



## **Diet of Common Bottlenose Dolphins, *Tursiops truncatus*, that Stranded in and Near Barataria Bay, Louisiana, 2010–2012**

Authors: Bowen-Stevens, Sabrina R., Gannon, Damon P., Hazelkorn, Rebecca A., Lovewell, Gretchen, Volker, Kristen M., et al.

Source: Southeastern Naturalist, 20(1) : 117-134

Published By: Eagle Hill Institute

URL: <https://doi.org/10.1656/058.020.0113>

---

BioOne Complete ([complete.BioOne.org](https://complete.BioOne.org)) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at [www.bioone.org/terms-of-use](https://www.bioone.org/terms-of-use).

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

---

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

## Diet of Common Bottlenose Dolphins, *Tursiops truncatus*, that Stranded in and near Barataria Bay, Louisiana, 2010–2012

Sabrina R. Bowen-Stevens<sup>1,\*</sup>, Damon P. Gannon<sup>2</sup>, Rebeccah A. Hazelkorn<sup>3</sup>, Gretchen Lovewell<sup>3</sup>, Kristen M. Volker<sup>4</sup>, Suzanne Smith<sup>5</sup>, Mandy C. Tumlin<sup>6</sup>, and Jenny Litz<sup>7</sup>

**Abstract** - The largest unusual mortality event of cetaceans recorded in the Gulf of Mexico occurred from 2010 to 2014. The majority of mortalities were *Tursiops truncatus* (Common Bottlenose Dolphin) that stranded near Barataria Bay, LA, an area heavily oiled by the Deepwater Horizon oil spill. The purpose of this study was to identify the diet of dolphins that stranded in and near Barataria Bay from 2010 to 2012. *Micropogonias undulatus* (Atlantic Croaker) was the most frequently occurring (86.5%) and numerically abundant ( $34.2 \pm 33.4\%$ ) prey in stomachs examined. Abundance of Engraulidae, Mugilidae, and Sciaenidae varied by season. Benthic prey and presence of sediment indicate that dolphins in Barataria Bay forage along the bottom of the bay, which could lead to long-term exposure to oil.

### Introduction

In February of 2010, an increase in the number of stranded cetaceans began in the northern Gulf of Mexico, which prompted a unusual mortality event (UME) to be declared extending from the Texas–Louisiana border to Franklin County in the Florida panhandle (Litz et al. 2014). The UME officially ended in July 2014. The majority of stranded cetaceans reported were *Tursiops truncatus* Montagu (Common Bottlenose Dolphin, hereafter referred to as “Dolphin”). Strandings between February and April 2010 were concentrated around Lake Pontchartrain, LA. Due to advanced decomposition, the cause could not be determined, although decreased salinity and temperatures are suspected due to increased rain and colder than normal temperatures (Venn-Watson et al. 2015a). On 20 April 2010, the Deepwater Horizon (DWH) incident occurred, releasing 4.9 million barrels of crude oil through 15 July 2010 (McNutt et al. 2011, Michel et al. 2013). Following the spill, the longest sustained increase in strandings occurred in and around Barataria Bay, LA, which was heavily oiled from the DWH spill (Litz et al. 2014, Venn-Watson et al. 2015a). The toxic effects of oil from DWH were found to be the most likely causes of the persistent increase in cetacean mortalities after April 2010 (NOAA 2019, Schwacke et al. 2014, Takeshita et al. 2017, Venn-Watson et al. 2015a).

<sup>1</sup>NOAA Affiliate, Southeast Fisheries Science Center, Miami, FL 33149. <sup>2</sup>University of Georgia Marine Institute, PO Box 32, Sapelo Island, GA 31327. <sup>3</sup>Stranding Investigations Program, Mote Marine Laboratory, Sarasota, FL 34236. <sup>4</sup>Virginia Aquarium and Marine Science Center, Virginia Beach, VA 23451. <sup>5</sup>Audubon Aquarium of the Americas, New Orleans, LA 70130. <sup>6</sup>Louisiana Department of Wildlife and Fisheries, Baton Rouge, LA 70898. <sup>7</sup>National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL 33149. \*Corresponding author - sabrina.r.stevens@gmail.com.

Manuscript Editor: Timothy Gowan

Knowledge of prey items of Dolphins in Barataria Bay is lacking, and such information is valuable in understanding how perturbations in their environment may secondarily impact Dolphins through changes in prey availability or exposure to contaminants through ingestion. Potential prey items for Dolphins include many species of fish and shrimp that are found in the salt marsh and estuarine habitat of Barataria Bay for at least a portion of their life cycle and are potentially vulnerable to the effects of oiling in the bay (Barros and Odell 1990, Elmgren et al. 1983, Gregg et al. 1997, Whitehead et al. 2012). Juvenile and adult fish can be sickened or killed by oil via direct toxic exposure of the gills or skin or indirect toxic exposure through their diet (Elmgren et al. 1983, Gregg et al. 1997, Whitehead et al. 2012). Polycyclic aromatic hydrocarbons (PAHs) are a toxic chemical component of oil that are first metabolized in the liver of fish before being removed through the gastrointestinal tract (Beyer et al. 2010, Murawski et al. 2014, Pulster et al. 2017, Snyder et al. 2015). However, not all PAHs are eliminated from fish following exposure, and some PAHs are stored in lipid-containing tissues such as the liver and muscle (Murawski et al. 2014, Ylitalo et al. 2012). In addition to the lethal and sub-lethal toxic effects of oil, fish and shrimp could also be indirectly impacted via changes in prey availability or destruction of marsh habitat through oiling of the bay (Fleeger et al. 2003, Lewis et al. 2020, Pasparakis et al. 2019). Lastly, larval fish exposed to weathered oil in controlled laboratory experiments have lower survival rates, impaired cardiovascular development, and reduced mobility that can reduce recruitment into adult populations, potentially impacting prey availability for Dolphins years later (Carls et al. 1999, Kocan et al. 1996, Mager et al. 2014).

Fish in the family Sciaenidae and other soniferous fish are consistently the most important prey in the diet of Dolphins in the southeastern United States; however, diet can vary by location (e.g., Florida vs. Louisiana) and habitat likely due to differences in fish communities (Barros 1993, Barros and Odell 1990, Barros and Wells 1998, Berens McCabe et al. 2010, Bowen 2011, Gannon and Waples 2004). Dolphins in estuarine waters of the Gulf of Mexico are separated into 31 stocks or management units, with 1 distinct stock for each area of contiguous, enclosed, or semi-enclosed body of water (Hayes et al. 2019). Multiple studies have documented long-term residency of Dolphins in estuarine environments including Barataria Bay (Irvine and Wells 1972, Irvine et al. 1981, Wells et al. 2017). More diet information has been published from Dolphins stranded in Florida than in Louisiana, leaving a knowledge gap for the latter (Barros 1993, Barros and Odell 1990, Barros and Wells 1998, Berens McCabe et al. 2010, Bowen 2011). The closest study geographically to Barataria Bay was on diets of Dolphins that stranded along the western and northern Gulf of Mexico coastlines (Barros and Odell 1990). However, the majority of strandings in that study were in Texas, whereas Louisiana, Mississippi, and Alabama only had 1 stranding each (Barros and Odell 1990). There are differences in habitat and fish communities between Louisiana, Florida, and Texas (Hoese and Moore 1998), and these differences are likely reflected in differences in diet among Dolphins from their respective geographic areas. Knowledge

of the Dolphins' key prey in Louisiana would be valuable to better understand their exposure to contaminants, identify potential changes in prey availability resulting from natural and anthropogenic environmental perturbations, and provide baseline data to assess dietary shifts in relation to future manmade or natural changes to the environment. This information is critical for assessing how stressors impact Dolphin stocks and their recovery.

Stomach-content analyses are widely used for the characterization of diets in marine mammal studies, but these methods have well-recognized biases (Bigg and Fawcett 1985, Hyslop 1980, Jobling and Breiby 1986). Biases could arise from the difficulty of distinguishing the diet of the predator (Dolphin) from that of its prey and from differences in digestion rates of individual species hard parts (e.g., small, thin otoliths vs. larger, thick otoliths; Bigg and Fawcett 1985, Jobling and Breiby 1986). In addition to those associated with the analytical methods, there may be biases from the use of strandings; the physiological condition of the predator may have been compromised prior to death and not represent the diet of a "healthy" individual. Despite these limitations, stomach contents of stranded individuals can provide valuable insights into Dolphin diet. These methods have been used in previous studies of Dolphin diets (e.g., Barros and Wells 1998, Gannon and Waples 2004), and using multiple metrics of prey importance, frequency and abundance, can help identify and account for analytical biases (Bigg and Fawcett 1985). Dunshea et al. (2013) compared molecular prey detection of gastric and fecal samples of free-ranging Dolphins to stomach-content analysis of stranded Dolphins and found that stomach-content analysis was a good indicator of diet in the free-ranging population. Barros and Odell (1990) compared unhealthy stranded Dolphins to those stranded via fishery interactions (presumed healthy) and found similarities with the most frequently observed prey species. While it is difficult to know where a stranded carcass came from prior to death, Hohn et al. (2017) and Thomas et al. (2017) assigned strandings from 2010 to 2013 in Barataria Bay as either originating from coastal or estuarine stocks based on stable isotope and genetic analyses. They found that the majority of these stranded Dolphins originated from the estuarine and barrier island stocks (Hohn et al. 2017, Thomas et al. 2017). Because many of the stranded Dolphins in these 2017 publications were the same animals used in this study, it is likely that the Dolphins used in this study are part of the Barataria Bay Estuarine System Stock and were foraging in the bay prior to stranding.

The purpose of this study was to document the diet of Dolphins that stranded and washed ashore in Barataria Bay and surrounding waters from 2010 to 2012, during the first 2 years following the DWH oil spill. We summarized and compared findings of stomach contents to known literature of Dolphin diets in other areas of the Gulf of Mexico. Most importantly, we identified for the first time the main prey species of Dolphins stranded in and around Barataria Bay. We investigated differences in diet between sex, season, and timing to the oil spill. We also tested sex and seasonal differences to gather more information regarding diet of Dolphins in this area and to compare with differences observed in other areas.

## Methods

We examined stomach contents from Dolphins that stranded in and near Barataria Bay from May 2010 to December 2012. We selected only stomachs from Dolphins with total length  $\geq 150$  cm for this study. Dolphins smaller than this would likely be nursing, dependent calves and would not provide a representative sample of the adult diet (Wells and Scott 2008). Stranding network responders determined sex in the field or during necropsy. In 2010, stranding responders collected either whole stomachs or stomach contents. In 2011, the stranding network members were instructed to collect whole stomachs only. To avoid bias with incomplete samples, this study only examined whole stomachs. Stomachs were frozen after collection and then thawed to room temperature before they were examined. In the lab, we strained gastric juices through a 0.5-mm sieve and collected remaining stomach contents, which we weighed to the nearest gram. We noted and described the presence of sediment and vegetation. We visually assessed and assigned sediment to one of the following categories: mud—fine particles, often difficult to separate from other stomach contents; sand—small to medium sized particles; and shell fragments—broken pieces of shells, largest of the sediment types found in stomachs. We separated prey parts for identification following methods outlined in Bowen (2011) and Gannon and Waples (2004). Otoliths were cleaned, dried, and stored at room temperature; squid beaks were cleaned and stored in 70% ethanol.

We identified and counted the separated prey parts. Otoliths were identified to genus and species when possible using Baremore and Bethea (2010), Barros (1993), and otolith reference collections at Mote Marine Laboratory and Virginia Aquarium and Marine Science Center independently by 2 trained observers. If the species identifications conflicted, then the entire group of 5 observers (S. Bowen-Stevens, D. Gannon, R. Hazelkorn, G. Lovewell, and K. Volker) worked together and identified the otolith to species, genus, or family. If an otolith could not be identified or was too damaged to be identified, we categorized it as an unknown fish. Otolith counts from each stomach were completed independently by 2 trained observers. Counts that differed by more than 1 for total counts under 10 or more than 10% for counts above 10 were re-counted. Otherwise, we used the average of the otolith counts for the total count. We determined the total number of fish for each stomach by using the total count of otoliths of the same species divided by 2. If otoliths were not present but there were fish parts, such as vertebrae or scales, in the stomach, then we estimated the prey count to be 1 unknown fish, or we used the count of vertebral columns. We identified squid beaks found in Dolphin stomachs using Clarke (1986) and the cephalopod reference collection at Rosenstiel School of Marine and Atmospheric Science, University of Miami. Lower squid beaks are more readily identifiable to species and families (Clarke 1986). Thus, we used only lower beaks for identification to the lowest taxonomic level possible and identified upper beaks to order. We counted the number of upper and lower squid beaks and used the higher of the two to determine the total number of squid. We identified shrimp to family; further identification was not attempted because most specimens were badly damaged or missing parts. We determined the number of shrimp using

the count of complete telsons. If only shrimp pieces were present (without any telsons), then we estimated the count of shrimp to be 1.

For the analysis, we defined seasons as follows: winter = December–February, spring = March–May, summer = June–August, and fall = September–November. We calculated average Dolphin length, stomach contents weight, and number of prey items by stranding year, season, and sex and compared these data across seasons and years using Kruskal–Wallis tests. We examined differences between the sexes using the Mann–Whitney U test. To identify if younger, juvenile Dolphins may be overrepresented in sample groupings by year or season, we tested differences in Dolphin body length using these statistics.

Prey importance was expressed using 2 metrics: frequency of occurrence (%O) and percentage of numerical abundance (%N). Using only stomachs containing prey items, we calculated %O and %N for prey grouped by family and by prey identified to species or lowest taxonomic group possible. We calculated the %O by dividing the number of stomachs with a particular prey by the total number of non-empty stomachs. This metric measured how widespread the consumption of a particular prey item was among a population of predators, irrespective of the number or size of prey consumed. We compared %O among stomachs grouped by season and sex. We calculated %N by dividing the number of a particular prey item by the total number of prey (from all species) found in each stomach, and averaged across all non-empty stomachs. This metric is a measure of the number of individual prey items consumed by a predator population, but it is vulnerable to biases caused by individual predators who eat a disproportionate amount of small prey (Bigg and Fawcett 1985, Hyslop 1980). We calculated standard deviation for %N values. In Microsoft Excel 2010 (Redmond, WA), we used Mann–Whitney U tests to evaluate differences in numerical abundance between sexes and Kruskal–Wallis tests to examine differences in numerical abundances of prey among seasons first for prey identified to family then by prey identified to the lowest taxonomic group identified. Because only 3 whole stomachs were collected in the 2010 calendar year, we used Mann–Whitney U tests to investigate differences in numerical abundance of prey family between stomachs collected the first year after the oil spill (20 April 2010–19 April 2011,  $n = 12$ ) to stomachs collected the second year after the spill (20 April 2011–19 April 2012,  $n = 18$ ).

## Results

A total of 37 whole stomachs were examined. Four stomachs had no hard parts or tissues to identify, and 1 stomach contained only milk (male, 161.3 cm). Empty stomachs were observed in spring ( $n = 3$ ) and winter ( $n = 1$ ). Three of the empty stomachs were from Dolphins  $\leq 165$  cm in length, and 1 empty stomach was from a 256.5-cm individual. Stomachs were evenly distributed by sex (Table 1). A total of 22 stomachs had at least 1 type of sediment mixed in the contents. The types of sediment observed were mud ( $n = 4$ , 10.8% of stomachs), sand ( $n = 17$ , 46.0%), and shell fragments ( $n = 2$ , 5.4%). Vegetation or detritus was found in 3 stomachs. On average, stomachs from Barataria Bay strandings had 224.9 prey items (min–max =

1–1740; Table 2). There were no significant differences in the total lengths of Dolphins by season or year (Table 2). Males were significantly larger than females ( $U = 5.02$ ;  $P = 0.025$ ; Table 2). However, neither stomach content weight nor number of prey items differed significantly between the sexes (Table 2). The average stomach content weight was 318.3 g (min–max = <1–1968 g; Table 2). Stomachs collected during summer had the lowest average content weight (66.9 g) and smallest average number of prey items (48.3); however, neither were significantly different by season (Table 2).

The most important prey in terms of frequency of occurrence and numerical abundance of all 37 dolphin stomachs collected in Barataria Bay from 2010 to 2012 were Sciaenidae (croakers). Sciaenidae, unknown fish, and Penaeidae (shrimp) were the most frequently observed prey groups (%O = 94.6, 86.5, and 48.6, respectively; Table 3). From the Sciaenidae family, *Micropogonias*

Table 1. Total number of whole stomachs containing prey items collected from *Tursiops truncatus* (Common Bottlenose Dolphin) that stranded near Barataria Bay, LA, from 2010 to 2012. Stomach count is broken down by calendar year, season, and sex.

Category	Winter	Spring	Summer	Fall	Total
Calendar Year					
2010	2	0	0	1	3
2011	5	5	6	4	20
2012	7	1	3	3	14
Sex					
Female	6	2	5	4	17
Male	8	4	4	4	20
Total	14	6	9	8	37

Table 2. Mean  $\pm$  standard deviation of total length, stomach contents weigh, and count of prey items of *Tursiops truncatus* (Common Bottlenose Dolphin) from Barataria Bay, LA, by year collected, season, and sex.  $n$  is the number of whole stomachs in each category. \*indicates Kruskal–Wallis or Mann–Whitney  $P$ -values  $< 0.05$ .

Category	$n$	Total length (cm)	Stomach contents (g)	Prey count
Total	37	216.5 $\pm$ 29.4	318.3 $\pm$ 499.7	224.9 $\pm$ 358.1
Year				
2010	3	190.8 $\pm$ 20.7	245.3 $\pm$ 338.1*	209.3 $\pm$ 186.6
2011	20	217.7 $\pm$ 29.0	481.9 $\pm$ 607.0*	257.3 $\pm$ 418.4
2012	14	220.2 $\pm$ 30.4	100.1 $\pm$ 203.8*	181.9 $\pm$ 300.3
Season				
Winter	14	218.0 $\pm$ 27.6	371.9 $\pm$ 587.1	366.0 $\pm$ 533.4
Spring	6	208.3 $\pm$ 26.3	301.5 $\pm$ 188.2	240.5 $\pm$ 193.4
Summer	9	216.4 $\pm$ 29.2	66.9 $\pm$ 80.1	48.3 $\pm$ 54.9
Fall	8	220.1 $\pm$ 38.5	519.8 $\pm$ 691.1	164.8 $\pm$ 128.6
Sex				
Female	17	205.7 $\pm$ 29.2*	344.2 $\pm$ 605.7	257.6 $\pm$ 469.3
Male	20	225.7 $\pm$ 26.9*	296.2 $\pm$ 403.7	197.1 $\pm$ 236.0

Table 3. Frequency of occurrence (%O) and numerical abundance (%N)  $\pm$  standard deviation for prey family or order and the lowest possible taxonomic unit (genus or species) from stomachs of 37 *Tursiops truncatus* (Common Bottlenose Dolphin) collected from Barataria Bay, LA, between 2010 and 2012. *n* represents the total number of stomachs containing each prey type. Presented in order of frequency of occurrence. [Table continued on following page.]

Prey	Common name	<i>n</i>	%O	%N
Sciaenidae	Croaker	35	94.6%	59.3 $\pm$ 35.5%
<i>Micropogonias undulatus</i> (L.)	Atlantic Croaker	32	86.5%	34.2 $\pm$ 33.4%
<i>Cynoscion</i> spp.	Seatrout	28	75.7%	11.1 $\pm$ 22.8%
<i>Leiostomus xanthurus</i> Lacepède	Spot	14	37.8%	3.0 $\pm$ 6.7%
Sciaenidae other	Croaker	14	37.8%	7.8 $\pm$ 20.2%
<i>Menticirrhus</i> sp.	Kingfish	9	24.3%	1.1 $\pm$ 3.5%
<i>Stellifer lanceolatus</i> (Holbrook)	Star Drum	5	13.5%	0.5 $\pm$ 1.7%
<i>Bairdiella chrysoura</i> (Lacepède)	Silver Perch	4	10.8%	0.2 $\pm$ 0.7%
<i>Larimus fasciatus</i> Holbrook	Banded Drum	2	5.4%	0.8 $\pm$ 4.6%
<i>Pogonias cromis</i> (L.)	Black Drum	2	5.4%	0.6 $\pm$ 3.3%
Unknown Fish	Unidentified otoliths	32	86.5%	14.4 $\pm$ 21.4%
Penaecidae	Penaecid shrimp	18	48.6%	2.2 $\pm$ 5.8%
Engraulidae	Anchovy	17	45.9%	12.8 $\pm$ 24.4%
<i>Anchoa</i> spp.	Anchovy	17	45.9%	12.8 $\pm$ 24.4%
Clupeidae	Herring	16	43.2%	2.1 $\pm$ 5.5%
Clupeidae other	Herring	16	43.2%	1.8 $\pm$ 5.0%
<i>Brevoortia</i> sp.	Menhaden	2	5.4%	0.3 $\pm$ 1.6%
Mugilidae	Mullet	11	29.7%	3.3 $\pm$ 16.4%
<i>Mugil</i> sp.	Mullet	11	29.7%	3.3 $\pm$ 16.4%
Ariidae	Sea catfish	10	27.0%	2.4 $\pm$ 9.3%
Ariidae other	Catfish	9	24.3%	2.3 $\pm$ 9.3%
<i>Ariopsis felis</i> (L.)	Hardhead Catfish	1	2.7%	0.1 $\pm$ 0.6%
Loliginidae	Inshore squid	9	24.3%	1.1 $\pm$ 4.2%
<i>Lolliguncula brevis</i> (Blainville)	Brief Squid	8	21.6%	1.1 $\pm$ 4.2%
Loliginidae other	Inshore squid	1	2.7%	<0.1 $\pm$ 0.2%
Synodontidae	Lizardfish	6	16.2%	0.4 $\pm$ 1.9%
<i>Synodus foetens</i> (L.)	Inshore Lizardfish	4	10.8%	0.3 $\pm$ 1.9%
Synodontidae other	Lizardfish	2	5.4%	<0.1 $\pm$ 0.1%
Phycidae	Hake	5	13.5%	1.0 $\pm$ 4.4%
<i>Urophycis</i> sp.	Hake	5	13.5%	1.0 $\pm$ 4.4%
Sparidae	Porgy	5	13.5%	0.1 $\pm$ 0.2%
<i>Lagodon rhomboids</i> (L.)	Pinfish	5	13.5%	0.1 $\pm$ 0.2%
Stromateidae	Butterfish	4	10.8%	0.4 $\pm$ 1.8%
<i>Peprilus alepidotus</i> (L.)	Harvestfish	4	10.8%	0.4 $\pm$ 1.8%
Bothidae	Flatfish	3	8.1%	0.1 $\pm$ 0.6%
Bothidae other	Flatfish	2	5.4%	<0.1 $\pm$ 0.1%
<i>Paralichthys lethostigma</i> Jordan & Gilbert	Southern Flounder	1	2.7%	<0.1 $\pm$ 0.2%
<i>Paralichthys</i> spp.	Flounder	1	2.7%	0.1 $\pm$ 0.2%
Haemulidae	Grunts	1	2.7%	0.3 $\pm$ 2.1%
<i>Orthopristis</i> sp.	Grunts	1	2.7%	0.3 $\pm$ 2.1%



*undulatus* L. (Atlantic Croaker; %O = 86.5) and *Cynoscion* spp. (seatrout; %O = 75.7) were the most frequently observed species (Table 3). The most numerically abundant prey groups in the stomachs of Barataria Bay Dolphins were Sciaenidae (%N = 59.3 ± 35.5), unknown fish (%N = 14.4 ± 21.4), and Engraulidae (anchovy; %N = 12.8 ± 24.4) (Table 3). Atlantic Croaker (%N = 34.2 ± 33.4), *Anchoa* spp. (anchovy; %N = 12.8 ± 24.4), and seatrout (%N = 11.1 ± 22.8) were the most abundant species (Table 3).

There were differences in prey frequency and numerical abundance among seasons. Sciaenidae were present in 85.7% of stomachs collected during winter and in all stomachs collected in the spring, summer, and fall (Table 4). From the family Sciaenidae, seatrout were present in half of the stomachs collected in winter (%O

Table 3, continued.

Prey	Common name	<i>n</i>	%O	%N
Lutjanidae	Snapper	1	2.7%	0.1 ± 0.3%
<i>Lutjanus</i> sp.	Snapper	1	2.7%	0.1 ± 0.3%
Triglidae	Searobin	1	2.7%	<0.1 ± 0.1%
<i>Prionotus</i> sp.	Searobin	1	2.7%	<0.1 ± 0.1%
Achiridae	Sole	1	2.7%	<0.1 ± 0.1%
<i>Trinectes maculatus</i> (Bloch & Schneider)	Hogchocker	1	2.7%	<0.1 ± 0.1%

Table 4. Frequency of occurrence (%O) by season for prey family or order from stomachs of 37 *Tursiops truncatus* (Common Bottlenose Dolphin) collected from Barataria Bay, LA. In parentheses just below the season name, *n* represents the total number of stomachs sampled that season, and then below as a column, it represents the number of stomachs containing each prey type within that season.

Prey	Common name	Winter ( <i>n</i> = 14)		Spring ( <i>n</i> = 6)		Summer ( <i>n</i> = 9)		Fall ( <i>n</i> = 8)	
		<i>n</i>	%O	<i>n</i>	%O	<i>n</i>	%O	<i>n</i>	%O
Sciaenidae	Croaker	12	85.7%	6	100.0%	9	100.0%	8	100.0%
Unknown Fish		12	85.7%	6	100.0%	7	77.8%	7	87.5%
Penaeidae	Penaeid shrimp	7	50.0%	5	83.3%	1	11.1%	5	62.5%
Engraulidae	Anchovy	9	64.3%	5	83.3%	-	-	3	37.5%
Clupeidae	Herring	5	35.7%	4	66.7%	4	44.4%	3	37.5%
Mugilidae	Mullet	8	57.1%	1	16.7%	-	-	2	25.0%
Ariidae	Catfish	4	28.6%	3	50.0%	3	33.3%	-	-
Loliginidae	Inshore squid	4	28.6%	1	16.7%	1	11.1%	3	37.5%
Synodontidae	Lizardfish	1	7.1%	2	33.3%	1	11.1%	2	25.0%
Phycidae	Hake	4	28.6%	1	16.7%	-	-	-	-
Sparidae	Porgy	2	14.3%	-	-	-	-	3	37.5%
Stromateidae	Butterfish	1	7.1%	2	33.3%	-	-	1	12.5%
Bothidae	Flatfish	2	14.3%	-	-	-	-	1	12.5%
Crustacea	Crab	2	14.3%	-	-	-	-	-	-
Haemulidae	Grunts	1	7.1%	-	-	-	-	-	-
Lutjanidae	Snapper	1	7.1%	-	-	-	-	-	-
Triglidae	Searobin	-	-	-	-	1	11.1%	-	-
Achiridae	Sole	1	7.1%	-	-	-	-	-	-
Cephalopoda	Squid	-	-	-	-	-	-	1	12.5%

= 50) and found in all stomachs from spring and summer (%O = 100). Engraulidae, including *Anchoa* spp., were not observed in the stomachs of Dolphins collected in the summer but were among the most frequently prey found in stomachs collected during spring (%O = 83.3) and winter (%O = 64.3) (Table 4). Mugilidae (mullet), including *Mugil* spp., occurred most frequently during winter months (%O = 57.1) and were not present in stomachs collected during summer months (Table 4). The numerical abundance of Sciaenidae ( $H = 9.18$ ,  $P = 0.027$ ), Engraulidae ( $H = 12.90$ ,  $P = 0.005$ ), and Mugilidae ( $H = 8.42$ ,  $P = 0.038$ ) varied by season (Fig. 1). The numerical abundance of Sciaenidae was 25% to 35% lower in winter months than the rest of the year (Fig. 1). Abundance of seatrout differed significantly among seasons ( $H = 13.40$ ,  $P = 0.004$ ). Seatrout were more abundant in the summer (%N =  $26.9 \pm 29.4$ ) than winter and spring (%N =  $3.2 \pm 8.3$  and  $2.1 \pm 1.5$ , respectively). Higher numerical abundances of Engraulidae were observed during spring and winter,  $5.7 \pm 5.1\%$  and  $30.5 \pm 32.8\%$ , respectively (Fig. 1). Mugilidae, including *Mugil* spp., had the highest numerical abundance ( $8.2 \pm 26.5\%$ ) during winter months, and were less than  $1.0 \pm 1.6\%$  in spring and fall (Fig. 1).

Males and females did not have significant differences in prey numerical abundance. The most common prey family for females and males in terms of frequency

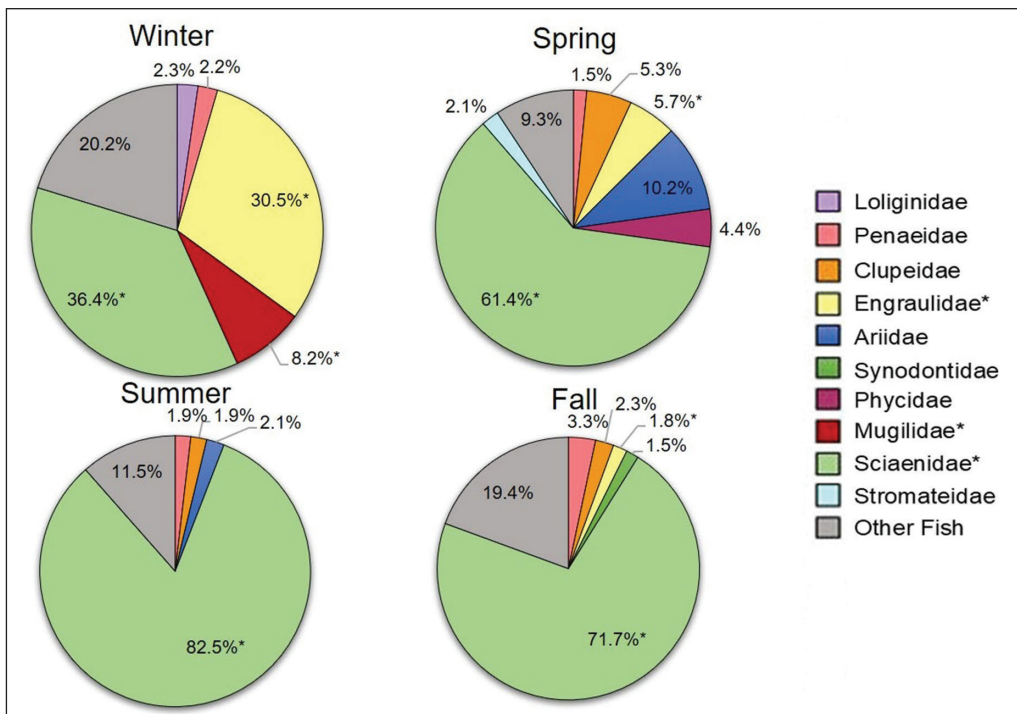


Figure 1. Numerical abundance (%) of prey families identified in stomachs from *Tursiops truncatus* (Common Bottlenose Dolphin) that stranded in winter ( $n = 14$ ), spring ( $n = 6$ ), summer ( $n = 9$ ), and fall ( $n = 8$ ) near Barataria Bay, LA. \*indicates Kruskal–Wallis  $P$ -values  $< 0.05$ . “Other Fish” category includes prey identified that had numerical abundances  $\leq 1.0\%$  and unidentifiable fish.

and numerical abundance was Sciaenidae (%O and %N were 94.1% and  $58.9 \pm 35.5\%$  for females and 95.0% and  $59.6 \pm 36.4\%$  for males, respectively). The differences in numerical abundance of other prey between females and males were no larger than 7 percentage points.

The frequencies of Penaeidae, Engraulidae, Mugilidae, and Phycidae in stomachs collected during the second year after the DWH oil spill were less than half of those from stomachs collected in the first year post DWH. The numerical abundances of Penaeidae ( $H = 13.13$ ,  $P < 0.001$ ), Engraulidae ( $H = 4.64$ ,  $P = 0.031$ ), Mugilidae ( $H = 6.68$ ,  $P = 0.010$ ), and Phycidae (Hake;  $H = 4.37$ ,  $P = 0.037$ ) differed significantly between the first and second year following DWH. The abundance of Penaeidae, Engraulidae, and Phycidae decreased from  $3.6 \pm 7.1\%$ ,  $18.7 \pm 26.2\%$ , and  $3.0 \pm 7.6\%$  in the first year after DWH to  $0.1 \pm 0.3\%$ ,  $12.5 \pm 26.4\%$ , and  $<0.1 \pm 0.2\%$  in the second year after DWH, respectively. Mugilidae, specifically *Mugil* spp., decreased in numerical abundance from  $9.9 \pm 28.4\%$  to  $0.1 \pm 0.3\%$  between those 2 years.

## Discussion

This study is the first to report stomach-content findings from Dolphins that stranded in and near Barataria Bay, LA. Fish in the family Sciaenidae (especially Atlantic Croaker and seatrout) were the most frequently occurring and numerically abundant prey in Dolphin stomachs. In addition, seasonal differences in consumption of prey species were observed. Finally, about 65% of the items in the stomachs were benthic and demersal species, which could lead to long-term oil exposure.

Similar to other studies of Dolphin diets in the southeastern United States, Sciaenidae were the most frequently occurring and numerically abundant prey of Dolphins in Barataria Bay, and Penaeidae were one of the most frequent prey families, which is similar to other Dolphin diet studies in the Gulf of Mexico (Barros 1993, Barros and Odell 1990, Barros and Wells 1998, Bowen 2011, Gannon and Waples 2004, Pate 2008). Within the Sciaenidae family, the most abundant species in stomachs from Barataria Bay were Atlantic Croaker and seatrout, which differs slightly from other areas in the Gulf of Mexico but is similar to findings in North Carolina. For example, *Leiostomus xanthurus* (Spot) was the most abundant Sciaenid in Dolphin stomachs from the Florida Panhandle (Bowen 2011), whereas Atlantic Croaker and seatrout were also the most important prey in terms of frequency, numeric abundance, and proportion of reconstructed mass in Dolphins stranded in North Carolina (Gannon and Waples 2004). This variability in Sciaenid species could be due to regional differences in prey availability. Shrimp were observed in almost half of the stomachs in this study, which was higher than the frequency of shrimp in Dolphins' stomachs from Texas (28.0%; Barros and Odell 1990) and the Northwest Florida Panhandle (31.8%; Bowen 2011). While the frequency of shrimp was high, their abundance as calculated in this study was low, which could be due to the indigestibility of the chitinous exoskeletons of crustaceans.

The high frequency and abundance of anchovies in the diet of Barataria Bay Dolphins was an unexpected finding. The frequency of anchovies in this study

(45.9%) is the highest reported among studies of Dolphin stomach contents collected in the bays and estuaries of the southeastern United States (Barros 1993, Barros and Odell 1990, Barros and Wells 1998, Bowen 2011, Gannon and Waples 2004, Pate 2008). Numerical abundance of anchovies was higher in Dolphin stomachs from Barataria Bay than in Dolphins stranded along the Northwest Florida Panhandle (0.4%, Bowen 2011). No anchovies were reported in stomachs collected from Dolphins stranded in Sarasota, FL (Barros and Wells 1998, Berens McCabe et al. 2010). While there are many similarities in prey species of Dolphins across the southeastern United States, there are differences in diet among Dolphins in Louisiana versus Florida and Texas.

One explanation for the high number of anchovies could be that they came indirectly from the stomachs of higher trophic-level Dolphin prey species. Anchovies represent a significant portion of the diet of *Cynoscion nebulosus* (Cuvier in Cuvier and Valenciennes) (Spotted Seatrout) in Barataria Bay (Simonsen and Cowan 2013). If anchovy otoliths found in Dolphin stomachs of this study came from their prey, such as seatrout, then the numerical abundance of anchovy and seatrout would be correlated. However, in this study, seatrout were more numerically abundant in the stomachs of Dolphins that stranded in summer, a time when anchovies were completely absent in stomachs examined. Therefore, it seems likely that Dolphins in Barataria Bay feed directly on anchovies. Due to a lack of samples prior to the oil spill, we cannot determine if anchovies are a typical prey item of Dolphins in this area, or if this is a result of a prey shift following environmental disruptions during 2010 to 2012.

Changes in diets of other marine organisms, unrelated to Dolphins, have been documented following oil spills (Brzorad and Burger 1994, Tarnecki and Patterson 2015). Diet and trophic level changes were identified for *Lutjanus campechanus* Poey (Red Snapper) following the DWH oil spill (Tarnecki and Patterson 2015). After the spill, Red Snapper consumed less zooplankton and more benthic invertebrates and fish than before DWH (Tarnecki and Patterson 2015). In our study, there was a decrease in the consumption of Engraulidae, Mugilidae, Penaeidae, and Phycidae over the 2 years following the DWH oil spill. However, due to lack of knowledge on diet of Dolphins in Barataria Bay prior to the oil spill in April 2010, and the small sample size of Dolphin stomachs from the 2 years following the spill, it is not known whether these potential changes in diet are biologically significant.

Dolphins in Barataria Bay consumed anchovies and mullet primarily during winter and spring and seatrout primarily during summer and fall. The seasonality of anchovies and seatrout in the diet of Dolphins correlates with the seasonal occurrences of these fish in the bay (Simonsen et al. 2013). *Mugil cephalus* L. (Striped Mullet) in the northwestern Gulf of Mexico congregate in schools in the lower estuary before spawning offshore during the months of October to January (Gunter 1945). Mullet spawning season overlaps with the presence of mullet in Dolphin stomachs from this study.

Acoustic activity of fish could also explain seasonal patterns in prey consumption by Dolphins in Barataria Bay. Several fish species, particularly the sciaenids,

consumed by Dolphins in this study are soniferous (Ramcharitar et al. 2006). High occurrences of soniferous prey were also identified in Dolphin stomachs from other studies (e.g., Barros and Wells 1998, Berens McCabe et al. 2010, Bowen 2011, Gannon and Waples 2004). Evidence suggests that Dolphins use passive listening to detect prey (Berens McCabe et al. 2010, Gannon et al. 2005). Many Dolphin prey species, such as seatrout, produce sound only during their spawning season; a notable exception is the Atlantic Croaker, which produces sound year-round (Gannon 2007, Ramcharitar et al. 2006). In Barataria Bay, Spotted Seatrout spawn from mid-March to October, which overlaps with the high abundance of fish in the bay and numeric abundance of seatrout found in Dolphin stomachs collected in summer and fall (Brown-Peterson et al. 2002, Simonsen et al. 2013). Atlantic Croaker were the first and second most numerically abundant prey species found in Dolphin stomachs regardless of the season stomachs were collected (Gannon 2007, Ramcharitar et al. 2006). Seasonal patterns in occurrence and calling behavior of fish in the bay could play a factor in the seasonality of prey observed in this study. The findings of significant seasonal differences in stomach contents of Dolphins highlight the importance of accounting for seasonality when making comparisons in future studies.

Salinity changes in the environment can impact prey availability for Dolphins through spatial displacement and changes in recruitment success (Akin et al. 2003, Baltz et al. 1998, Boeuf and Payan 2001, Gelwick et al. 2001, Lankford and Targett 1994, Rakocinski et al. 1992). During response to the DWH oil spill in 2010, releases of freshwater into Barataria Bay occurred in an attempt to reduce the oiling inside the basin (Martínez et al. 2012). It is unknown if the changes in salinity from this freshwater release had any impact on Dolphin diet during 2010. In this study, we did not test for variances in diet related to fish abundance and salinity changes in the bay because of sample-size limitations and lack of stomach-content data prior to 2010. Currently, there are plans to increase freshwater flow into Barataria Bay in order to rebuild eroding coastlines by introducing sediment from the Mississippi River (CPRA 2012). Data from this study will provide an important baseline for future assessments of the impact of the river diversion on Dolphins.

The presence of benthic and demersal prey (e.g., croakers, drums, seatrouts, and shrimp) and of mud and other sediment in the stomachs of Dolphins in this study suggest that Dolphins forage along the bottom of Barataria Bay. The majority of prey identified from stomachs of Dolphins in Florida and other areas in the Gulf of Mexico were also benthic species (Barros and Odell 1990). The presence of sediment in the stomachs of Dolphins has not been well documented in the literature, and we are unable at this time to compare these findings with stomach analyses from other areas. However, there are unpublished reports of Dolphins in the Barataria Basin “drilling” into the benthos with their rostrum (and presumably foraging) in shallow waters (B. Quigley, National Marine Mammal Foundation, San Diego, CA, unpubl. data) in a manner similar to the crater-feeding behavior of Dolphins in the Bahamas (Rossbach and Herzing 1997). The amount of sediment in Dolphin stomachs in our study was not quantified, though 3 examined stomachs were more

than half full of mud. It would be beneficial to quantify and compare sediment presence in future studies of Dolphin stomachs from Barataria Bay and nearby areas (i.e., estuaries in Louisiana, Mississippi, and Alabama).

Differences in fish life history and physiology can cause differences in oil exposure and uptake of PAHs (Snyder et al. 2015). Fish are affected by oil spills through direct exposure to the gills or skin, indirect exposure through diet, and ecological changes in prey availability or destruction of marsh habitat (Elmgren et al. 1983, Gregg et al. 1997, Whitehead et al. 2012). For demersal fish, exposure to PAH-contaminated sediment and diet of benthic prey are thought to be an important source of oil exposure (MacDonald et al. 2015; Romero et al. 2015, 2016, 2017). If benthic and demersal fish were affected by the heavy oiling of Barataria Bay, then this could impact the Dolphins that consume these fish. The important finding of this study is the identification of prey which provides a figurative puzzle piece to understanding how environmental changes in Barataria Bay could impact the local Dolphin stock.

The presence of sediment in the majority of Dolphin stomachs from this study can be indicative of a route of exposure to oil and PAHs through ingestion. Ingested sediment may lead to long-term exposure as oil and its chemical components can remain buried in sediments for a long time. Turner et al. (2014) found that the concentrations of PAHs in wetland soils remained 33 times higher than pre-DWH levels 3 years after the spill. The same study also estimated that alkanes would reach baseline levels in 2015, but it could take decades for PAHs to go down to pre-spill levels (Turner et al. 2014). Exposure to PAHs has been linked to adrenal deficiencies and impaired immune function in Dolphins in Barataria Bay, and can impair their ability to respond to stressors (Colegrove et al. 2016, Schwacke et al. 2014, Venn-Watson et al. 2015b). Dolphins in and around Barataria Bay may be continuously exposed to weathered oil embedded in sediments through the ingestion of sediments and consumption of benthic and demersal prey for years to come.

In conclusion, this study documented the diet of Dolphins that stranded in Barataria Bay and surrounding waters from 2010 to 2012. This study found some similarities and differences of diet among Dolphins in Barataria Bay compared to those from other areas in the southeastern United States. There were seasonal differences in abundance and frequencies of occurrence in anchovies, mullet, and seatrout that could be related to seasonal variability of prey and/or prey sound-production during spawning. Lastly, benthic prey and presence of sediment indicate that Dolphins in Barataria Bay forage along the bottom of the bay, which could lead to long-term oil exposure. Knowledge of the Louisiana Dolphins' key prey provides a better understanding of exposure to contaminants and baseline data to assess dietary shifts in relation to future manmade or natural changes to the environment. This information is critical for assessing how stressors impact Dolphin stocks and their recovery.

### **Acknowledgments**

This work could not have been conducted without the efforts of the Southeast Region Marine Mammal Stranding Network, including personnel from those agencies working on the

northern Gulf of Mexico UME: Louisiana Department of Wildlife and Fisheries (especially staff from the Fisheries Research Lab in Grand Isle and the Marine Mammal Stranding and Rescue Team) and Audubon Aquarium of the Americas. The authors acknowledge the northern Gulf of Mexico UME Investigative Team and the past and present members of the Working Group for Marine Mammal Unusual Mortality Events. We thank Blair Mase-Guthrie, Elizabeth Stratton, and Lauren Noble for coordination of the SER Marine Mammal Stranding Network, and the following individuals who helped with the stomach data collection: Gina Rappucci, Laura Dias, and Shelby Proie. We are grateful to R. Takeshita, T. Gowan, and 2 anonymous reviewers for their helpful comments and meticulous reviews of the manuscript. Funding for this investigation was provided in part by the NMFS UME contingency fund, NOAA Marine Mammal Health and Stranding Response Program and as part of the Deepwater Horizon oil spill Natural Resource Damage Assessment. The scientific results and conclusions as well as any views of opinions expressed herein are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

### Literature Cited

- Akin S., K.O. Winemiller, and F.P. Gelwick. 2003. Seasonal and spatial variations in fish and microcrustacean assemblage structure in Mad Island Marsh estuary, Texas. *Estuarine, Coastal, and Shelf Science* 57:269–282.
- Baltz D.M., J.W. Fleeger, C.F. Rakocinski, and J.N. McCall. 1998. Food, density, and microhabitat: Factors affecting growth and recruitment potential of juvenile saltmarsh fishes. *Environmental Biology of Fishes* 53:89–103.
- Baremore, I.E., and D.M. Bethea. 2010. A guide to otoliths from fishes of the Gulf of Mexico. NOAA Technical Memorandum. NMFS-SEFSC-599. Panama City, FL. 102 pp.
- Barros, N.B. 1993. Feeding ecology and foraging strategies of Bottlenose Dolphins on the central east coast of Florida. Ph.D. Dissertation. University of Miami, Coral Gables, FL. 328 pp.
- Barros, N.B., and D.K. Odell. 1990. Food habits of Bottlenose Dolphins in the Southeastern United States. Pp. 309–328, *In* S. Leatherwood and R.R. Reeves (Eds.). *The Bottlenose Dolphin*. Academic Press, San Diego, CA. 672 pp.
- Barros, N.B., and R.S. Wells. 1998. Prey and feeding patterns of resident Bottlenose Dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Journal of Mammalogy* 79:1045–1059.
- Berens McCabe, E., D.P. Gannon, N.B. Barros, and R.S. Wells. 2010. Prey selection in a resident Common Bottlenose Dolphin (*Tursiops truncatus*) community in Sarasota Bay, Florida. *Marine Biology* 157(5):931–942.
- Beyer, J., G. Jonsson, C. Porte, M.M. Krahn, and F. Arises. 2010. Analytical methods for determining metabolites of polycyclic aromatic hydrocarbon (PAH) pollutants in fish bile: A review. *Environmental Toxicology and Pharmacology* 30(3):224–244.
- Bigg, M.A., and I. Fawcett. 1985. Two biases in diet determination of Northern Fur Seals (*Callorhinus ursinus*). Pp. 284–291, *In* J.R. Reddington, R.J.H. Beverton, and D. Lavigne (Eds.). *Marine Mammals and Fisheries*. George Allen and Unwin, London UK. 354 pp.
- Boeuf, G., and P. Payan. 2001. How should salinity influence fish growth? *Comparative Biochemistry and Physiology – Part C: Toxicology* 130:411–423.
- Bowen, S.R. 2011. Diet of Bottlenose Dolphins (*Tursiops truncatus*) from the Northwest Florida Panhandle and foraging behavior near Savannah, Georgia. M.Sc. Thesis. Savannah State University, Savannah, GA. 162 pp.

- Brown-Peterson, N.J., M.S. Peterson, D.L. Nieland, M.D. Murphy, R.G. Taylor, and J.R. Warren. 2002. Reproductive biology of female Spotted Seatrout, *Cynoscion nebulosus*, in the Gulf of Mexico: Differences among estuaries? *Environmental Biology of Fishes* 63:405–415.
- Brzorad, J.N., and J. Burger. 1994. Fish and shrimp populations in the Arthur Kill. Pp. 178–200, *In* J. Burger (Ed.). *Before and after an Oil Spill: The Arthur Kill*. Rutgers University Press, Rutgers, NJ. 305 pp.
- Carls, M.G., S.D. Rice, and J.E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: Part 1. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific Herring (*Clupea pallasii*). *Environmental Toxicology and Chemistry* 18:481–493.
- Clarke, M.R. 1986. *A Handbook for the Identification of Cephalopod Beaks*. Clarendon Press, Oxford, UK. 220 pp.
- Coastal Protection and Restoration Authority (CPRA). 2012. *Louisiana’s comprehensive master plan for a sustainable coast*. State of Louisiana, Baton Rouge, LA. 190 pp.
- Colegrove, K.M., S. Venn-Watson, J. Litz, M.J. Kinsel, K.A. Terio, E. Fougères, R. Ewing, D.A. Pabst, et al. 2016. Fetal distress and in utero pneumonia in perinatal dolphins during the Northern Gulf of Mexico unusual mortality event. *Diseases of Aquatic Organisms* 119:1–16.
- Dunsha, G., N.B. Barros, E.J. Berens, N.J. Gales, M.A. Hindell, S.N. Jarman, and R.S. Wells. 2013. Stranded dolphin stomach contents represent the free-ranging population’s diet. *Biology Letters* 9:20121036.
- Elmgren, R., S. Hansson, U. Larsson, B. Sundelin, and P.D. Boehm. 1983. The “Tsesis” oil spill: Acute and long-term impact on the benthos. *Marine Biology* 73:51–65.
- Fleeger, J.W., K.R. Carman, and R.M. Nisbet. 2003. Indirect effects of contaminants in aquatic ecosystems. *Science of the Total Environment*. 317:207–233.
- Gannon, D.P. 2007. Acoustic behavior of Atlantic Croaker, *Micropogonias undulatus* (Sciaenidae). *Copeia* 2007(1):193–204.
- Gannon, D.P., and D.M. Waples. 2004. Diets of coastal Bottlenose Dolphins from the US Mid-Atlantic coast differ by habitat. *Marine Mammal Science* 20:527–545.
- Gannon, D.P., N.B. Barros, D.P. Nowacek, A.J. Read, D.M. Waples, and R.S. Wells. 2005. Prey detection by Bottlenose Dolphins, *Tursiops truncatus*: An experimental test of the passive listening hypothesis. *Animal Behavior* 69(3):709–720.
- Gelwick, F.P., S. Akin, D.A. Arrington, and K.O. Winemiller. 2001. Fish assemblage structure in relation to environmental variation in a Texas gulf coastal wetland. *Estuaries* 24:285–296.
- Gregg, J.C., J.W. Fleeger, and K.R. Carman. 1997. Effects of suspended, diesel contaminated sediment on feeding rate in the Darter Goby, *Gobionellus boleosoma* (Teleostei: Gobiidae). *Marine Pollution Bulletin* 34:269–275.
- Gunter, G. 1945. *Studies on marine fishes of Texas*. Publications of the Institute of Marine Science. 1(1). 190 pp.
- Hayes, S.A., E. Josephson, K. Maze-Foley, and P.E. Rosel. 2019. US Atlantic and Gulf of Mexico marine mammal stock assessments – 2018. NOAA Tech Memo. NMFS-NE-258. Woods Hole, MA. 306 pp.
- Hoese, H.D., and R.H. Moore. 1998. *Fishes of the Gulf of Mexico, Texas, Louisiana, and Adjacent Waters*. Second Edition Texas A & M University Press, TX. 422 pp.
- Hohn, A.A., L. Thomas, R.H. Carmichael, J. Litz, C. Clemons-Chevis, S.F. Shippee, C. Sinclair, S. Smith, T.R. Speakman, M.C. Tumlin, and E.S. Zolman. 2017. Assigning stranded Bottlenose Dolphins to source stocks using stable isotope ratios following the Deepwater Horizon oil spill. *Endangered Species Research* 33:235–252.



- Hyslop E.J. 1980. Stomach contents analysis: A review of methods and their application. *Journal of Fish Biology* 17:411–429.
- Irvine, A.B., and R.S. Wells. 1972. Results of attempts to tag Atlantic Bottlenose Dolphins (*Tursiops truncatus*). *Cetology* 13:1–5.
- Irvine, A.B., M.D. Scott, R.S. Wells, and J.H. Kaufmann. 1981. Movements and activities of the Atlantic Bottlenose Dolphin, *Tursiops truncatus*, near Sarasota, Florida. *Fishery Bulletin* 79(4):671–688.
- Jobling, M., and A. Breiby. 1986. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. *Sarsia* 71:265–274.
- Kocan, R.M., J.E. Hose, E.D. Brown, and T.T. Baker. 1996. Pacific Herring (*Clupea pallasii*) embryo sensitivity to Prudhoe Bay petroleum hydrocarbons: Laboratory evaluation and in situ exposure at oiled and unoiled sites in Prince William Sound. *Canadian Journal of Fisheries and Aquatic Sciences* 53:2366–2375.
- Lankfort, T.E., Jr., and T.E. Targett. 1994. Suitability of estuarine nursery zones for juvenile Weakfish (*Cynoscion regalis*): Effects of temperature and salinity on feeding, growth, and survival. *Marine Biology* 119:611–620.
- Lewis, J.P., J.H. Tarnecki, S.B. Garner, D.D. Chagaris, and W.F. Patterson III. 2020. Changes in reef fish community structure following the Deepwater Horizon Oil Spill. *Scientific Reports* 10:5621.
- Litz, J.A., M.A. Baran, S.R. Bowen-Stevens, R.H. Carmichael, K.M. Colegrove, L.P. Garrison, S.E. Fire, E.M. Fougères, et al. 2014. Review of historical unusual mortality events (UMEs) in the Gulf of Mexico (1990–2009): Providing context for the multi-year Northern Gulf of Mexico cetacean UME declared in 2010. *Diseases of Aquatic Organisms* 112:161–175.
- MacDonald, I.R., O. Garcia-Pineda, A. Beet, S. Daneshgar Asl, L. Feng, G. Graettinger, D. French-McCay, J. Holmes, et al. 2015. Natural and unnatural oil slicks in the Gulf of Mexico. *Journal of Geophysical Research: Oceans* 120(12):8364–8380.
- Mager, E.M., A.J. Esbaugh, J.D. Stieglitz, R. Hoening, C. Bodinier, J.P. Incardona, N.L. Scholz, D.D. Benetti, and M. Grosell. 2014. Acute embryonic or juvenile exposure to Deepwater Horizon crude oil impairs the swimming performance of Mahi-mahi (*Coryphaena hippurus*). *Environmental Science and Technology* 48:7053–7061.
- Martínez, M.L., R.A. Feagin, K.M. Yeager, J. Day, R. Costanza, J.A. Harris, R.J. Hobbs, J. Lopez-Portillo, I.J. Walker, E. Higgs, P. Moreno-Casasola, J. Sheinbaum, and A. Yáñez-Arancibia. 2012. Artificial modifications of the coast in response to the Deepwater Horizon oil spill: Quick solutions or long term liabilities? *Frontiers in Ecology and the Environment* 10:44–49.
- McNutt, M.R., R. Camilli, T.J. Crone, G.D. Guthrie, P.A. Hsieh, T.B. Ryerson, O. Savas, and F. Shaffer. 2011. Review of flow rate estimates of the Deepwater Horizon oil spill. *Proceedings of the National Academy of Sciences of the United States of America* 109:20260–20267.
- Michel J., E.H. Owens, S. Zengel, A. Graham, Z. Nixon, T. Allard, W. Holton, P.D. Reimer, et al. 2013. Extent and Degree of Shoreline Oiling: Deepwater Horizon Oil Spill, Gulf of Mexico, USA. *PLoS ONE* 8(6):e65087. <https://doi.org/10.1371/journal.pone.0065087>.
- Murawski, S.A., W.T. Hogarth, E.B. Peebles, and L. Barbeiri. 2014. Prevalence of external skin lesions and Polycyclic Aromatic Hydrocarbon concentrations in Gulf of Mexico fishes, post-Deepwater Horizon. *Transactions of the American Fisheries Society* 143(4):1084–1097.

- National Oceanic and Atmospheric Administration (NOAA). 2019. 2010–2014 Cetacean unusual mortality event in northern Gulf of Mexico (closed). Available online at <https://www.fisheries.noaa.gov/national/marine-life-distress/2010-2014-cetacean-unusual-mortality-event-northern-gulf-mexico>. Accessed 20 September 2020.
- Pasparakis, C., A.J. Esbaugh, W. Burggren, and M. Grosell. 2019. Physiological impacts of Deepwater Horizon oil on fish. *Comparative Biochemistry and Physiology Part C: Toxicology and Pharmacology* 224:108558.
- Pate, S.M. 2008. Stomach-content analysis of stranded Bottlenose Dolphins (*Tursiops truncatus*) in South Carolina. M.Sc. Thesis. College of Charleston, Charleston, SC. 121 pp.
- Pulster, E.L., K. Main, D. Wetzel, and S. Murawski. 2017. Species-specific metabolism of Naphthalene and Phenanthrene in 3 species of marine teleosts exposed to Deepwater Horizon crude oil. *Environmental Toxicology and Chemistry* 36(11):3168–3176.
- Rakocinski, C.F., D.M. Baltz, and J.W. Fleeger. 1992. Correspondence between environmental gradients and the community structure of marsh-edge fishes in a Louisiana estuary. *Marine Ecology Progress Series* 80:135–148.
- Ramcharitar, J., D.P. Gannon, and A.N. Popper. 2006. Bioacoustics of fishes of the family Sciaenidae (croakers and drums). *Transactions of the American Fisheries Society* 135:1409–1431.
- Romero, I.C., P.T. Schwing, G.R. Brooks, R.A. Larson, D.W. Hastings, G. Ellis, E.A. Goddard, and D.J. Hollander. 2015. Hydrocarbons in deep-sea sediments following the 2010 Deepwater Horizon blowout in the Northeast Gulf of Mexico. *PLoS One* 10(5):e0128371.
- Romero, I.C., T. Ozgokmen, S. Snyder, P. Schwing, B.J. O'Malley, F.J. Beron-vera, M.J. Olascoaga, P. Zhu, E. Ryan, S.S. Chen, D.L. Wetzel, D. Hollander, and S.A. Murawski. 2016. Tracking the Hercules 265 marine gas well blowout in the Gulf of Mexico. *Journal of Geophysical Research: Oceans* 121:706–724.
- Romero I.C., G. Toro-farmer, A. Diercks, P. Schwing, F. Muller-Karger, S. Murawski, and D.J. Hollander. 2017. Large-scale deposition of weathered oil in the Gulf of Mexico following a deep-water oil spill. *Environmental Pollution* 228:179–189.
- Roszbach, K.A., and D.L. Herzing. 1997. Underwater observations of benthic-feeding Bottlenose Dolphins (*Tursiops truncatus*) near Grand Bahama Island, Bahamas. *Marine Mammal Science* 13(3):498–504.
- Schwacke, L.H., C.R. Smith, F.I. Townsend, R.S. Wells, L.B. Hart, B.C. Balmer, T.K. Collier, S. De Guise, et al. 2014. Health of Common Bottlenose Dolphins (*Tursiops truncatus*) in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. *Environmental Science Technology* 48:93–103.
- Simonsen, K.A., and J.H. Cowan Jr. 2013. Effects of an inshore artificial reef on the trophic dynamics of three species of estuarine fish. *Bulletin of Marine Science* 89(3):657–76.
- Simonsen, K.A., J.H. Cowan, and A.J. Fischer. 2013. Examination of an estuarine fish assemblage over an inshore artificial reef. *Open Fish Sciences Journal* 6:48–57.
- Snyder, S.M., E.L. Pulster, D.L. Wetzel, and S.A. Murawski. 2015. PAH exposure in Gulf of Mexico demersal fishes, post-Deepwater Horizon. *Environmental Science and Technology* 49(14):8786–8795. <https://doi.org/10.1021/acs.est.5b01870>.
- Takeshita, R., L. Sullivan, C. Smith, T. Collier, A. Hall, T. Brosnan, T. Rowles, and L. Schwacke. 2017. The Deepwater Horizon oil spill marine mammal injury assessment. *Endangered Species Research* 33:95–106.
- Tarnecki, J.H., and W.R. Patterson III. 2015. Changes in Red Snapper diet and trophic ecology following the Deepwater Horizon oil spill. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 7:135–147.

- Thomas, L., C.G. Booth, P.E. Rosel, A. Hohn, J. Litz, and L.H. Schwacke. 2017. Where are they from? Modelling the source of stock of dolphins stranded after the Deepwater Horizon oil spill using genetic and stable isotope data. *Endangered Species Research*. 33:253–264.
- Turner, R.E., E.B. Overton, B.M. Meyer, M.S. Miles, G. McClenachan, L. Hopper-Bui, A.S. Engel, M.E. Swenson, J.M. Lee, C.S. Milan, and H. Gao. 2014. Distribution and recovery trajectory of Mocondo (Mississippi Canyon 252) oil in Louisiana coastal wetlands. *Marine Pollution Bulletin* 87:57–67.
- Venn-Watson, S., L. Garrison, J. Litz, E. Fougères, B. Mase, G. Rappucci, E. Stratton, R. Carmichael, et al. 2015a. Demographic clusters identified within the Northern Gulf of Mexico Common Bottlenose Dolphin (*Tursiops truncatus*) unusual mortality event: January 2010–June 2013. *PLoS ONE*10(2):e0117248. <https://doi.org/10.1371/journal.pone.0117248>.
- Venn-Watson, S., K. Colegrove, J. Litz, M. Kinsel, K. Terio, J. Saliki, S. Fire, R. Carmichael, et al. 2015b. Adrenal gland and lung lesions in Gulf of Mexico Common Bottlenose Dolphins (*Tursiops truncatus*) found dead following the Deepwater Horizon oil spill. *PLoS ONE* 10(5):e0126538. <https://doi.org/10.1371/journal.pone.0126538>.
- Wells, R.S., and M.D. Scott. 2008. Common Bottlenose Dolphins *Tursiops truncatus*. Pp 249–254, *In* W.F. Perrin, B. Würsig, and J.G.M. Thewissen (Eds.). *Encyclopedia of Marine Mammals*. Academic Press, San Diego, CA. 1160 pp.
- Wells, R.S., L.H. Schwacke, T.K. Rowles, B.C. Balmer, E. Zolman, T. Speakman, F.I. Townsend, M.C. Tumlin, A. Barleycorn, and K.A. Wilkinson. 2017. Ranging patterns of Common Bottlenose Dolphins, *Tursiops truncatus*, in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. *Endangered Species Research* 33:159–180.
- Whitehead, A., B. Dubansky, C. Bodinier, T.I. Garcia, S. Miles, C. Pilley, V. Raghunathan, J.L. Roach, N. Walker, R.B. Walker, C.D. Rice, and F. Galvez. 2012. Genomic and physiological footprint of the Deepwater Horizon oil spill on resident marsh fishes. *Proceedings of the National Academy of Sciences* 109:20298–20302.
- Ylitalo, G.M., M.M. Krahn, W.W. Dickhoff, J.E. Stein, C.C. Walker, C.L. Lassitter, E.S. Garrett, L.L. Desfosse, et al. 2012. Federal seafood safety response to the Deepwater Horizon oil spill. *Proceedings of the National Academy of Sciences* 109(50):20274–20279.