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Short Note

Fence Fishing: The Use of Algae by Bottlenose Dolphins (*Tursiops truncatus*) to Attract Fish

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Innovation has been documented among several animal taxa (e.g., birds; Lefebvre, 2000), primates (Reader & Laland, 2002), and marine mammals (Patterson & Mann, 2015) and is defined as "a new or modified learned behavior not previously found in the population" (Reader & Laland, 2003, p. 14), characterized by behavioral flexibility and advanced cognitive processing (Lefebvre, 2000). Marine mammals exhibit innovative behaviors both in managed care (e.g., Herman, 2002) and in the wild, the latter noted in response to human activities (see Chilvers & Corkeron, 2001; Mann & Kemps, 2003) and foraging techniques (Mann & Sargeant, 2003; Sargeant et al., 2005). Reader & Laland (2003) described learning as an essential component of innovation, which occurs following a successful or rewarding innovation, enhancing the likelihood that the behavior(s) will be repeated, refined, and potentially transferred to conspecifics. However, the distinction between innovation and learning remains unclear (Reader & Laland, 2003), and innovation at the individual level may be a form of asocial learning (Rendell et al., 2007). Fundamental processes inherent to innovation include exploration, motivation (Kummer & Goodall, 1985), examination of extrinsic factors (e.g., environment, conspecifics; Hauser, 1988; Lee, 1991; Reader & Laland, 2001; Patterson & Mann, 2015), creativity (Ramsey et al., 2007; Bateson & Martin, 2013), play (Bateson & Martin, 2013), and the expression of behavioral flexibility across various contexts (Reader & Laland, 2003).

The ability to adapt to an ever-changing environment, while avoiding predators, securing mates, and acquiring resources, dictates animal fitness and survival (e.g., Dingemanse & Réale, 2005). Unique foraging strategies have been thoroughly documented in free-ranging common bottlenose dolphins (*Tursiops truncatus*; e.g., Mann & Sargeant, 2003; Sargeant et al., 2005), but descriptions of novel foraging behaviors exhibited by captive dolphins in natural seawater habitats are limited (Patterson & Mann, 2015). As zoos and aquariums place a greater emphasis on welfare, the expression of species-specific behaviors is a benchmark of best practices (e.g., Morgan & Tromborg, 2007; Clegg et al., 2015). To increase the rehearsal of species-specific behaviors, zoos and aquariums with closed systems provide complex environmental enrichment that mimics foraging opportunities in the wild (e.g., Kastelein et al., 1989; Clark, 2013; Troxell-Smith et al., 2017). However, many captive bottlenose populations are housed in ambient seawater facilities with access to local flora and fauna, enhancing enclosure complexity and providing unique opportunities to investigate foraging behaviors.

An innovative fishing strategy, in which common bottlenose dolphins manipulated various macroalgal species to interact with and attract fish through a fence line into their enclosures, was documented 32 times at a natural seawater zoological facility in Key Largo, Florida. Observations included above and underwater video recordings, ranging in duration from 0:20 s to 21:05 min (GoPro Hero4 and Cannon G12 cameras) for a total of 198.18 min (the compiled video and the supplemental figure for this short note are available in the "Supplemental Material" section on the *Aquatic Mammals* website). Additionally, the animal care and research staff transcribed behavioral details opportunistically *in situ*. The information documented during opportunistic observations and post-hoc descriptive video analyses included the date, animal(s) involved, algal species utilized, and a detailed description of the event. Fence fishing was operationally defined as the collection and transport of any algal species by a resident dolphin to the fence that separated the animal habitat from

a public access canal to entice fish for the purposes of play (e.g., enrichment, cognitive stimulation) or foraging, regardless of whether the fish was caught and/or consumed.

From mid-February to April 2014, the fence fishing behavior was exhibited by one adult (reproductive) and four subadults (independent, not sexually mature) ($N_{Male} = 1$; $N_{Female} = 4$) (see Eskelinen et al., 2015, for age class definitions). The subadults and adults frequently interacted with the various algal species in different contexts prior to these observations, mainly during play (Kuczaj & Eskelinen, 2014). Two algal species were used predominantly during the fence fishing bouts: hooked red weed (*Hypnea cervicornis*) and sea lettuce (*Ulva* spp.) (Figure 1); however, a species in the genus *Codium* (Littler & Littler, 2000) was also utilized by a subadult female on one occasion. In the observed fence fishing context, individual dolphins gathered algae—one species at a time on all occurrences but multiple types between bouts—and carried it to the fence in their mouths or draped over their pectoral flippers. Individuals held small and large pieces of algae, manipulating the algae with their mouths; shaking it along the fence; expelling water from their mouths toward the algae, following release, to alter its position in the water column; or threading it through the fence openings (at depths ranging from 1 to 3 m). Fence fishing bouts were practiced by five of the seven dolphins in the enclosure, predominantly while solo (79%). Although many fish reside in the dolphins' enclosures and are consumed by more traditional foraging strategies (e.g., chasing), dolphins engaged in elaborate displays with the algae to attract the same fish species (e.g., mangrove snapper [*Lutjanus griseus*] and grunts [*Haemulon plumierii*]), which congregated in much larger schools on the opposing side of the fence in the open-access canal adjacent to the Atlantic Ocean.

The fish outside the fence were attracted by the algal "bait" and predictably schooled (dozens at a time) at the fence to consume the algae, especially when the dolphins actively manipulated the algal strands. In one of the initial observations, a subadult female guided the algae through the fence opening, holding the other end in her mouth, then slowly pulled the algae as the fish followed through the fence and into the lagoon (see Supplemental Video X, timestamp 3:36 to 3:45). Although this strategy appeared highly effective in attracting the fish, she was not observed consuming the fish. Though most observations did not involve confirmation of consumption, a subadult and adult female were noted to capture and swallow the fish they attracted into the lagoon on three occasions. The development of foraging strategies is dynamic (MacArthur & Pianka, 1966), characterized by learning, cultural transmission, and the evolution of the behavior. As such, lack of consumption in some cases may indicate that the behavior was still evolving or served a dual function of enrichment as a form of play (i.e., as both primary and secondary reinforcement) or cognitive stimulation.

According to Beck (1980), tool use is defined as the purposeful use of an object by an individual to carry out a task in a more effective or innovative way. The use of the algae to attract the fish for ingestion or play aligns with this definition. The dolphins engaging in fence fishing were selective in choosing various algal species and sizes, as well as the strategies employed to attract the fish. On three occasions, subadult females approached the fence with one type of algae, exhibited the fence fishing behaviors, and then left the fence, returning with a different algal species and engaging in the behavior again (see Supplemental Video Y, timestamp 1:25 to 3:34). Unique foraging strategies have been noted among free-ranging bottlenose dolphins such as preparing cuttlefish prey (Finn et al., 2009) and using conch shells (Allen et al., 2011) and sponges (Mann et al., 2008) as tools. Dolphins in managed care have also been noted to use tools (Jaakkola, 2012) innovatively, including dolphins mimicking a dive team's

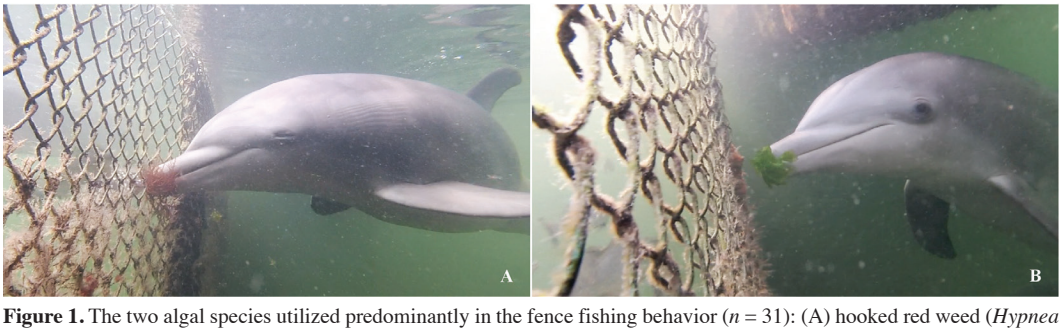

Figure 1. The two algal species utilized predominantly in the fence fishing behavior ($n = 31$): (A) hooked red weed (*Hypnea cervicornis*) and (B) sea lettuce (*Ulva* spp.). (Screenshots provided by DPMMR and Dolphins Plus Research Departments)

use of a scraping tool to remove algae from the bottom of their enclosure (Tayler & Saayman, 1973) and two dolphins luring a moray eel out of hiding using the poisonous spine of a scorpionfish (Brown & Norris, 1956). Learning and flexibility are synonymous (Yeater & Kuczaj, 2010); thus, the fundamental purpose of the behavior may vary by individual and context.

Foraging behaviors have been noted to vary among individuals (Nowacek, 2002; Spitz et al., 2006; Cantor et al., 2018), with marked plasticity and variability, and are influenced by ecological conditions and social learning (Connor, 2001; Estes et al., 2003; Mann & Sargeant, 2003; Krützen et al., 2005; Sargeant et al., 2007; Torres & Read, 2009). The dolphins in this study employed varying strategies when participating in the fishing behavior, including variations in approach, duration, the type of algae utilized, and the manipulation of the algae (e.g., shaking, feeding it through the fence, holding it stationary). Generally, the dolphins remained fixed at the fence, holding the algae for periods exceeding 30 s (M = 17.73 s, SD = 15.97 s, range: 2 to 70 s). On some occasions, the same animals were also observed rapidly manipulating the algae for the entire recorded event. Once the fence fishing bout ended, the dolphins would often swim away from the fence with the piece of algae rather than leaving it at the fence.

Observational learning and imitation are well-documented among cetaceans and may influence variability and the strategies employed (e.g., Kuczaj et al., 2006, 2012b; Marino et al., 2007; Yeater & Kuczaj, 2010). The novelty of the behavior (Kuczaj et al., 2012b), as well as age class (Kuczaj et al., 2005), personality (Whittle, 1996; Seferta et al., 2001; Highfill & Kuczaj, 2007; Kuczaj et al., 2012a), and motivation (see Dingemanse & Réale, 2005), is known to influence engagement and the rate at which behaviors are initiated and practiced in a population. However, the fence fishing behavior was practiced by most but not all the dolphins in the enclosure, with no clear trends regarding age class and/or sex, the latter skewed by the predominantly female population. Some individuals are more apt to learn socially, while others innovate (Fragaszy & Visalberghi, 1990; Laland & Reader, 1999; Pfeffer et al., 2002; Reader, 2007), and errors during social learning can result in the expression of novel behaviors (Reader, 2007). In managed care, killer whales (*Orcinus orca*) were observed capturing birds for play (Kuczaj et al., 2005), with noted trial and error learning through cultural transmission and the relevant rate of success varying among individuals. Observational learning can be assumed, though not confirmed, in the short video recordings, as the fence fishing behavior was subsequently noted among calves housed with the fence fishing animals, born 2 y after data collection ended (i.e., 2016). Though the origin of the behavior remains unclear, the individuals that participated in the fence fishing behavior may have acquired the behavior independently or through cultural transmission. Individual participation in the fence fishing behavior, as well as success and persistence, may be related to differences in the propensity to practice in social learning, personality, affective state, satiation, and/or reinforcement history.

Although single animals practiced fence fishing behaviors, multiple animals simultaneously engaged in the behaviors at distances of > 3 m from each other 25% of the time. Dyads of mothers and non-dependent offspring were observed together 21% of the time, yet only one actively participated in the fence fishing behavior. Similarly, sponge carrying is practiced by a small proportion of animals in Shark Bay, Australia—typically by solitary adult females (Smolker et al., 1997; Sargeant & Mann, 2009). This contrasts with group hunting efforts, which are coordinated by multiple individuals (Silber & Fertl, 1995; Samuelson et al., 2020), such as beach hunting (Sargeant et al., 2005) and strand feeding (Hoese, 1971; Duffy-Echevarria et al., 2008).

Bubble emissions, or a large burst of air creating a cloud-like clustering of smaller bubbles or a single, large bubble (for definitions, see Moreno & Macgregor, 2019), were observed during 15% of the fence fishing events. Bubble bursts have been documented during aggressive interactions (Baker & Herman, 1984; Helweg et al., 1992; Dudzinski, 1996; Bowles & Anderson, 2012), sexual encounters (Herzing, 1996), social bouts (Hill et al., 2011), curiosity (Delfour & Marten, 2001; Lilley et al., 2018), play (Paulos et al., 2010), exposure to a novel stimulus (Lopes et al., 2015), cognitive enrichment tasks (Clark et al., 2013), and foraging contexts (Fertl & Wilson, 1997). During solo fence fishing bouts, bubble blowing behavior was observed among four subadult dolphins—one male and three females. Bubble bursts occurred during approaches to the fence and manipulations of the algae, followed by fence fishing. Most bubbles produced during the fence fishing behavior were classified as a single, large underwater air exhalation, resulting in a cloud-like formation (Supplemental Figure W). However, each dolphin that emitted bubble bursts was actively engaged in fence fishing, aligning with Moreno's (2017) findings of bubble bursts occurring during object manipulation and task engagement.

Underwater recordings accounted for the majority of documented observations. Due to the limited sampling precision, compression, and the

inability to localize sounds using the recording equipment available, vocalizations were noted in each recording and only characterized by type (i.e., whistles, burst pulses, clicks; for review, see Jones et al., 2019). Whistles were sporadically recorded, typically at the end of the fence foraging bout, as individuals reunited with their cohorts. Broad-band burst pulse signals, clicks, and click trains were documented on all underwater recordings, noted during fence approaches and fence fishing bouts. Clicks were produced in succession, with varying, distinguishable interclick intervals. Although clicks are more commonly associated with object identification and navigation (Au, 1993), click trains have been recorded in foraging contexts (Herzing, 1996) and were the most common vocalizations emitted by spinner dolphins (*Stenella longirostris*) during cooperative foraging events (Benoit-Bird & Au, 2009). Burst pulses have been documented during aggressive interactions (Overstrom, 1983; Herzing, 1996; Blomqvist et al., 2005), herding of females by males (Connor & Smolker, 1996), cooperative events (Connor & Smolker, 1996; Eskelinen et al., 2016), and during a coordinated behavior task (Bastain, 1967). Though associated with various behavioral contexts, the identification of click trains in this descriptive overview aligns with acoustic data collected during other foraging events (Smolker et al., 1997). However, conclusions about the context of a novel behavior are often limited by how the data are collected (Ramsey et al., 2007); therefore, acoustic descriptions herein should be treated as anecdotal.

Innovation observed during foraging may be influenced by the availability and ease of acquiring other resources, predation risk, social variables (e.g., cooperation), and the ability to perform alternate behaviors (Dewar, 2004; Reader, 2004), including costly behaviors, such as play and exploration (De Oliveira et al., 2003; Moller & Garamszegi, 2012). Kummer & Goodall (1985) theorized that the rate of innovation may reflect the relative surplus of time in managed care, as captive animals do not practice predator avoidance or the need to access resources for sustenance (i.e., they are provided food by their caretakers). Additionally, increased and sustained access to the animals provides opportunities to observe behaviors that may not be practiced or cannot be viewed in a wild setting. Although the study subjects were provided with fish as part of their daily care regimen, fence fishing represented an optional, relatively low-cost foraging strategy. While the same fish species were available free-swimming in the dolphin lagoon, the use of algae to entice large schools of fish, rather than chasing them individually, was more energetically efficient. However, consuming the fish may not have been the objective of each bout, particularly given the low rate of fish consumption noted in the recordings. Instead, the process of selecting algae and attracting the fish was likely reinforcing to the animals, or cognitively stimulating, such that they continued to practice the behavior even when the catch rate was low. Continued assessments of external and internal drivers may provide insight into the purpose and evolution of this novel behavior and further elucidate how the behavior was adopted and practiced within the population, including whether it was for the purpose of consumption and/or enrichment/play.

Note: A supplemental figure and video for this short note are available in the "Supplemental Material" section of the *Aquatic Mammals* website: https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147.

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