, placed in a zoo or transferred to a wildlife center or other rehabilitation center, and an additional 29 have an unknown fate.

There are also a number of uncertainties that may result in an underestimate. For instance, as mentioned above, there are time periods without usable search intervals where stranded birds potentially went unfound. The regional correction factor was applied to birds that are found in areas that are not being modeled due to a lack of search data. However, this correction factor can only be applied to birds that are found. All of the birds depositing on shorelines that were not searched (and not found) cannot be modeled and likely represent a number of birds that are not incorporated in the results.

Additionally, there are some birds collected and used in the SDM that do not attribute to the deposition rate, which may also lead to an underestimation (i.e., including more birds in the deposition rate calculations could increase the number of carcasses depositing per km). Since the carcass deposition rate (carcasses/km) is calculated on a segment-basis, any bird that is collected from inland or offshore areas not covered by a shoreline segment or birds collected from segments with a habitat type of "clad", are not included in the deposition rate calculations. On days the Extrapolation Area is modeled, the birds are considered "modeled" to avoid double counting, but do not contribute to the deposition rate calculation.

Additionally, the shoreline assigned to each documented search may overestimate the shoreline actually searched. As described in Section 3, SDM Data Inputs, search teams did not always record specific details on search locations. In order to consistently identify the set of segments searched, all of the segments in the area described on a search form were assumed to have been searched. For example, teams that described searching "Dauphin Island" may have only searched part of the island, but because no additional data is available to further refine the search area, all of the segments covering the

perimeter of the island were assumed to have been searched. The length of shoreline searched directly affects the deposition rate. With the same number of birds collected, a shorter length searched results in a higher deposition rate (more birds found per area searched). Therefore overestimating the shoreline searched results in an underestimate of birds deposited.

Also, the SDM utilized a searcher efficiency value for live birds that is greater than that of dead birds, based on professional judgment that live birds may be easier to find than dead birds. However, it is possible that live birds are able to hide and that it is harder for a searcher to find a live bird as compared to a dead bird. If this was the case, our approach may underestimate the number of birds killed by the DWH oil spill.

TABLE 6. LOW END ESTIMATE OF TOTAL NEARSHORE MORTALITY (NUMBER OF BIRDS)

REGION	BIRDS COVERED BY THE SDM[1]	SDM RESULTS[2]	BIRDS LOST AT SEA[3]	BIRDS NOT COVERED BY THE SDM[4]	BIRDS WITH REGIONAL CORRECTION[5]	NRDA STUDY BIRDS[6]	TOTAL BIRDS BY REGION[7]
South Texas	0	0	0	36	0	0	36
North Texas-West Louisiana	229	1,829	0	10	80	10	1,919
Lake Mechant	5	6	39	0	0	0	45
Terrebonne Bay	123	202	1,012	121	1,194	1	2,409
Barataria Bay	1,335	1,869	6,790	172	1,116	21	9,796
Louisiana Offshore	0	0	0	32	0	0	32
Birdsfoot West	167	267	860	45	304	8	1,438
Birdsfoot East	383	926	2,298	24	202	0	3,426
Birdsfoot Outer	0	0	0	36	0	0	36
Biloxi Marsh	154	117	255	1,672	4,041	1	4,414
Mississippi-Alabama Coast	836	1,517	2,872	160	840	4	5,234
Mississippi-Alabama Gulf Islands	231	600	1,326	60	500	0	2,425
Mississippi Offshore	0	0	0	4	0	0	4
Mobile Bay Seashore	352	718	1,364	42	249	0	2,331
Mobile Bay Interior	222	513	1,753	130	1,327	0	3,594
Alabama Offshore	0	0	0	25	0	0	25
Pensacola	228	250	240	58	125	0	615
Apalachicola West	238	428	413	25	88	0	930
Apalachicola East	66	221	383	15	137	0	740
Florida Offshore	0	0	0	33	0	0	33
South Florida	0	0	0	65	0	0	65
Federal Offshore Waters	0	0	0	40	0	0	40
Birds with No Region[8]	0	0	0	147	0	0	147
Total	**4,569**	**9,464**	**19,606**	**2,952**	**10,203**	**45**	
						Grand Total (across regions and including birds with no region)[9]	**39,736**

[1] This represents the number of birds collected during NRDA and spill response efforts from an Extrapolation Area within the Region that is being modeled on the date they were collected. See Section 7, Birds Covered by the SDM for details.
[2] Total number of bird deaths, estimated/modeled by the SDM, calculated using birds collected, search effort, searcher efficiency, and carcass persistence values. See Section 7, SDM Results for details.
[3] Number of birds, added to SDM output, that are estimated to have been lost at sea using the Lost at Sea Factor (see Section 6, Birds Lost at Sea).
[4] Number of birds not covered by the SDM because they were collected from an Extrapolation Area and a day that was not modeled due to insufficient search effort data or

birds that were collected from an area not associated with a segment utilized by the SDM. See Section 7, Regional Correction Factor (Temporal Extrapolation).
[5] # of additional birds added to SDM output based on applying the regional correction factor to the Birds Not Covered by the SDM. See Section 7, Regional Correction Factor (Temporal Extrapolation).
[6] Number of NRDA study birds not included in the SDM because they were birds that were collected during specific DWH NRDA studies. See Section 7, NRDA Study Birds.
[7] Total number of birds, estimated by the SDM and Lost at Sea Factor, to have been killed, by region. For regions where carcass deposition was calculated, this includes the sum of SDM results, birds lost at sea, birds with regional correction factor, and NRDA study birds. If a deposition rate was not estimated for the region (i.e., SDM Results field is zero), this includes the sum of Birds Not Covered by the SDM and NRDA Study Birds. See Section 7, Total Birds by Region.
[8] Number of birds that do not have associated location information (i.e., have no coordinates or location description) and cannot be assigned to a region. These birds are simply added to the sum of birds by region.
[9] Sum of all birds by region and birds with no region (or those with no location data that could not be modeled).

TABLE 7. HIGH END ESTIMATE OF TOTAL NEARSHORE MORTALITY (NUMBER OF BIRDS)

REGION	BIRDS COVERED BY THE SDM[1]	SDM RESULTS[2]	BIRDS LOST AT SEA[3]	BIRDS NOT COVERED BY THE SDM[4]	BIRDS WITH REGIONAL CORRECTION[5]	NRDA STUDY BIRDS[6]	TOTAL BIRDS BY REGION[7]
South Texas	0	0	0	36	0	0	36
North Texas-West Louisiana	229	2,500	0	10	109	0	2,610
Lake Mechant	5	13	82	0	0	21	116
Terrebonne Bay	123	337	1,691	121	1,995	1	4,024
Barataria Bay	1,335	2,706	9,828	172	1,615	0	14,149
Louisiana Offshore	0	0	0	32	0	0	32
Birdsfoot West	167	445	1,435	45	507	8	2,395
Birdsfoot East	383	1,541	3,822	24	336	0	5,699
Birdsfoot Outer	0	0	0	36	0	0	36
Biloxi Marsh	154	161	351	1,672	5,553	0	6,065
Mississippi-Alabama Coast	836	2,619	4,958	160	1,450	0	9,028
Mississippi-Alabama Gulf Islands	231	857	1,895	60	715	0	3,466
Mississippi Offshore	0	0	0	4	0	4	8
Mobile Bay Seashore	352	1,043	1,982	42	361	0	3,386
Mobile Bay Interior	222	735	2,511	130	1,901	0	5,148
Alabama Offshore	0	0	0	25	0	0	25
Pensacola	228	331	318	58	165	10	825
Apalachicola West	238	589	568	25	122	0	1,279
Apalachicola East	66	304	528	15	189	0	1,021
Florida Offshore	0	0	0	33	0	0	33
South Florida	0	0	0	65	0	1	66
Federal Offshore Waters	0	0	0	40	0	0	40
Birds with No Region[8]	0	0	0	147	0	0	147
Total	**4,569**	**14,182**	**29,971**	**2,952**	**15,018**	**45**	
					Grand Total (across regions and including birds with no region)[9]		**59,634**

[1] This represents the number of birds collected during NRDA and spill response efforts from an Extrapolation Area within the Region that is being modeled on the date they were collected. See Section 7, Birds Covered by the SDM for details.
[2] Total number of bird deaths, estimated/modeled by the SDM, calculated using birds collected, search effort, searcher efficiency, and carcass persistence values. See Section 7, SDM Results for details.
[3] Number of birds, added to SDM output, that are estimated to have been lost at sea using the Lost at Sea Factor (see Section 6, Birds Lost at Sea).

[4] Number of birds not covered by the SDM because they were collected from an Extrapolation Area and a day that was not modeled due to insufficient search effort data or birds that were collected from an area not associated with a segment utilized by the SDM. See Section 7, Regional Correction Factor (Temporal Extrapolation).
[5] # of additional birds added to SDM output based on applying the regional correction factor to the Birds Not Covered by the SDM. See Section 7, Regional Correction Factor (Temporal Extrapolation).
[6] Number of NRDA study birds not included in the SDM because they were birds that were collected during specific DWH NRDA studies. See Section 7, NRDA Study Birds.
[7] Total number of birds, estimated by the SDM and Lost at Sea Factor, to have been killed, by region. For regions where carcass deposition was calculated, this includes the sum of SDM results, birds lost at sea, birds with regional correction factor, and NRDA study birds. If a deposition rate was not estimated for the region (i.e., SDM Results field is zero), this includes the sum of Birds Not Covered by the SDM and NRDA Study Birds. See Section 7, Total Birds by Region.
[8] Number of birds that do not have associated location information (i.e., have no coordinates or location description) and cannot be assigned to a region. These birds are simply added to the sum of birds by region.
[9] Sum of all birds by region and birds with no region (or those with no location data that could not be modeled).

TABLE 8. LOW AND HIGH END ESTIMATES OF TOTAL NEARSHORE MORTALITY BY SPECIES, FOR THOSE SPECIES CLAIMED BY DOI AS INJURED BY THE SPILL

SPECIES	PROPORTION OF TOTAL	# OF BIRDS, LOW END SDM RESULTS	# OF BIRDS, HIGH END SDM RESULTS
American White Pelican	0.600%	238	358
Brown Pelican	17.881%	7,105	10,663
Herring Gull	0.404%	161	241
Laughing Gull	49.420%	19,637	29,471
Lesser Black-backed Gull	0.052%	21	31
Ring-billed Gull	0.039%	16	23
Audubon's Shearwater	0.065%	26	39
Cory's Shearwater	0.026%	10	16
Great Shearwater	0.326%	129	194
Leach's Storm-Petrel	0.026%	10	16
Magnificent Frigatebird	0.182%	73	109
Manx Shearwater	0.013%	5	8
Masked Booby	0.104%	41	62
Northern Gannet	6.360%	2,527	3,793
Sooty Shearwater	0.013%	5	8
White-tailed Tropicbird	0.013%	5	8
American Coot	0.039%	16	23
Clapper Rail	0.873%	347	521
Common Gallinule	0.039%	16	23
Purple Gallinule	0.039%	16	23
Sora	0.039%	16	23
Virginia Rail	0.013%	5	8
Osprey	0.182%	73	109
American Oystercatcher	0.182%	73	109
Black-bellied Plover	0.013%	5	8
Black-necked Stilt	0.039%	16	23
Dunlin	0.026%	10	16
Killdeer	0.052%	21	31
Least Sandpiper	0.013%	5	8
Long-Billed Dowitcher	0.013%	5	8
Piping Plover	0.052%	21	31
Ruddy Turnstone	0.209%	83	124
Sanderling	0.391%	155	233
Semipalmated Sandpiper	0.052%	21	31
Short-billed Dowitcher	0.039%	16	23
Spotted Sandpiper	0.013%	5	8
Willet	0.156%	62	93
Wilson's Plover	0.039%	16	23
Black Skimmer	2.554%	1,015	1,523
Black Tern	0.117%	47	70
Bridled Tern	0.026%	10	16

Brown Noddy	0.013%	5	8
Caspian Tern	0.300%	119	179
Common Tern	0.417%	166	249
Forster's Tern	0.678%	269	404
Gull-billed Tern	0.065%	26	39
Least Tern	1.616%	642	964
Royal Tern	5.187%	2,061	3,093
Sandwich Tern	1.290%	513	769
Sooty Tern	0.039%	16	23
Black-Bellied Whistling-Duck	0.026%	10	16
Black-crowned Night-heron	0.287%	114	171
Cattle Egret	0.665%	264	396
Great Blue Heron	0.834%	331	497
Green Heron	0.235%	93	140
Least Bittern	0.065%	26	39
Little Blue Heron	0.065%	26	39
Reddish Egret	0.052%	21	31
Roseate Spoonbill	0.547%	218	326
Snowy Egret	0.365%	145	218
Tricolored Heron	0.626%	249	373
White Ibis	0.091%	36	54
Yellow-crowned Night-Heron	0.130%	52	78
Bufflehead	0.026%	10	16
Canada Goose	0.026%	10	16
Fulvous Whistling-Duck	0.013%	5	8
Green-winged Teal	0.026%	10	16
Lesser Scaup	0.013%	5	8
Mallard	0.404%	161	241
Mottled Duck	0.117%	47	70
Red-Breasted Merganser	0.026%	10	16
Ruddy Duck	0.026%	10	16
Surf Scoter	0.039%	16	23
Double-crested Cormorant	0.691%	274	412
Neotropic Cormorant	0.026%	10	16
Belted Kingfisher	0.013%	5	8
Boat-tailed Grackle	0.013%	5	8
Glossy Ibis	0.013%	5	8
Red-winged Blackbird	0.013%	5	8
Seaside Sparrow	0.013%	5	8
Common Loon	1.121%	445	668
Pied-billed Grebe	0.508%	202	303
Great Egret	0.274%	109	163
Blue-winged Teal	0.209%	83	124
Yellowlegs; Unidentified	0.013%	5	8
	Total	**38,923**	**58,414**

Note: may not sum to total due to rounding.
Species DOI is not including in their injury quantification (e.g., European starling) have been excluded from this table; therefore the totals in this table do not equal the totals in Tables 6 and 7.

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