Evidence of marine mammals' direct exposure to petroleum products during the Deepwater Horizon Oil Spill in the Gulf of Mexico
DWH NRDA Marine Mammal Technical Working Group Report

Laura Aichinger Dias[1]

[1] Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami FL 33149, USA.

Between April 20 and July 15, 2010 the Deepwater Horizon (DWH) incident spilled an estimated 3.19 million barrels of oil into the north-central Gulf of Mexico (hereafter referred to as Gulf)(U.S. District Court, 2015). By April 22 response activities including in-situ burns, application of dispersants, and oil skimming were intensively taking place in the waters of the Gulf (Houma ICP, 2010).

Several agencies, including the National Oceanic and Atmospheric Administration (NOAA) through the offices of the National Marine Fisheries Service (NMFS) and the National Ocean Service (NOS)[1], the Louisiana Department of Wildlife and Fisheries (LDWF), the United States Coast Guard (USCG), and others began immediately monitoring oil spill response activities as well as marine mammals seen during these activities or distributed throughout the north-central Gulf. During these monitoring assignments, evidence of marine mammal's direct exposure to petroleum products was collected by means of opportunistic field notes and photographs of the animals swimming through oiled waters or with oil on their bodies, and by systematic record of oil and sheen during cetacean surveys. A cetacean sighting or encounter was defined as all marine mammals (dolphins or whales) within the observers' sight at the moment of observation. Further evidence of exposure was gathered from stranded dolphins with oil on their bodies; the oil was consistent with oil from the DWH spill site. In total, 85 occurrences evidencing marine mammals' direct exposure to petroleum products were recorded for 11 cetacean species and 2 categories of unidentified dolphins and mammals (Figure 1).

[1] NMFS and NOS activities were conducted under MMPA Permit 779-1633.

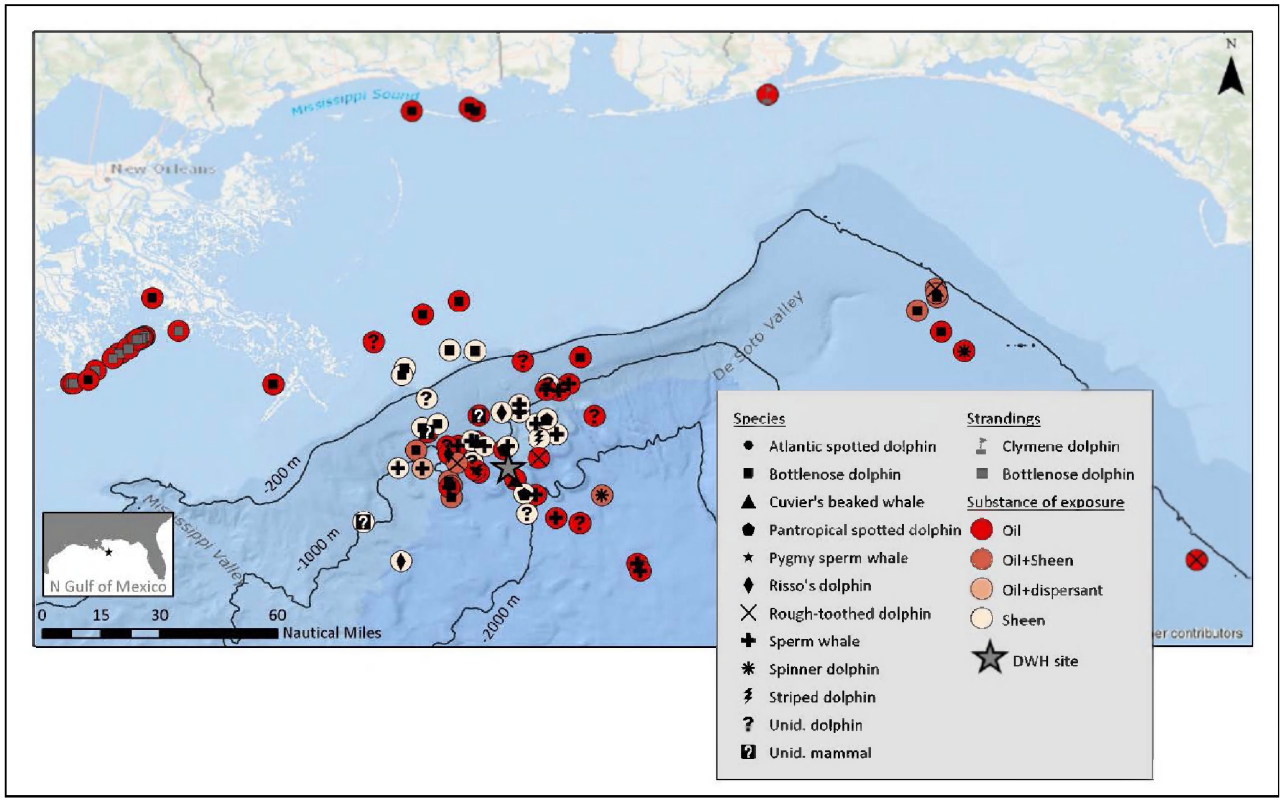

Figure 1: Total occurrences evidencing marine mammals' direct exposure to petroleum products recorded in the north-central Gulf. (Unid.- unidentified).

Cetacean sighting databases and some of the photographs were maintained at NMFS in Miami, FL. Other photographs were obtained directly from the agency that collected them or acquired through *PhotoLogger*. *PhotoLogger* was a photo management application used for site documentation of the DWH oil spill maintained by NOAA's Office of Response and Restoration (ORR). In *PhotoLogger*, one of the authors (Laura Dias-LD) searched for photographs of cetaceans in oil using keywords (e.g. whale, dolphin, marine mammal), date of known operations that reported marine mammals sightings (e.g. USCG overflights), or known sources of the photos (e.g. photographer's name). Spreadsheets containing date, location, file name, and other comments were provided with each search. The comment section of some records provided the species and information on the petroleum substances present in the moment the photo was taken. If not available, cetologists at NMFS independently identified the species and LD inferred the substances from the photographs.

Marine mammal monitoring – NMFS-guided projects

Aerial surveys: Helicopter and Synoptic Twin Otter Surveys

Marine mammal observer teams conducted aerial surveys from the shoreline to the 2,000 m isobath, covering areas from the Mississippi River Delta to the western Florida (FL) Panhandle (Table 1). The Helicopter Survey departed out of Houma, Louisiana (LA) surveying mainly the area around the DWH spill site from April 28 until July 14 (Figure 2). The Synoptic Twin Otter Survey departed out of Mobile, Alabama (AL), covering the southeastern coast of LA, Mississippi

(MS), AL and a portion of the western FL Panhandle between April 28 and September 2 (figure 3). During the Helicopter Survey, marine mammal observers recorded the absence or presence of petroleum products during all marine mammal encounters. For the Synoptic Twin Otter Survey, in addition to marine mammal sightings, oil and oil-derived substances were recorded continuously throughout the project (not necessarily during marine mammal encounters). During the first leg, only the category "oil slick" was recorded whereas in the second leg oil was further described as "dark" and "weathered", and the observation of sheen and tarballs were also specifically recorded (Table 1).

Project	Date range	Survey effort area	Survey boundaries	Substance recording
Helicopter	April 28-July 14, 2010	Out of Houma, LA. Mainly on the Mississippi River Delta up to -87.9° longitude.	Shoreline up to the 2000m isobath.	Concomitant to marine mammal sightings.
Synoptic Twin Otter	April 28-May 24, 2010 (leg 1)	Between 91.4°W and 86.8°W longitude covering the SE coasts of LA, MS, AL, and a portion of the W FL Panhandle.	Mainly from the shoreline to the 200m isobath; limited survey effort in waters between 400-2000 m.	Throughout the survey.
	June 7-Sept 2, 2010 (leg 2)			

Table 1: Effort dates, survey range and schedule for recording petroleum substances during NMFS aerial surveys.

Of the 66 marine mammal sightings observed during the Helicopter Survey, over 70% were recorded in petroleum substances, corresponding to nearly 68% of all individual animals observed (Table 2). A comprehensive search of photographs taken during the survey was not performed but photos of marine mammals swimming in oil were obtained through *PhotoLogger* for two sightings (Figures 2A and 2B).

Species	Substance of exposure	Number of sightings	Number of animals
Common bottlenose dolphin (hereafter, bottlenose dolphin)	Oil	4	23
	Oil and Sheen	4	13
	Sheen	5	45
	None	12	81
Cuvier's beaked whale	Oil	1	1
Pantropical spotted dolphin	Sheen	1	75
Pygmy sperm whale	Oil	1	2
	None	1	1
Risso's dolphin	Sheen	1	100
	None	3	28
Sperm whale (Figure 2A)	Oil	10	12
	Sheen	6	12
Striped dolphin (Figure 2B)	Oil	1	100
	Sheen	1	30
	None	1	60
Unidentified dolphin	Oil	5	62
	Sheen	4	41
Unidentified mammal	Oil	2	6
	Sheen	1	1
	None	2	81
Total		**66**	**774**

Table 2: Number of marine mammal sightings and total number of animals recorded during the Helicopter Survey according to substance of exposure.

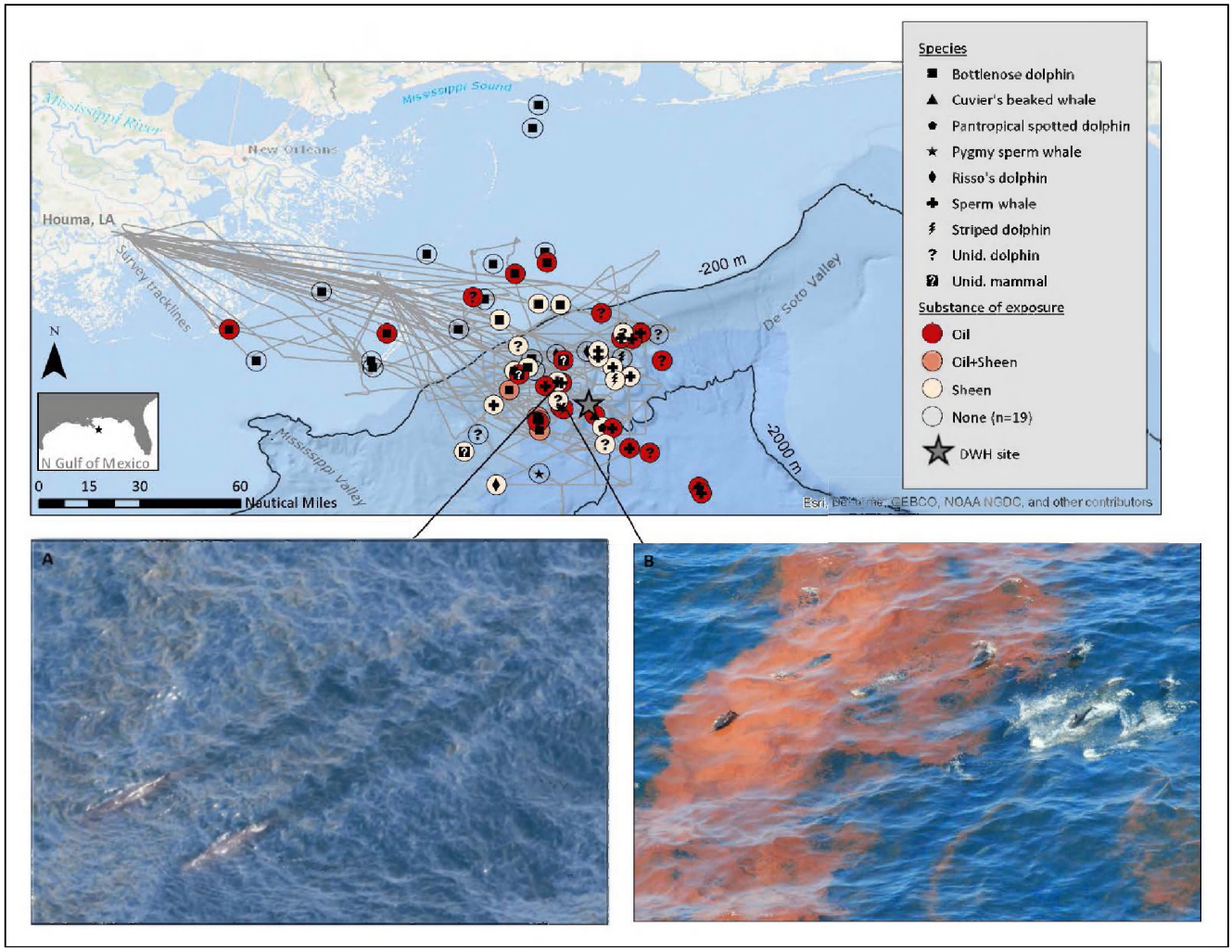

Figure 2: Marine mammal sightings in the presence or absence of petroleum products and survey tracklines during the Helicopter Survey. A: sperm whales swimming through oil, April 28, photo by NMFS; B: striped dolphins swimming through oil, April 29, photo by NMFS. (Unid. - unidentified).

A total of 503 marine mammal sightings were recorded during both legs of the Synoptic Twin Otter Survey (Table 3).

Species	Number of sightings	Number of animals
Atlantic spotted dolphin	3	210
Bottlenose dolphin	460	2586
Pantropical spotted dolphin	4	390
Risso's dolphin	13	323
Rough-toothed dolphin	1	40
Sperm whale	3	5
Unidentified cetacean	19	212
Total	**503**	**3766**

Table 3: Number of marine mammal sightings and total number of animals recorded during the Synoptic Twin Otter Survey.

In addition, petroleum substances were registered in 537 instances (table 4).

Date and Leg	Substance	Substance description	Number of records
April 28-May 24, Leg 1	Oil	Oil Slick	66
June 7-Sept 2, Leg 2	Oil	Dark Oil - Multiple Patches	12
		Dark Oil - Small Patch	2
		Dark Oil - Streamers	42
		Tarballs - Few	22
		Tarballs - Many	17
	Weathered oil	Large Patch	7
		Multiple Patches	31
		Small Patch	18
		Streamers	95
	Sheen	Metallic Sheen	26
		Rainbow Sheen	63
		Silver Sheen	136
Total			**537**

Table 4: Records of petroleum substances during the Synoptic Twin Otter Survey.

Direct observations of marine mammals in petroleum products were documented in six instances during the Synoptic Survey (Table 5). Differently from the Helicopter Survey in which the presence or absence of oil products were recorded for every sighting, these six observations were documented opportunistically on field notes. A comprehensive search of photographs taken during the Synoptic Survey was not performed but photos of marine mammals swimming in oil were obtained through *PhotoLogger* for one sighting (Figure 3A).

Source of evidence	Species and sighting number	Substance of exposure	Group size
Field notes: "dolphins in sheen"	Bottlenose dolphin, 6	Sheen	7
Field notes: dolphins "in and around small circles of sheen"	Pantropical spotted dolphin, 4	Sheen	50
Field notes: dolphins "in the oil, in the dark streaks. They were active and leaving a footprint in the oil as they traveled."	Risso's dolphin, 17	Oil	14
Field notes: 3 whales "within rainbow sheen"	Sperm whale, 9	Sheen	3
Field notes: "oily patches. The dolphins were just on the other side of patches"	Unidentified dolphin, 16	Oil	27
Photographic (Figure 3A)	Pantropical spotted dolphin, 33	Oil	80
Total			**181**

Table 5: Opportunistic observations of marine mammals in petroleum products recorded during the Synoptic Twin Otter Survey.

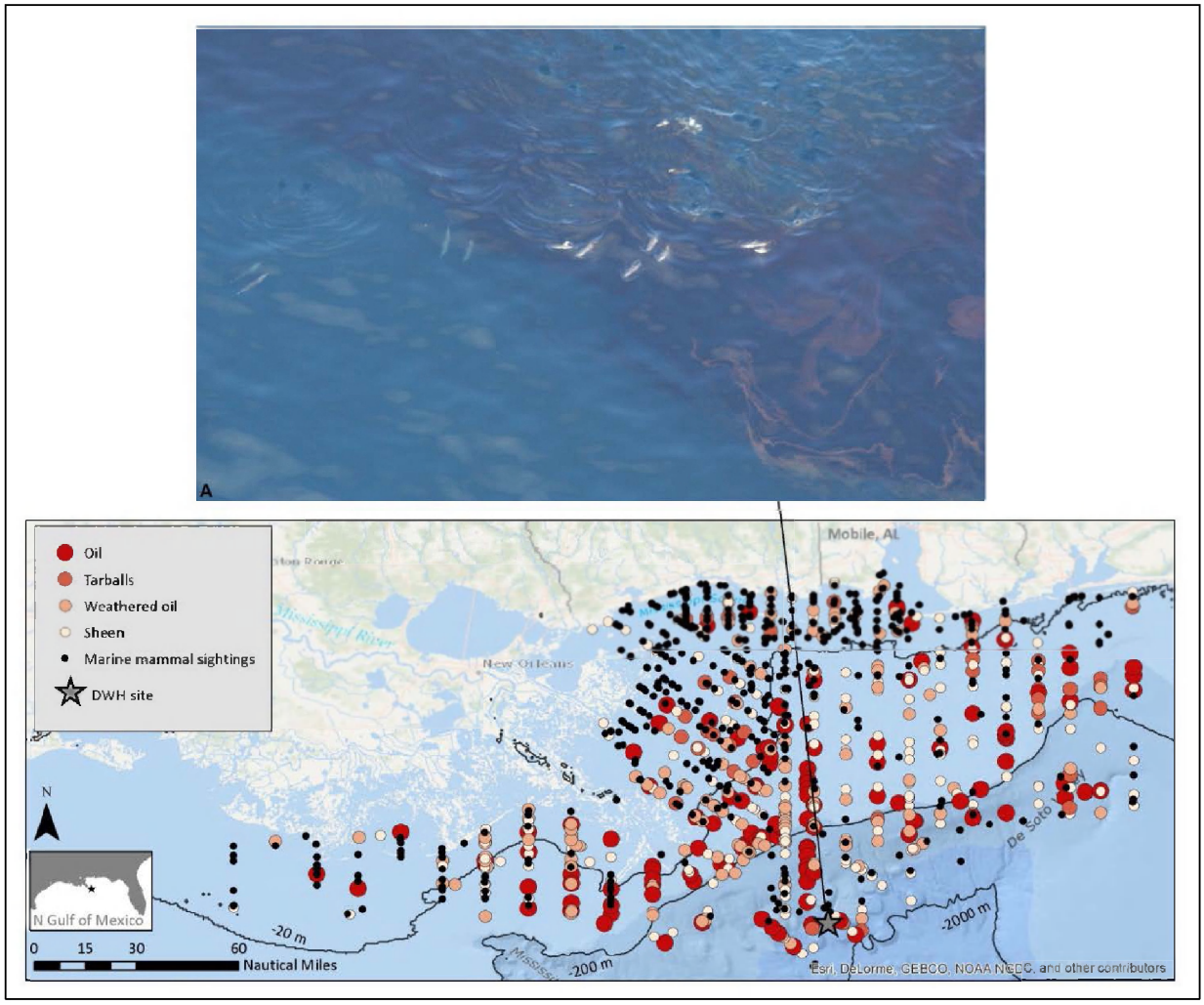

Figure 3: Marine mammal sightings and records of petroleum substances registered during the Synoptic Twin Otter Survey. A: pantropical spotted dolphins swimming through oil, sighting number 33, 28 April 2010, photo by NMFS.

Vessel-based survey: MaMOSAS

A vessel-based survey, Marine Mammal Oil Spill Assessment Survey (MaMOSAS) was conducted aboard the NOAA Ship *Gordon Gunter* between June 16 and August 8, 2010 with the main goal of collecting data on oceanic marine mammal stocks in the Gulf and around the DWH site. Areas surveyed included the De Soto Canyon region and the southeastern Gulf near the Dry Tortugas archipelago (not included in this report). Marine mammal observers opportunistically recorded and photographed cetaceans in oil or with oil in their bodies during nine sightings (Table 6 and Figure 4).

Source of evidence	Species	Subst. of exposure	Sighting number
Field notes: "sheen on the water's surface was continuously observed", "red/brown clumps were sporadically observed"	Atlantic spotted dolphin	Oil and Sheen	29
	Bottlenose dolphin	Oil and Sheen	28
	Rough-toothed dolphin	Oil and Sheen	30
Photographic	Bottlenose dolphin	Oil	26 (Figure 4B) and 84 (Figure 4A)
	Rough-toothed dolphin	Oil	1 (Figure 4D)
	Spinner dolphin	Oil	25
Photographic and field notes: "sheen on the water's surface was continuously observed", "red/brown clumps were sporadically observed"	Bottlenose dolphin	Oil and Sheen	27
Photographic and field notes: ""Floating red blobs and rainbow sheens throughout entire sighting"	Spinner dolphin	Oil and Sheen	83 (Figure 4C)

Table 6: Opportunistic observations of marine mammal sightings in petroleum products during the MaMOSAS cruise.

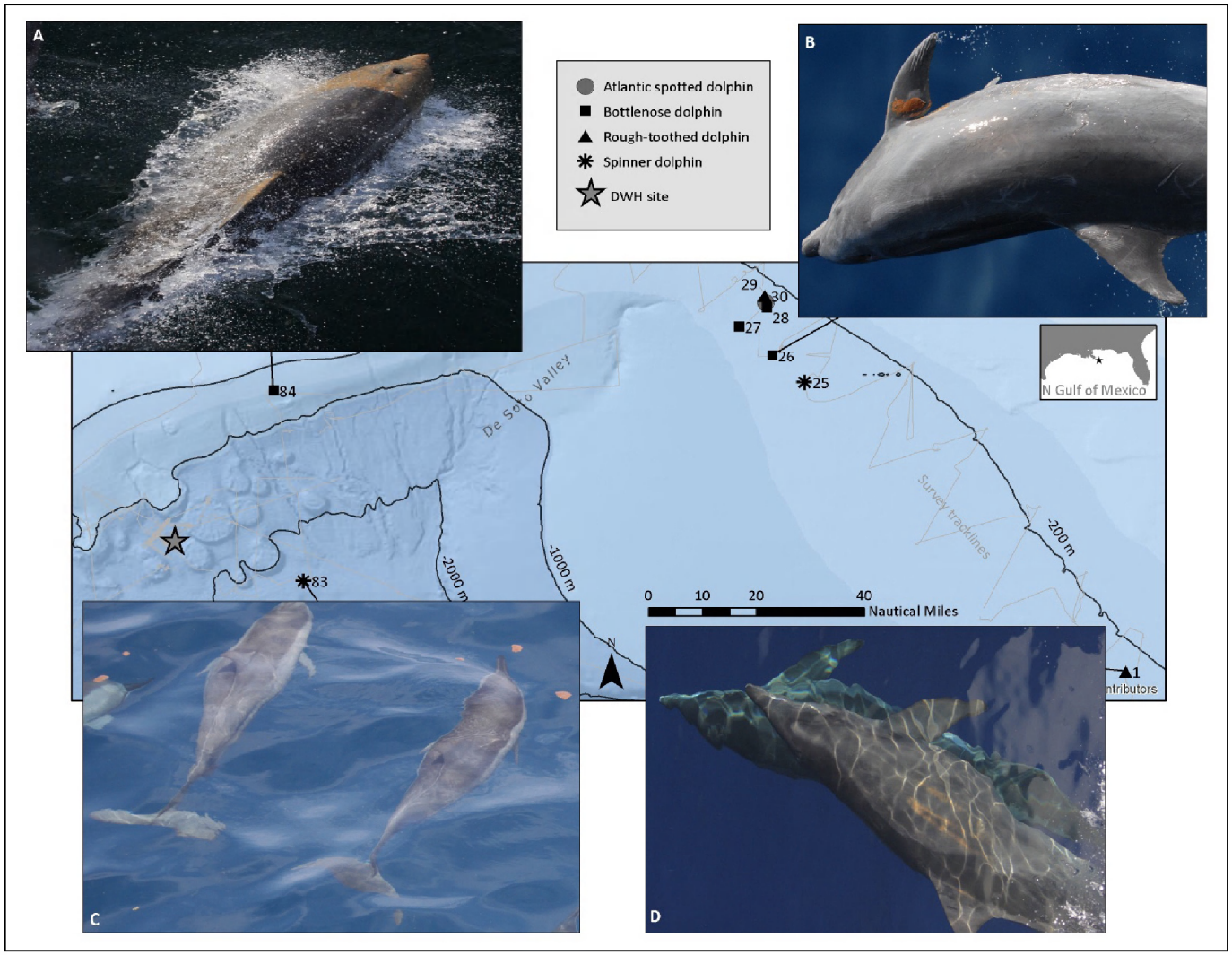

Figure 4: Opportunistic observations of marine mammals in petroleum products or with oil on their bodies recorded during the MaMOSAS cruise. A: bottlenose dolphin with oil on the head and dorsal fin, sighting number 84, 11 July 2010, photo by NMFS; B: bottlenose dolphin with oil on the pectoral fin, sighting number 26, 19 June 2010, photo by NMFS; C: spinner dolphins swimming through oil and sheen, sighting number 83, 11 July 2010, photo by NMFS; D: rough-toothed dolphin with oil on the right flank, sighting number 1, 17 June 2010, photo by NMFS.

Vessel-based survey: MSS NRDA Photo-ID Survey

Near the coast, NOS and NMFS conducted the Mississippi Sound (MSS) Natural Resource Damage Assessment (NRDA) Photo-identification (Photo-ID) Survey from June 2010 through May 2012. During this Survey, opportunistic photographs were collected of bottlenose dolphins with oil adhered to their bodies (Figure 5). The photographs were obtained directly from NOS.

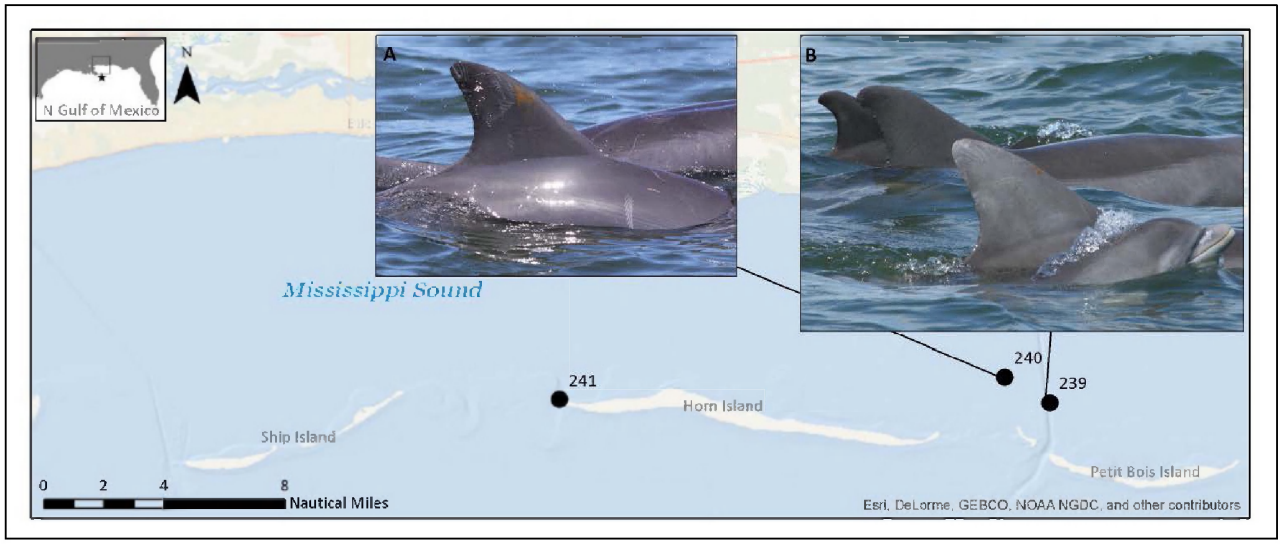

Figure 5: Opportunistic observations of bottlenose dolphins with oil adhered to their bodies photographed during the Mississippi Sound Natural Resource Damage Assessment Photo-identification Survey. A: survey number 240 conducted on 24 June 2010; photo by NOS; B: survey number 239 conducted on 24 June 2010, photo by NOS.

Response activities monitoring – NOAA, USCG and LDWF

Marine mammals were opportunistically photographed by the NMFS, the USCG and the LDWF in petroleum products and with oil on their bodies during spill monitoring activities (figure 6). The photographic evidence presented here does not represent a comprehensive search; it was acquired through NOS (LDWF photo) or *PhotoLogger* (NOAA and USCG photos).

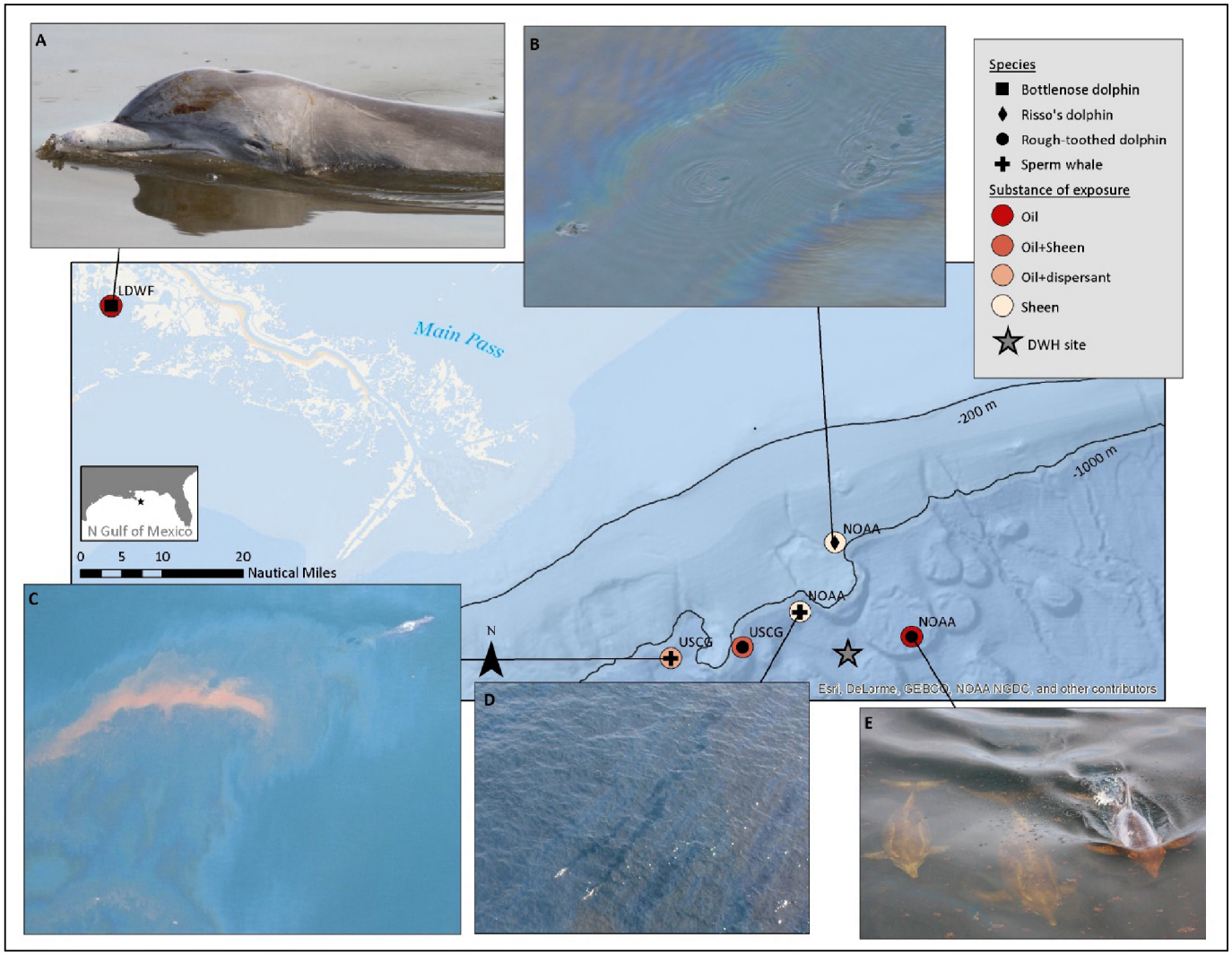

Figure 6: Opportunistic observations of marine mammals swimming through petroleum products or with oil adhered to their bodies registered during oil spill response monitoring activities. A: bottlenose dolphin with oil on the head, 5 August 2010, photo by LDWF; B: Risso's dolphins swimming through sheen, 15 June 2010, photo by NOAA; C: sperm whales swimming through a dispersed oil slick, 13 June 2010, photo by USCG; D: sperm whales swimming through sheen, 28 April 2010, photo by NOAA; E: rough-toothed dolphins swimming through oil, 16 June 2010, photo by NOAA.

Marine mammals were sighted throughout aerial dispersant operations, which had to be cancelled if animals were less than three nautical miles from the intended area of application. On June 13, 2010, sperm whales were documented by the USCG swimming through a dispersed oil slick (Houma ICP, 2010); photographs and video were captured (Figure 6C and Figure 7).

Figure 7: Screenshot at 00:01:27 minutes from the video of sperm whales swimming through a dispersed oil slick, 13 June 2010, video by USCG.

Strandings

Between May 2010 and February 2012, 14 dolphins stranded in Louisiana (LA) and in the FL Panhandle with oil on their bodies (Table 7 and Figure 8). The oil was fingerprinted and matched to oil from the DWH spill site. For stranding data and the photographs shown on figure 8 refer to the Marine Mammal Health and Stranding Response Program (MMHSRP) National Database (MMHSRP - https://mmhsrp.nmfs.noaa.gov/mmhsrp/).

Species	County and State	Field Number	Observation Date	Total
Clymene dolphin	Escambia County, FL	ECWR062310-13	23-Jun-10	1
Bottlenose dolphin	Jefferson Parish, LA	CES-20110218-LA001	18-Feb-11	9
		MCT-20100524-LA001	24-May-10	
		MCT-20101203-LA001	03-Dec-10	
		MCT-20110228-LA001	28-Feb-11	
		MCT-20110325-LA001	25-Mar-11	
		MCT-20110608-LA001	08-Jun-11	
		MCT-20110709-LA001	09-Jul-11	
		MB-20110125-LA001	25-Jan-11	
		SDD-20110219-LA001	19-Feb-11	
	Lafourche Parish, LA	MCT-20100606-LA001	06-Jun-10	3
		MCT-20100902-LA002	02-Sep-10	
		MCT-20110329-LA001	29-Mar-11	
	Plaquemines Parish, LA	BCF-20120223-LA001	23-Feb-12	1
Total				14

Table 7: Dolphin strandings in FL and LA with DWH oil on their bodies.

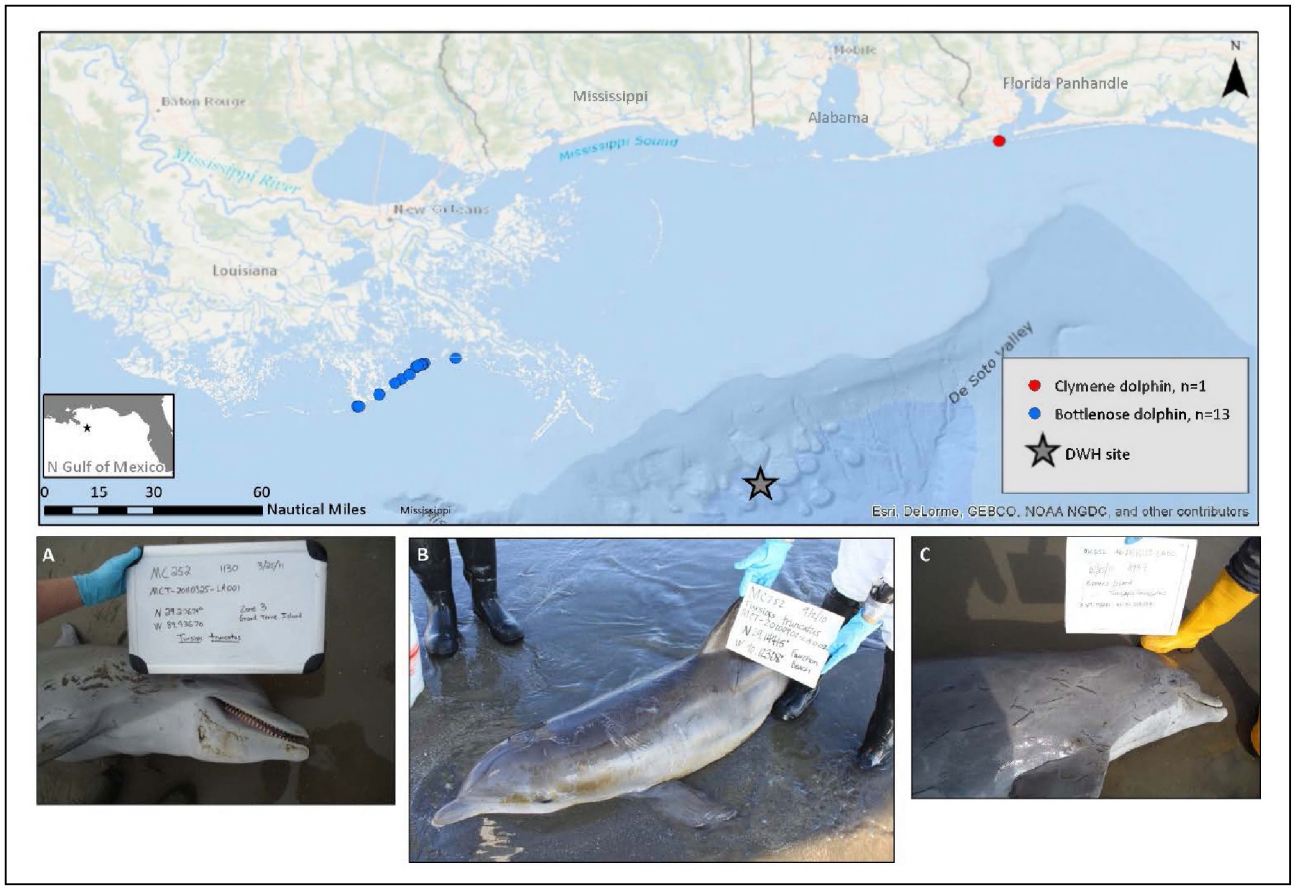

Figure 8: Dolphins that stranded with DWH oil on their bodies. A: MCT-20110325-LA001, Grand Terre Island Beach, 25 March 2011; B: MCT-20100902-LA002, Fourchon Beach, 2 September 2010; C: MB-20110125-LA001, Caminada Pass, 25 January 2011; all photos by LDWF.

Circumstantial evidence of exposure: oil footprint and dispersant envelope from ERMA

Evidence of likely direct exposure to oil was obtained by overlapping the Synthetic Aperture Radar (SAR) satellite imagery of the oil (i.e. oil footprint) with marine mammal sightings recorded within a similar time frame. The oil footprint was obtained from data downloaded from NOAA's Environmental Response Management Application (ERMA) and is a polygon of the presence of oil for one or more days captured between April 24 and August 11, 2010 (ERMA, 2015a). A total of 510 cetacean sightings and over 6,400 animals, recorded during the Helicopter and Synoptic Twin Otter surveys and the MaMOSAS cruise between April 28 and August 10, 2010 overlapped the oil footprint (Table 8 and Figure 9).

Species	Number of sightings	Number of animals
Stenellids*	27	1919
Bottlenose dolphin	343	2775
Beaked whales**	4	13
Melon-headed / Pygmy killer whale	1	5
Pygmy/Dwarf sperm whale	6	12
Risso's dolphin	18	454
Rough-toothed dolphin	2	103
Sperm whale	39	89
Unidentified dolphin	60	997
Unidentified cetacean	10	41
Total	**510**	**6408**

Table 8: Number of marine mammal sightings and number of animals that overlapped the oil footprint, April through August, 2010. *Stenellids included Atlantic spotted, pantropical spotted, spinner, striped and non-specified *Stenella* sp. dolphins. **Beaked whales included Cuvier's and other non-specified members of the Ziphiid family. (Data downloaded from ERMA).

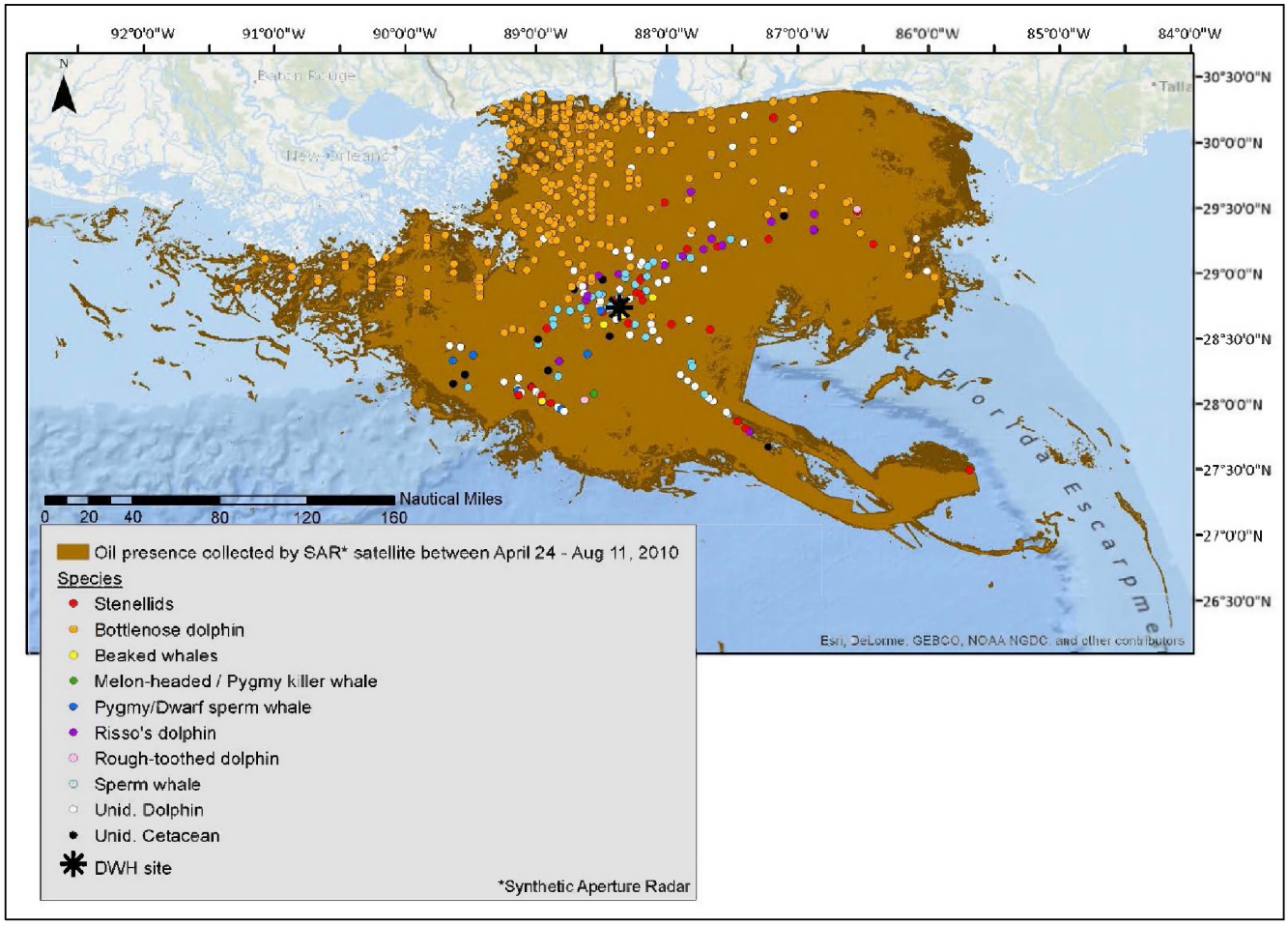

Figure 9: Marine mammal sightings observed during ship-based and aerial surveys between April 28 – August 10, 2010 overlapping the oil footprint captured by SAR satellite between April 24 – August 11, 2010. (Unid. -unidentified). (Data downloaded from ERMA).

Similarly, evidence of likely exposure to dispersants was obtained by overlapping the Aerial Dispersant Envelope with marine mammal sightings recorded within a similar time frame. The dispersant envelope was obtained from ERMA and shows the bounding box for all locations where aerial dispersants were applied between April 22 and July 19, 2010 (ERMA, 2015b, downloaded on June 18, 2015). A total of 144 marine mammal sightings and over 2,300 animals, recorded during the Helicopter and Synoptic Twin Otter surveys and the MaMOSAS cruise between April 28 and July 15, 2010 overlapped with the dispersant envelope (table 9 and figure 10).

Species	Number of sightings	Number of animals
Atlantic spotted dolphin	1	125
Bottlenose dolphin	71	813
Cuvier's beaked whale	1	1
Pantropical spotted dolphin	4	420
Pygmy/Dwarf sperm whale	3	5
Risso's dolphin	9	188
Sperm whale	24	61
Spinner dolphin	2	189
Stenella sp.	1	80
Striped dolphin	3	190
Unidentified cetacean	25	289
Total	**144**	**2361**

Table 9: Number of marine mammal sightings and number of animals that overlapped the Aerial Dispersant Envelope, April through July, 2010.

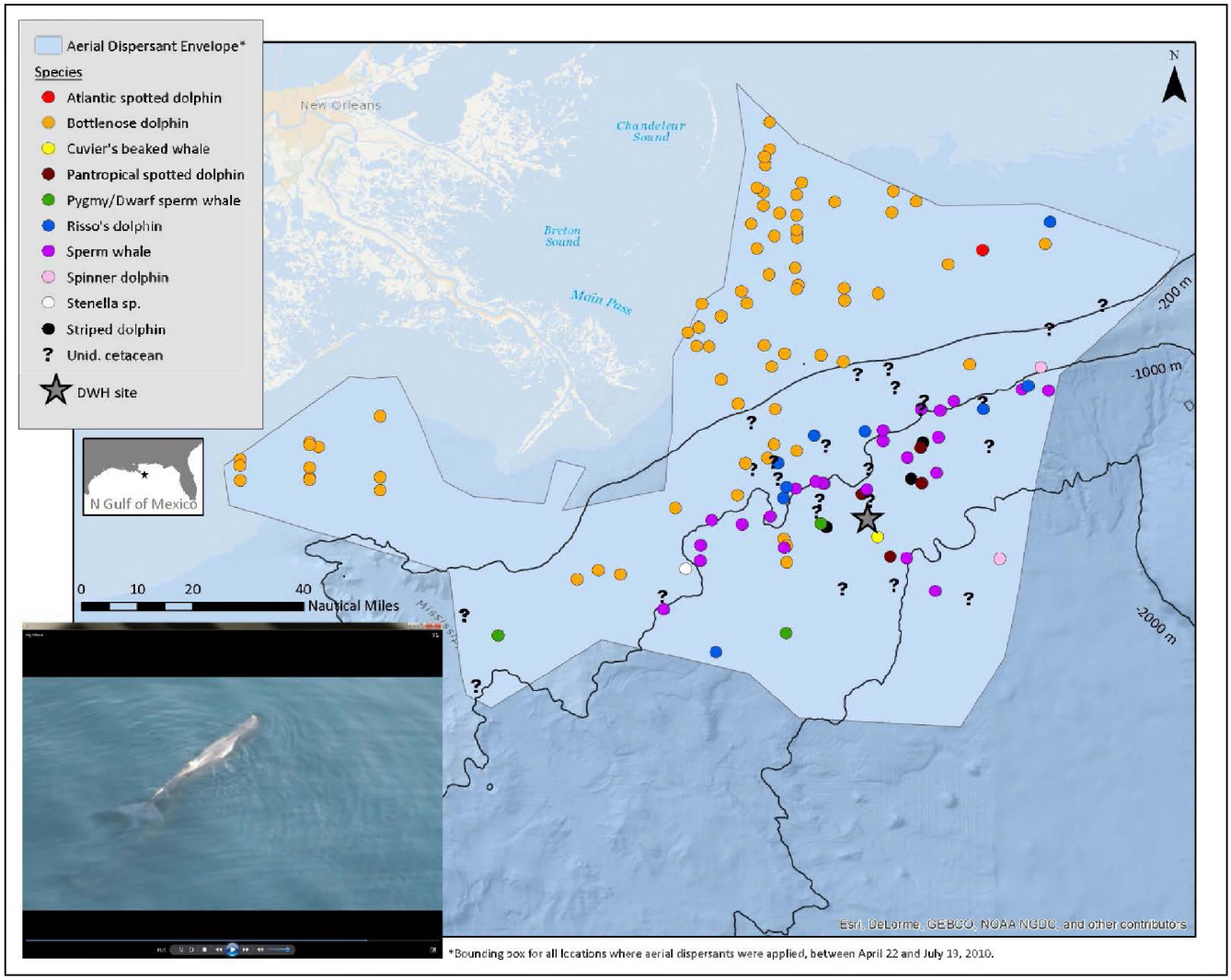

Figure 10: Marine mammal sightings observed during ship-based and aerial surveys between April 28 – July 15, 2010 overlapping the Aerial Dispersant Envelope. (Unid. -unidentified). (Data downloaded from ERMA).

It has been suggested that cetaceans are able to detect and avoid oiled waters and, when in contact, oil would not adhere to their slick skin due to the absence of hairs and the frequent sloughing of skin cells (Helm et al, 2015). The evidence presented here included photographs and observations of several dolphin and whale species swimming through different stages of oil and with oil adhered to their bodies. This evidence further documents the underlying mechanisms of exposure of marine mammals to oil and oil-derived substances. Even though cetaceans are likely able to detect certain stages of oil, they may not completely avoid it and can potentially be in jeopardy when in contact with petroleum substances. The documentation of offshore cetaceans affected by direct exposure to oil further increases the concern that pelagic species, which might be closer to a spill site, are in fact at a higher risk of exposure to the most toxic compounds of an oil slick than coastal species.

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