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Short Note

Observations of a Benthic Foraging Behavior Used by Common Bottlenose Dolphins (*Tursiops truncatus*) in Barataria Basin, Louisiana, USA

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Across their worldwide distribution, bottlenose dolphins (*Tursiops* spp.) use a variety of techniques to detect, pursue, and capture prey. Dolphins may hunt independently or in groups, and specialized foraging behaviors have been identified at both the individual and population levels. These behaviors can involve tool use (Patterson & Mann, 2011), coordinated herding of prey (Engleby & Powell, 2019), benthic foraging techniques (Rossbach & Herzing, 1997), and even cooperative interactions with fishermen (Daura-Jorge et al., 2012). In many bay, sound, and estuary populations along the U.S. coast, dolphins have developed foraging strategies that incorporate local habitat features (Wells, 2019). For example, along the southeast coast of the U.S., strand-feeding dolphins utilize exposed mud and sand banks to drive prey onto shore (Hoese, 1971; Fox & Young, 2012). Other strategies are more specifically adapted to target and handle individual prey species. For instance, in the northern Gulf of Mexico, several dolphin populations have developed a technique to remove the spiny heads from catfish (Ariidae), consuming the remaining bodies (Ronje et al., 2017).

Following the *Deepwater Horizon* (DWH) oil spill in 2010, the Barataria Bay Estuarine System (BBES) Stock (Hayes et al., 2020) of common bottlenose dolphins (*Tursiops truncatus*; hereafter referred to as dolphins) became the focus of a long-term, multifaceted study. Over the course of this study, dolphins were observed engaging in a previously undescribed behavior, which we term *drilling* (or *drill feeding*), in which a single dolphin positions itself almost vertically in shallow water and thrashes its flukes/tailstock across the surface, presumably to forage for prey in the substrate below. Herein, we report on observations of this behavior and discuss its significance for the BBES Stock.

The Barataria Basin is a large estuarine-wetland system in southeastern Louisiana (USA), extending from Bayou Lafourche in the west to the Mississippi River in the east (Figure 1). The southern boundary consists of a series of barrier islands that separate the estuary from the Gulf of Mexico. The estuarine waters are turbid and shallow, with a mean depth of ~2 m and salinities that range from tidally influenced saline waters (~25‰) in the south to freshwater lakes (~0‰) in the north (U.S. Environmental Protection Agency [U.S. EPA], 1999; Das et al., 2012). The substrate is soft and muddy, primarily composed of silty clay sediment (Conner & Day, 1987).

After the DWH oil spill, the Barataria Basin experienced prolonged oil contamination and was one of the most severely impacted areas in the northern Gulf of Mexico (Michel et al., 2013). As a result of the spill, the BBES Stock of dolphins

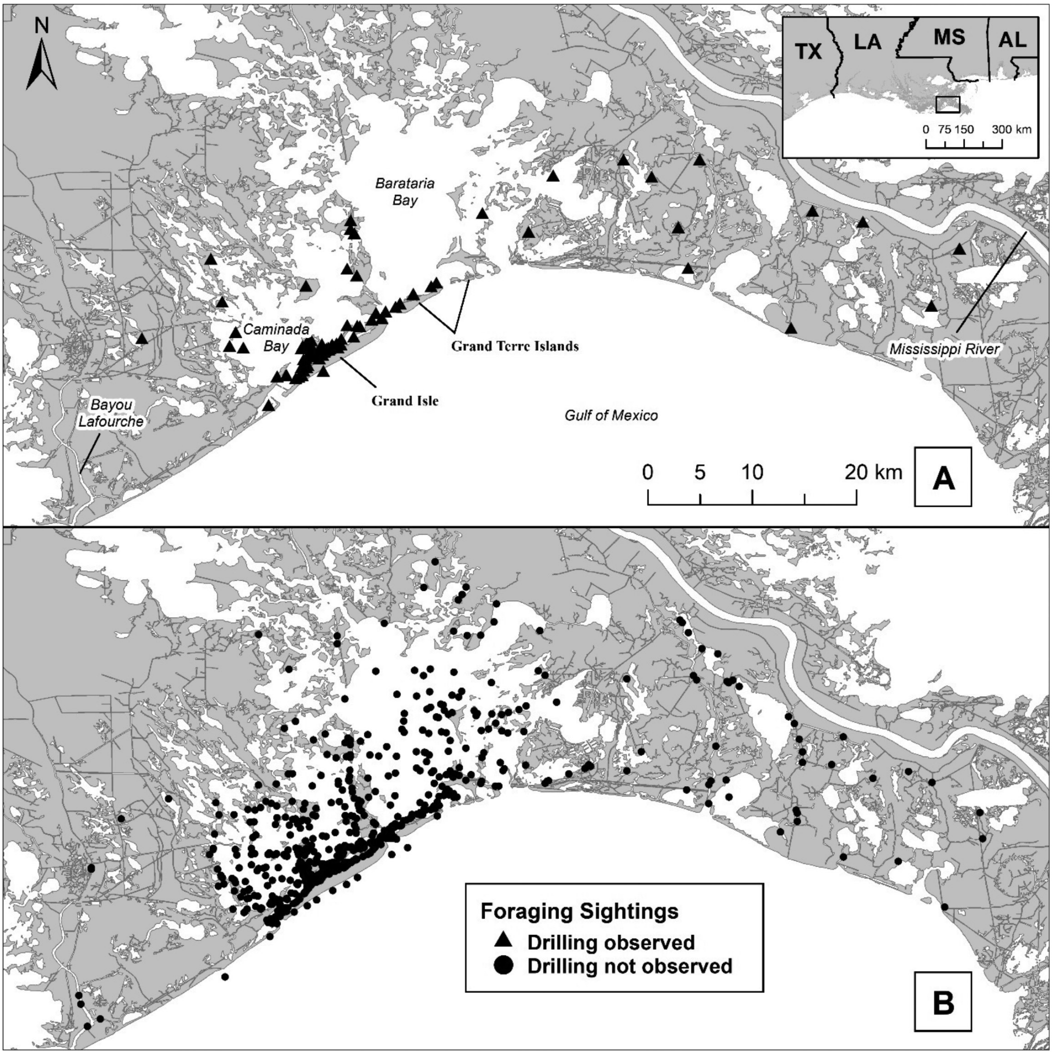

Figure 1. Barataria Basin study area with sighting locations ($n = 836$) where common bottlenose dolphin (*Tursiops truncatus*) foraging (feeding and probable feeding behavioral states) was documented. Sightings are categorized based on whether drilling behavior (A) was ($n = 88$) or (B) was not ($n = 748$) observed.

experienced a significant decline (Schwacke et al., 2017, 2021), and, in the years that followed, health assessments of dolphins in the region documented persistent, chronic health effects (Schwacke et al., 2014, 2021; Lane et al., 2015; Smith et al., 2017).

We opportunistically documented drilling behavior during surveys (2010-2019) that were conducted to assess injury to and identify restoration strategies for the BBES Stock following the spill. Survey types included mark-recapture (McDonald et al., 2017; Garrison et al., 2020), remote biopsy sampling (Balmer et al., 2015), capture-release health assessment (Schwacke et al., 2014), reproductive follow-up (e.g., Lane et al., 2015), and radio/satellite tag monitoring (Wells et al., 2017). In addition, three dedicated surveys using an unoccupied aerial system (UAS) were conducted in July 2018 to obtain overhead images of dolphin foraging activity (methods reviewed in Durban et al., 2015). During all survey efforts, we collected data for dolphin photo-identification (ID) using standardized methods described in Melancon et al. (2011). In short, surveys were conducted from a small (~6 to 7 m) outboard-powered vessel with three or more crew members. Upon observing a group of dolphins, we obtained photographs of dorsal fins for identification and recorded sighting information, including GPS coordinates, environmental conditions (e.g., water salinity, temperature, depth), and dolphin behavioral state. Behavioral states were identified based on definitions from Urian & Wells (1996) and included travel, social, feeding (FD), and probable feeding (pFD).

Drilling was distinct from other behaviors and could be readily identified from the survey vessel. Typically, the first indication of this behavior was a splash of whitewater created by the dolphin vigorously sweeping its tailstock/flukes across the surface of the water (Figure 2). This was often visible from several hundred meters away. During this motion, the dolphin is mostly submerged, with its head underwater and up to one third of its body (peduncle to flukes) at or above the water surface. The animal's position in the water remains relatively stationary while engaging in the behavior, and the fluke sweeps appear to be a means for the dolphin to position itself over a fixed point in the substrate. Consecutive bouts of this behavior were common; typically, a dolphin would drill in one location, making several fluke sweeps, and then move subsurface to another location roughly 5 to 10 m away and repeat the behavior. During all survey efforts, we documented this behavior as pFD.

Between May 2010 and June 2019, we documented dolphin foraging (pFD and FD behavioral states) during 836 sightings. Drill feeding occurred during 88 (10.5%) of these sightings (Figure 1). We observed this behavior across the study area, though most observations (68%; *n* = 60/88) occurred along the interior of the barrier islands (e.g., Grand Isle and western Grand Terre Island) and near the marsh islands in the

Figure 2. (A) Dolphin drill feeding in Barataria Basin, photographed from the survey vessel during dolphin photo-ID surveys; and (B) dolphin pictured sweeping its tailstock and flukes across the water surface, creating a large splash of whitewater.

southwestern portion of the estuary. Drill feeding sightings were primarily in close proximity to shore; the behavior was not observed in the central, open water portions of the study area's largest water bodies (i.e., Barataria and Caminada Bays).

Drill feeding occurred across all seasons. The median temperature across sightings was 26.1°C (13.8 to 33.1°C), and the median salinity was 16.4‰ (3.2 to 30.5‰). We only observed this behavior in shallow water (~2 m or less), and mud plumes were typically visible from the survey vessel during and immediately following a drilling event. We photographed dolphins engaged in the behavior via UAS on several occasions. In these images, suspended sediment is visible and appears to originate near the head of the animal (Figure 3). The UAS images suggest that dolphins are digging into the substrate with their rostrum, although the possibility that the mud displacement is caused by the dolphin's pectoral fins or even indirectly by the dolphin's body rotation cannot be discounted.

We identified the individual dolphins engaged in drill feeding from 12.5% (n = 11/88) of the sightings. In total, 10 dolphins observed drilling were identified as unique individuals. These dolphins were regularly sighted in the Barataria Basin over the course of the study, with an average of 33.2 sightings (± SD = 14.8 sightings) spanning a mean of 7.8 years (± SD = 1.3 y). Sex and estimated age class for these dolphins were determined during health assessment efforts (Schwacke et al., 2014; Smith et al., 2017). The dolphins were mostly female (7/10), and age class included six subadults, three adults, and one unknown.

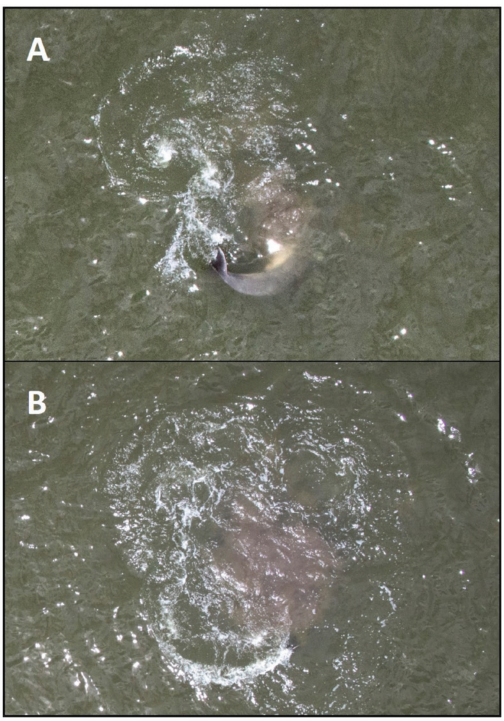

Figure 3. Overhead images of a bottlenose dolphin drill feeding in Barataria Basin, obtained using an unoccupied aerial system (UAS). A mud plume of suspended sediment, which first appears near the dolphin's head (A), grows in size (B) as the dolphin presumably burrows into the substrate.

Our observations of drilling behavior provide insight on an apparent foraging strategy used by BBES dolphins. This behavior is similar to benthic foraging techniques described for dolphins in other regions. For example, Rossbach & Herzing (1997) described crater-feeding, a behavior in which dolphins near The Bahamas burrow head first into the sandy bottom to pursue prey. Drill feeding may be a variation of crater-feeding; however, it is still unclear if these can be considered the same behavior. For instance, crater-feeding dolphins actively search for prey by scanning the seafloor using echolocation. Since acoustic data were not collected in the current study, we could not assess whether dolphins were searching for prey in the same manner prior to drill feeding. Also, the dissimilarity in habitat types between The Bahamas and Barataria Basin may necessitate variation in the behaviors. Crater-feeding occurred over sand flats in depths > 7 m where dolphins remained fully submerged and could maintain a vertical position with the support of the water column. This allowed dolphins to burrow, at times, up to their pectoral fins (Rossbach & Herzing, 1997). In contrast, we observed drill feeding in shallower water depths (< 2 m) where dolphins were partially exposed above the surface. With less support from the water column, the sweeping motion we observed presumably helps dolphins maintain their position and remain as vertical as possible so that they can effectively dig into the sediment. Although it is possible that drill feeding has gone undetected in deeper waters, water depth is generally shallow throughout the Barataria Basin (mean depth ~2 m; U.S. EPA, 1999). Therefore, if BBES dolphins are actually crater-feeding, they have likely adapted the behavior to compensate for the shallower environment.

In Sarasota Bay, Florida, dolphins also engage in similar behaviors, termed *rooting* and *drifting* (Nowacek, 2002). *Rooting* is described as a behavioral state in which a dolphin is oriented vertically in the water column and actively maintains position with its rostrum near or below the seafloor, presumably to flush prey from the substrate. *Drifting* involves the same posture, but the animal is not stationary. Nowacek (2002) described rooting/drifting as the initial stage in a sequence of foraging behaviors during which dolphins would root in the sediment to expose fish and then actively pursue them by performing other behaviors such as side-swimming and pinwheeling. Because of the high turbidity in the Barataria Basin, we were unable to observe the full range of dolphin behavior in between bouts of drill feeding. We suspect that drilling behavior is more similar to crater-feeding in that dolphins are capturing prey at or within the sediment rather than flushing them out; however, with no visibility through the water column, this has not been confirmed.

Similar to other benthic foraging techniques, drilling is primarily a solitary behavior and is unlikely to function in a cooperative context. During most sightings, only a single dolphin was observed drill feeding. In cases where more than one individual was drilling, the dolphins were typically separated by 10 m or more and appeared to behave independently. On at least one occasion, dolphins performed the behavior simultaneously and in close proximity (< 10 m) to each other; however, this did not appear to be a coordinated effort as has been reported for more complex, cooperative foraging strategies (e.g., mud-ring feeding; Engleby & Powell, 2019).

Researchers in southern Florida have reported bottom disturbance behaviors wherein dolphins use their flukes to kick up sediment into mud plumes (Lewis & Schroeder, 2003; Engleby & Powell, 2019), and they hypothesized that the suspended sediment is utilized to concentrate or potentially disorient prey species such as mullet (*Mugil* spp.). The mud plumes we documented in UAS images did not appear to serve the same function. Still, these mud plumes were common across drill feeding observations, suggesting a potential association between this behavior and habitat with fine sediments. The vast majority of bottom type in the Barataria Basin, particularly near the barrier islands where drilling behavior was most frequently observed, is described as silty clay sediment (Conner & Day, 1987). This sediment type may not only facilitate the act of digging into the substrate, but it could also influence the composition of benthic or demersal prey that dolphins are likely targeting.

Dorsal fin images were difficult to obtain while dolphins were drilling; therefore, we were only able to positively identify a small number of dolphins (n = 10) from our observations. However, all of these dolphins had sighting histories that extend over multiple seasons and years in the study area, suggesting long-term site fidelity to the Barataria Basin. This is consistent with other studies that have identified limited movements and high site fidelity of BBES dolphins (Wells et al., 2017; Takeshita et al., 2021). Wells (2019) hypothesized that residency to a well-established home range may benefit prey detection and foraging success due to an increased familiarity with local conditions and experience with the most effective foraging methods. The sighting histories of the dolphins observed drilling suggest such a familiarity; therefore, it is likely that BBES dolphins have developed this behavior as a result of adapting to the local environment and prey species available in the Barataria Basin.

Because of the poor water clarity in the Barataria Basin, underwater observations are infeasible, and identifying the prey species targeted during drilling behavior has not been possible to date. However, the supposition that BBES dolphins are foraging for benthic or demersal prey is supported by recent stomach content analyses. Bowen-Stevens et al. (2021) analyzed stomach contents of dolphins that stranded in the Barataria Basin and identified benthic and demersal prey species as a significant component of dolphin diet. Specifically, shrimp (Penaeidae) were found in nearly half of the stomachs analyzed. These results suggest that shrimp may be one of the primary prey species targeted during drilling. Penaeid shrimp species such as brown shrimp (*Farfantepenaeus aztecus*) are historically abundant in the Barataria Basin and reach peak abundance annually in late spring (Jones et al., 2002). Shrimp densities are highest near marsh edges and over shallow nonvegetated bottoms (Rozas & Minello, 2015)—areas where drilling frequently occurred. We did not observe a seasonal pattern in the occurrence of drill feeding; however, seasonal variations in prey distribution may influence the use of this behavior and should be investigated further.

In addition to identifying prey items, Bowen-Stevens et al. (2021) found sediment in several of the stomachs analyzed. Although ingestion of sediment could occur during a live stranding, it is also likely that drill feeding dolphins indirectly ingest sediment while foraging. This type of interaction with bottom sediment raises concern for the BBES Stock as it creates a potential pathway for exposure to oil-associated chemicals sequestered in the substrate. Kirman et al. (2016) found evidence of DWH hydrocarbons in sediment samples taken from the Barataria Basin 1.5 years after the spill, and several studies have shown that oil can persist in salt marshes for years or decades after the initial contamination (Reddy et al., 2002; Peacock et al., 2007). Similar long-term pathways of exposure have been suggested for other marine mammal species following environmental disasters such as the *Exxon Valdez* oil spill (Bodkin et al., 2012). Further investigation that incorporates sediment sampling in areas where drilling behavior has been observed could provide additional insight into this potential pathway for petroleum exposure.

Large-scale restoration efforts to restore coastal and wetland habitat impacted by the DWH oil spill are currently in the planning stages. These efforts, such as the proposed Mid-Barataria Sediment Diversion (MBSD), will divert large amounts of freshwater and sediment from the Mississippi River into the Barataria Basin and create substantial changes to salinity (U.S. Army Corps of Engineers, 2021). Our observations of drilling behavior suggest that BBES dolphins have adapted their behavior to the local environment. These data further support the evidence that BBES dolphins have inhabited this region across multiple seasons and years (Wells et al., 2017; Takeshita et al., 2021), and are therefore unlikely to shift their range to adjacent coastal waters in response to abrupt changes in salinity.

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