Short Note

Observations of a benthic foraging behavior used by common bottlenose dolphins (*Tursiops truncatus)* in Barataria Basin, Louisiana, U.S.A.

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Across their world-wide 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 population and individual 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 fisherman (Daura-Jorge et al., 2012). In many bay, sound, and estuary (BSE) 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*) and consume the remaining catfish 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*) became the focus of a long-term, multi-faceted study in the Barataria Basin, Louisiana, USA. Over the course of this study, dolphins were observed exhibiting 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. In this short note, 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 ~2m and salinities that range from tidally-influenced saline waters (~25 parts per thousand (ppt)) in the south to freshwater lakes (~0 ppt) in the north (USEPA, 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 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 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 documented drilling behavior opportunistically during surveys (2010-2019) that were conducted post-spill to assess injury to and identify restoration strategies for the BBES Stock. Survey types included mark-recapture (McDonald et al., 2017), 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 unmanned 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 (~6-7m) outboard-powered vessel with three or more crew members. Upon observing a group of dolphins, the survey team obtained photographs of dorsal fins for identification and completed a sighting datasheet to document relevant sighting information, including GPS coordinates, environmental conditions (e.g., water salinity, temperature, and 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 white water 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 1/3 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. That is, a dolphin would drill in one location, making several fluke sweeps, and then move subsurface to another location roughly 5-10m away and repeat the behavior. When drilling behavior was observed, it was documented on the sighting datasheet and pFD was noted in the behavioral observations.

Between May 2010 and June 2019, we documented dolphin foraging (pFD and FD behavioral states) during 836 sightings. Drilling behavior was observed during 88 (10.5%) of these sightings (Figure 1A). Dolphins were seen drilling 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 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 waterbodies (i.e., Barataria and Caminada Bays).

Drilling behavior was observed across all seasons. The median temperature across sightings was 26.1 (13.8-33.1) degrees Celsius and median salinity was 16.4 (3.2-30.5) ppt. This behavior was witnessed exclusively in shallow water (~2m or less), and mud plumes were typically visible from the survey vessel during and immediately following a drilling event. Drilling behavior was photographed 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.

Based on photographic data and notes recorded on sighting datasheets, we were able to identify the dolphins observed drill feeding in 12.5% (*n*=11/88) of 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 (+/- SD: 14.8) sightings spanning a mean of 7.8 (+/- SD: 1.3) years.

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, dolphins near the Bahamas engage in crater-feeding, during which a dolphin burrows into the substrate while vigorously thrashing its flukes to maintain position (Rossbach & Herzing, 1997). Unlike drilling behavior, crater-feeding was only observed in depths >7m, and dolphins remained fully submerged while digging into the substrate. Water depth is generally shallow throughout the Barataria Basin (mean depth ~2m; USEPA, 1999), however, it is possible that drilling behavior occurs at similar depths but has gone undetected in the current study. 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) documented these behaviors as part of longer behavioral sequences, in which rooting/drifting were used to initially search for and flush prey from the substrate. Other behaviors, such as side-swimming and pinwheeling, commonly followed rooting/drifting as dolphins actively pursued said prey. Unlike the foraging sequences documented in Sarasota Bay, we did not observe dolphins chasing prey in between bouts of drilling; however, the high turbidity in the Barataria Basin limited our ability to

fully compare these behaviors. Additional surveys employing UAS-obtained video and passive acoustics could provide further insight on the sequence of events preceding and following drilling behavior.

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 10m or more and appeared to behave independently. On at least one occasion, dolphins performed the behavior simultaneously and in close proximity (<10m) 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 hypothesize that the suspended sediment is utilized to concentrate or potentially disorient prey species such as mullet (*Mugil* spp.). A similar function is not evident from the observations of drilling behavior. 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 could also influence the composition of benthic 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). In shallow inshore environments, 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 (Wells, 2019). Therefore, it is likely that BBES dolphins have developed drilling 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. Particularly, 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. Drilling was most frequently observed in areas of the Basin known to have a high density of dolphins (McDonald et al., 2017), and targeting small benthic prey such as shrimp could reduce intraspecific competition for larger prey items in these areas.

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 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 (USACE, 2021). The observations of drilling behavior reported in this note 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.

Acknowledgements

The authors would like to thank the countless staff from multiple institutions that supported the data collection and subsequent analyses used for this study, including Jake Barbaro, Kevin Barry, Kerry Coughlin, James Daugomah, John Durban, Michael Hendon, Suzanne Lane, Jenny Litz, Ross Martinson, Keith Mullin, Lauren Noble, Errol Ronje, Jennifer Sinclair, Angie Stiles, Jamie Thompson, Mandy Tumlin, and Blaine West. Data collection was conducted under Marine Mammal Protection Act Permits #18786 and #14450. This is National Marine Mammal Foundation Contribution #XXX to peer-reviewed scientific literature.

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Figures

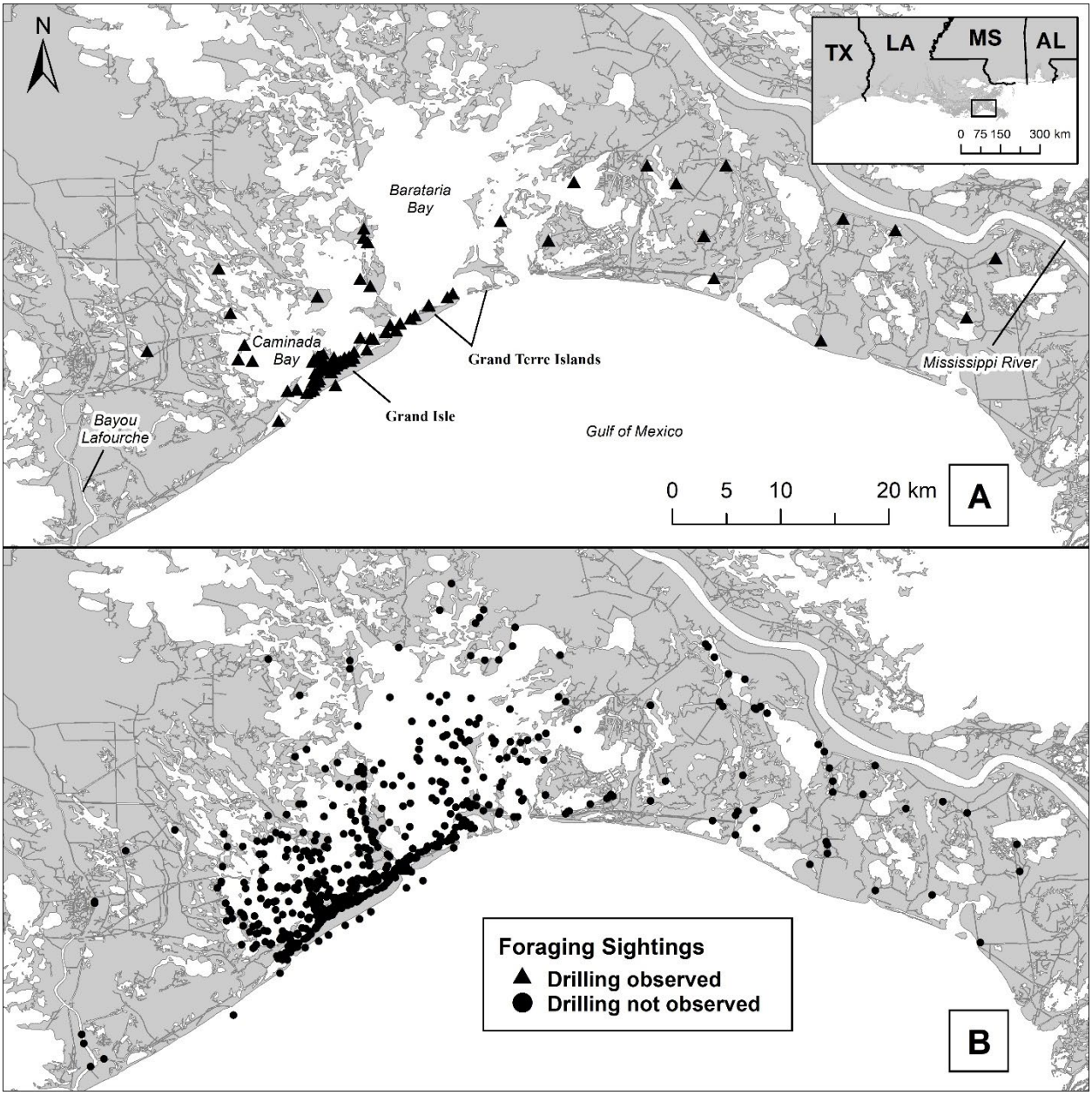

Figure 1. Barataria Basin study area with sighting locations (n = 836) during which dolphin foraging (pFD and FD behavioral states) was documented. Sightings are categorized based on whether drilling behavior was (A; n=88) or was not (B; n=748) observed.

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

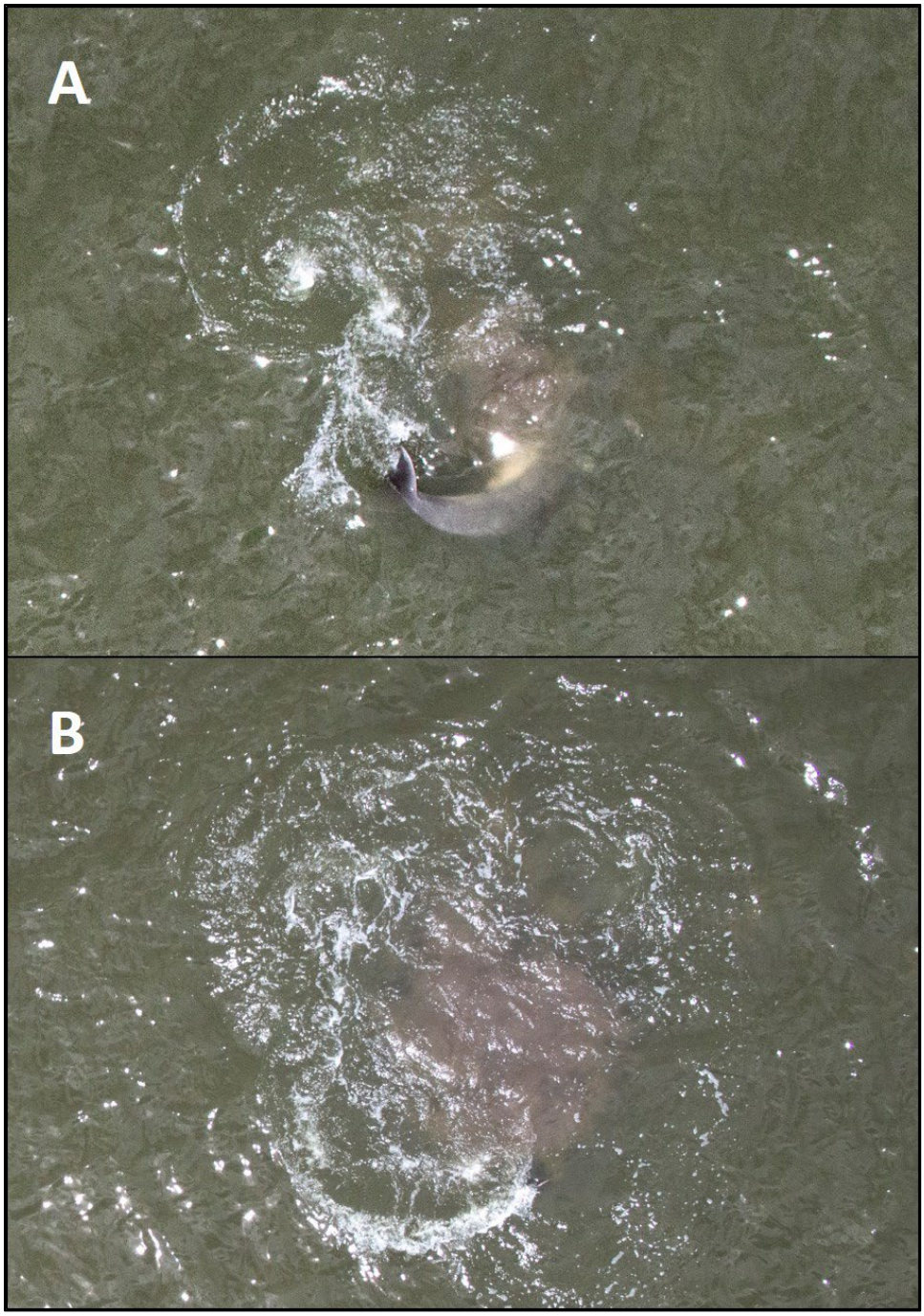

Figure 3. Overhead images of a dolphin drill feeding in Barataria Basin, obtained using an unmanned aerial system (UAS). A mud plume of suspended sediment, which first appears near the dolphin's head (A), grows in size (B) as the dolphin presumably burrows into the substrate.