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Short Note

Foraging Behavior of the Rough-Toothed Dolphin *(Steno bredanensis)* in Coastal Waters of the Mexican Central Pacific

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The rough-toothed dolphin (*Steno bredanensis*) is found in tropical-subtropical oceanic waters worldwide (Miyazaki & Perrin, 1994). Individuals are usually sighted in waters of > 1,000 m depth (e.g., in the French Polynesian Islands [Gannier & West, 2005]; and Hawaii [Baird et al., 2008, 2013]), but there are some sightings in coastal areas (e.g., Brazil; Flores & Ximinez, 1997). Their recognized distribution in the Eastern Pacific Ocean (EPO) is from the western coast of the United States to southern Peru where sightings have been linked mainly to tropical oligotrophic waters (Jefferson, 2009). In the tropical region of the EPO, Wade & Gerrodette (1993) conducted surveys from 1986 to 1990 and estimated an abundance of ~146,000 rough-toothed dolphins. However, little is known about this species, including its population structure, survival, site fidelity, home range, and other aspects of its basic biology (Gannier & West, 2005; Baird et al., 2008; Jefferson, 2009). Information on the trophic ecology is also scarce. Some data are available from reports of stomach content analysis of stranded individuals, which contained fish and cephalopod species from coastal and oceanic environments (Pitman & Stinchcomb, 2002; Jefferson, 2009). Additionally, reports on foraging behavior have been described for this species, such as chase activities, prey weakening, and prey herding (Baird et al., 2008; de Boer, 2010), which have occurred even on large prey species, such as dolphinfish (*Coryphaena hippurus*), some of which were over 1 m in length (Pitman & Stinchcomb, 2002).

A foraging strategy can be defined as a decision rule (or set of rules) that results from the particular use of certain tactics, which are themselves actions or behaviors that allow the pursuit of such strategy (Gross, 1996; Heithaus & Dill, 2009). Dolphins employ the feeding strategy of direct capture on single prey, and use various tactics to do so such as (1) individual chase (Mann & Sargeant, 2003; Silva-Jr. et al., 2007), (2) prey herding (Vaughn et al., 2007), (3) prey weakening (dos Santos et al., 2007; Guinet et al., 2007), (4) tool use (Mann & Sargeant, 2003; Mann et al., 2008), (5) group attack (Silva-Jr. et al., 2007), (6) consumption of bait in fishing lines (Nitta & Henderson, 1993), and (7) strand-feeding behavior (Duffy-Echevarria et al., 2008).

Rough-toothed dolphins can optimize one or more of these tactics, depending on particular circumstances, in order to maximize energetic gains (Aguilar de Soto et al., 2008). In some instances, foraging tactics appear to be socially transmitted, particularly from mothers to offspring (Mann & Sargeant, 2003; Whitehead, 2003; Bender et al., 2009). In this short note, we describe behavioral foraging aspects of rough-toothed dolphins off the coast of Colima and south of Jalisco, Mexico, including some of their tactics, with the aim of generating information on the ecology of this species, which is poorly studied globally and regionally.

A total of 109 marine surveys were conducted from January 2010 to December 2013 on board a small (7.9 m, *FACIMAR II*) outboard motor watercraft (Yamaha, 75 hp) off the Colima and southern Jalisco coasts (18.9° to 19.3° N and 104.5° to 105° W) in the Mexican Central Pacific (MCP) (Figure 1). The trajectories of these surveys were not systematic; three observers, positioned on the bow, starboard, and port, searched for rough-toothed dolphins using

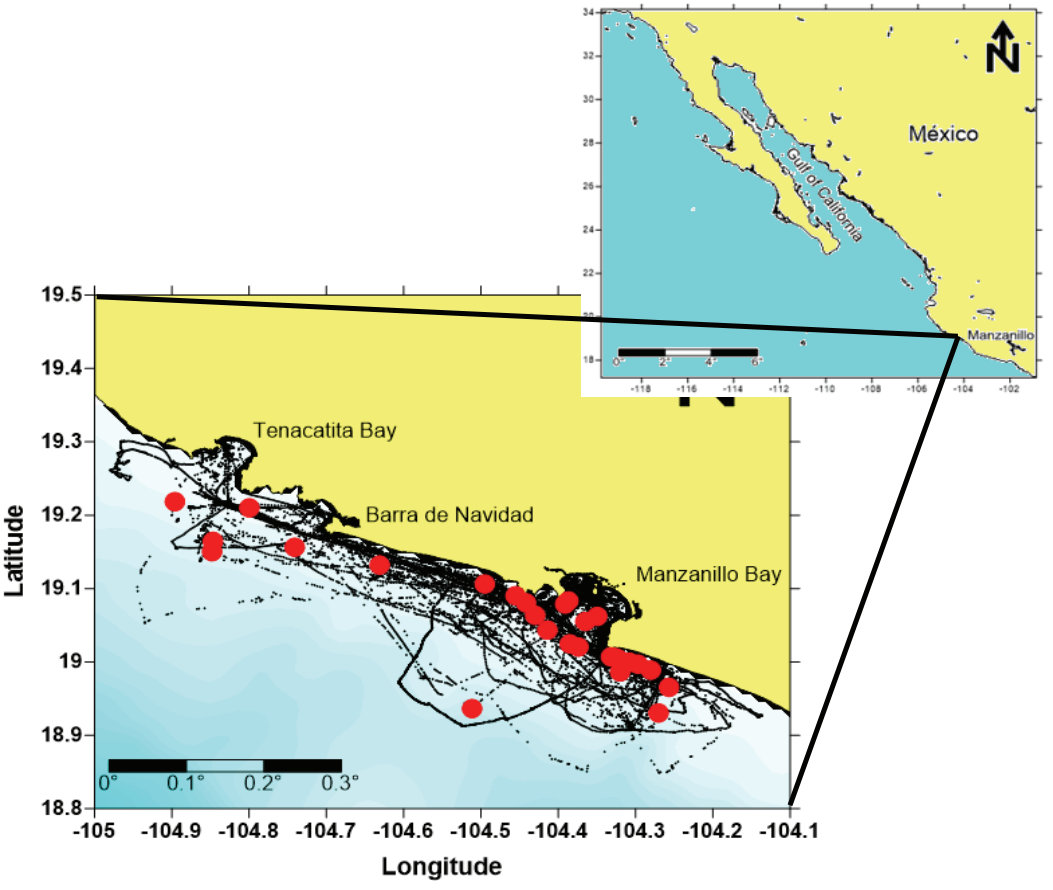

Figure 1. Geographic location of sightings of rough-toothed dolphins (*Steno bredanensis*) (red dots) in the Mexican Central Pacific during the period 2010 through 2013; black track lines represent the total search effort.

high-powered binoculars (Fujinon 7 × 50). Once a group of dolphins was sighted, records were taken, including the date, geographic position (using a *Garmin map76CS* global positioning system [GPS] device), group size range, and predominant activity of the group, which was classified as (1) traveling, (2) resting, (3) socializing, or (4) foraging according to criteria described by Vaughn et al. (2007) for dusky dolphins (*Lagenorhynchus obscurus*), given a lack of a published ethogram for this species. The average encounter time for each sighting was ~15 min; however, it was variable (from 2 to 40 min) depending on several factors such as oceanographic and climatic conditions (e.g., wind intensity and rain), daylight conditions, group size (the record of activities and photographs were easier to obtain for small groups), and availability of the group (sometimes the dolphins were missed due to an accelerated or sudden displacement). From the sighting number and search effort (km sailed) information, the annual and seasonal encounter rates (ER) were calculated. These rates showed a normal distribution (Shapiro-Wilk test: SW-W = 0.91; p = 0.14); therefore, it was compared between years and seasons using a parametric statistical analysis (ANOVA F test) with a 0.05 significance level (*Statistica*, Version 7). Finally, photographs of the individuals and their behaviors were taken using a Canon EOS 60D camera, and an underwater video camera (Canon Powershot D20) was used to record subsurface behavior.

The total search effort was ~11,200 km, but it varied by season and year, with the lowest effort (241 km) occurring in the spring of 2010, and the highest effort (1,343.3 km) occurring in the winter of 2012 (Table 1). There were a total of 37 rough-toothed dolphin sightings (Figure 1). After correcting for differences in search effort, there were no significant differences in ER among years (0.004 to 0.003 sightings/km, $F_{(3, 12)} = 0.65$, p = 0.59) or among seasons (0 to 0.006 sightings/km, $F_{(3, 12)} = 0.88$, $p = 0.47$) (Table 1). These

Table 1. Sailing effort (E, in km), number of sightings (*n*), and encounter rate (ER = *n*/E) of the rough-toothed dolphin (*Steno bredanensis*) in adjacent waters of Manzanillo, Colima, during the period 2010 through 2013

	2010	2011	2012	2013
Winter	E = 829.3 *n* = 4 ER = 0.005	E = 1,001.5 *n* = 5 ER = 0.005	E = 1,343.3 *n* = 1 ER = 0.001	E = 867.3 *n* = 5 ER = 0.006
Spring	E = 241 *n* = 1 ER = 0.004	E = 328 *n* = 1 ER = 0.003	E = 722.8 *n* = 4 ER = 0.006	E = 620.6 *n* = 0 ER = 0
Summer	E = 483 *n* = 2 ER = 0.004	E = 758.2 *n* = 2 ER = 0.003	E = 417 *n* = 0 ER = 0	E = 658.9 *n* = 1 ER = 0.002
Autumn	E = 645 *n* = 3 ER = 0.005	E = 792.6 *n* = 2 ER = 0.003	E = 613.1 *n* = 3 ER = 0.005	E = 860.4 *n* = 3 ER = 0.003
Total E	2,198.3	2,880.3	3,096.2	3,007.2
Total *n*	10	10	8	9
ER average	0.004	0.003	0.003	0.003

results are in contrast with those found in Hawaii and the French Polynesian Islands where sighting frequency was higher during the warm season (Gannier & West, 2005; Baird et al., 2008).

The minimum and maximum sighting distance to shore was 0.5 and 18 km, respectively (Figure 1); however, most sightings (84%) occurred on the continental shelf (in areas < 200 m depth). A possible explanation of this result is that the oceanic environment is closer to shore than other regions due to a narrow continental shelf in this MCP region (De la Lanza-Espino, 1991).

During this study, rough-toothed dolphins were traveling during 43.3% of sightings; during the remaining 56.7%, at least one foraging activity was observed. This is in contrast to data from the Hawaiian archipelago where only 25% of sightings included foraging (Baird et al., 2008). Through direct field observations and photographs it was possible to identify four prey species of rough-toothed dolphins: (1) the black skipjack tuna (*Euthynnus lineatus*) (two foraging events), (2) the Californian needlefish (*Strongylura exilis*) (three foraging events), (3) the gafftopsail pompano (*Trachinotus rhodopus*) (one foraging event), and (4) the dolphinfish (*Coryphaena hippurus*) (six foraging events); these prey species show a high abundance in the region during winter-spring (Trigueros-Salmerón, 1999; Espino-Barr et al., 2006; Santana-Hernández et al., 2009).

Five distinct foraging behaviors were observed: (1) individual chase (Figure 2a); (2) prey beating, probably to stun their prey (Figure 2b); (3) prey herding (Figure 2c); and (4) group attack (Figure 2d). The fifth and most frequent behavior was the individual chase, recorded during 73.7% of sightings with foraging activity, with a tendency to be more common during winter-spring (66.6%). Leaping, a behavior that could be associated with a different possible tactic, was also observed during 42.8% of foraging events.

Of particular interest is a foraging event on 23 March 2013 when a group of five to six foraging rough-toothed dolphins was observed 0.5 km from the Colima coast (Punta Tortuga, adjacent to Manzanillo Bay). The individuals swam in circles, chasing approximately five juvenile dolphinfishes and one Californian needlefish, in what appeared to be prey herding (Figure 2c). The water surface was stirred by surfacing bubbles and leaping dolphins. Our watercraft was positioned 5 to 6 m away, and an underwater video camera was used to record several occurrences of an undescribed foraging behavior for this species: using bubbles to capture fish. One of the dolphins placed itself exactly underneath the fish herded at the surface and created a series of bubbles, directing them with a movement of the head towards the fish. Simultaneously, this dolphin swam swiftly towards the surface, blending in with the bubbles as an apparent strategy to facilitate the capture of the fish (Figure 3). The capture was accomplished by a leap of about 0.5 to 1 m over the water surface (Figure 4). If the attack was successful, the fish was observed in the dolphin's snout; if the fish escaped, it was badly injured due to the assault

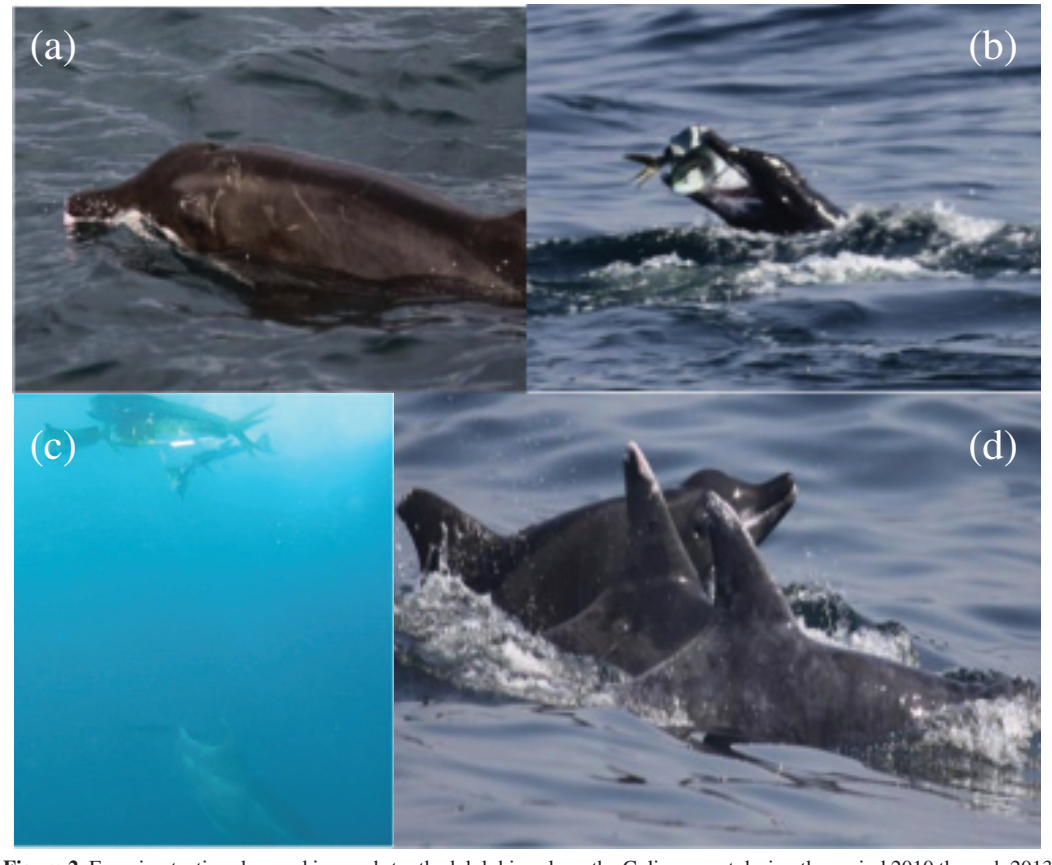

Figure 2. Foraging tactics observed in rough-toothed dolphins along the Colima coast during the period 2010 through 2013: (a) *Individual chase* – dolphin moving on surface in pursuit of prey; (b) *Prey beating* – photograph of a dolphin handling a juvenile dolphinfish (*Coryphaena hippurus*) with its snout; (c) *Prey herding* – subsurface photograph in which a dolphin is observed beneath a group of dolphinfishes and a Californian needlefish (*Strongylura exilis*), which were herded to the surface; and (d) *Group attack* – a group of three individuals in pursuit of a group of black skipjack tunas (*Euthynnus lineatus*).

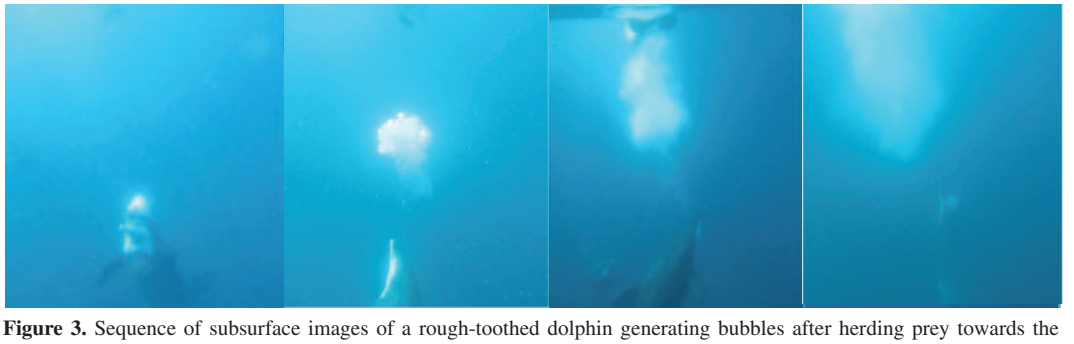

Figure 3. Sequence of subsurface images of a rough-toothed dolphin generating bubbles after herding prey towards the surface (23 March 2013, Colima coast, México)

(Figure 5). This foraging behavior was carried out by multiple group members and occurred for ~40 min until all fish were apparently consumed.

The production of bubbles as a foraging tactic is employed by several other cetacean species. Fertl & Wilson (1997) and Zaeschmar et al. (2013) reported this behavior in bottlenose dolphins (*Tursiops truncatus*) from the coastal waters of Texas and Florida, and off the New Zealand coast, respectively. In general, this tactic consisted of surrounding prey to

Figure 4. Rough-toothed dolphin leaping and catching a Californian needlefish after bubble production (23 March 2013, Colima coast, Mexico)

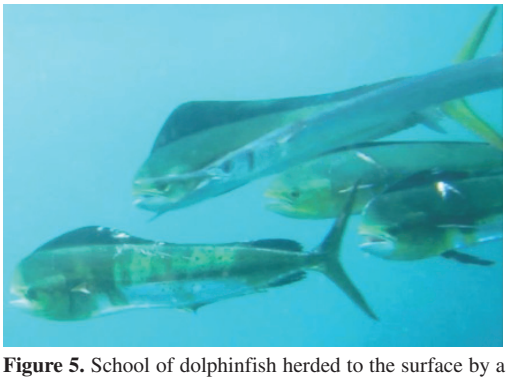

Figure 5. School of dolphinfish herded to the surface by a group of rough-toothed dolphin; white marks or scars were observed in three of these fishes and may be caused by bites inflicted by dolphins during previous predation attempts.

herd them, and then blowing bubbles towards the middle of the school to keep it close to the surface and simultaneously catch the prey, which stayed immobile or confused by the water stirring. Bubble-making behavior as a foraging tactic has also been reported for Atlantic spotted dolphins (*Stenella frontalis*; Fertl & Würsig, 1995), short-beaked common dolphins (*Delphinus delphis*; Neumann & Orams, 2003), dusky dolphins (Trudelle, 2010), killer whales (*Orcinus orca*; Similä & Ugarte, 1996), and humpback whales (*Megaptera novaeangliae*; Leighton et al., 2004). However, in humpbacks, the tactic is more complex since bubbles form a spiral structure that may create a sonic trap for the prey (Leighton et al., 2006). The probable tactic of creating bubbles by the rough-toothed dolphins described herein is not as complex as this spiral structure; however, it is somewhat unique in that it involves leaping over the water surface after bubble production. Moreover, this is just one of five distinct foraging behaviors we recorded for this species. Additionally, fishermen in the area have reported rough-toothed dolphins depredating their fishing lines, a behavior recorded once during our survey period (winter 2010) and also reported elsewhere for other odontocetes (e.g., Nitta & Henderson, 1993). Thus, all these observations are a reliable evidence of the notable plasticity of the rough-toothed dolphins in their foraging behavior during different seasons of the year; and they also highlight the importance of the coastal waters of the Colima and southern Jalisco as a foraging habitat for this dolphin species.

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