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Strand-feeding by coastal bottlenose dolphins (*Tursiops truncatus*) in the Gulf of Guayaquil, Ecuador

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Strand-feeding as a predatory strategy was first observed in bottlenose dolphins, *Tursiops truncatus,* inhabiting waters of *Spartina* marshes of South Carolina and Georgia, United States (Hoese, 1971; Rigley *et al.,* 1981; Duffy-Echevarria *et al.,* 2008). This behavior occurs when bottlenose dolphins simultaneously swim toward the shore, emerge out of the water and strand onto mud banks to feed on small fishes forced out during the surge wave generated by the dolphins, followed by the dolphins' retreat into the water (Duffy-Echevarria *et al.,* 2008). This strategy is similar to barrier-feeding or herd and chase behaviors, which are also foraging specializations observed in bottlenose dolphins of Sarasota and Florida Bays (Florida), where dolphins rapidly chase a group of fish using a barrier to herd the fish up against a mud bank, mangrove island, or sea grass bed (Weiss, 2006; Torres and Read, 2009). Other locations in the United States where similar feeding tactics have been documented are the coastal areas of Louisiana and Texas (Mullin, 1988; McHugh, 1989). Strand-feeding was also reported in the Sado Estuary, Portugal, by Dos Santos and Lacerda (1987). Likewise, Sargeant *et al.* (2005) described beach hunting as a rare foraging tactic, involving partial and nearly complete stranding on beach shores used by wild bottlenose dolphins in shallow, inshore habitats of Shark Bay, Australia. In the Pacific, beach-feeding was reported for the first time in bottlenose dolphins inhabiting the Colorado River delta and in Sinaloa, Baja California, Mexico[1] (Silber and Fertl, 1995). Strand-feeding had also been described as a hunting technique in killer whales (Guinet, 1991; Hoelzel, 1991; Guinet and Bouvier, 1995) suggesting that this foraging tactic is a specialized behavior in delphinid species. While a substantial body of documented observations exists for many regions of the world, current evidences and photo-documentation of these types of foraging behaviors by bottlenose dolphins in the Pacific coast of South America are scarce.

In Ecuador, the coastal bottlenose dolphin is a charismatic marine mammal and top predator inhabiting the mangrove estuarine waters of the Gulf of Guayaquil (03°S 80°W; Figure 1), including other areas along the Ecuadorian coast (Carvajal and Alava, 2007; Jiménez *et al.,* 2011). This small cetacean has been categorized as a vulnerable (VU) species in Ecuador due to several conservation threats according to the last update of the Ecuador's Mammals Red Data Book (Jiménez *et al.,* 2011). The bottlenose dolphin population of the Gulf of Guayaquil has preliminarily been estimated at close to 640 individuals (Félix, 1994). This population represents a proportion of the coastal and resident animals of the inner estuary, distributed mainly along the Jambelí Channel at the east border of Puna Island (Figure 1), including the surrounding waters and northward; however, it does not represent other populations existing in adjacent areas in the Gulf (*i.e.* El Morro Channel), including inner channels and waters of the El Morro Mangrove Wildlife refuge (Figure 1), where resident animals are also sighted year round exhibiting inter-tidal and inter-seasonal distributional patterns. Local people from some of the rural fishing communities of the Gulf of Guayaquil (*e.g.* Puerto El Morro and Posorja; Figure 1) carry out dolphin

[1]De la Parra, R. and Galvan, B. (1987) Observaciones del tursión costero del Pacífico en el sistema Topolobmapo-Ohuira, Sinaloa, con notas acerca del comportamiento, ritmo respiratorio e identificación individual. Pages 137-160 *in* Memorias, *X Reunión Internacional sobre Mamíferos Marinos*, 24-27 Marzo, 1985, La Paz, México.

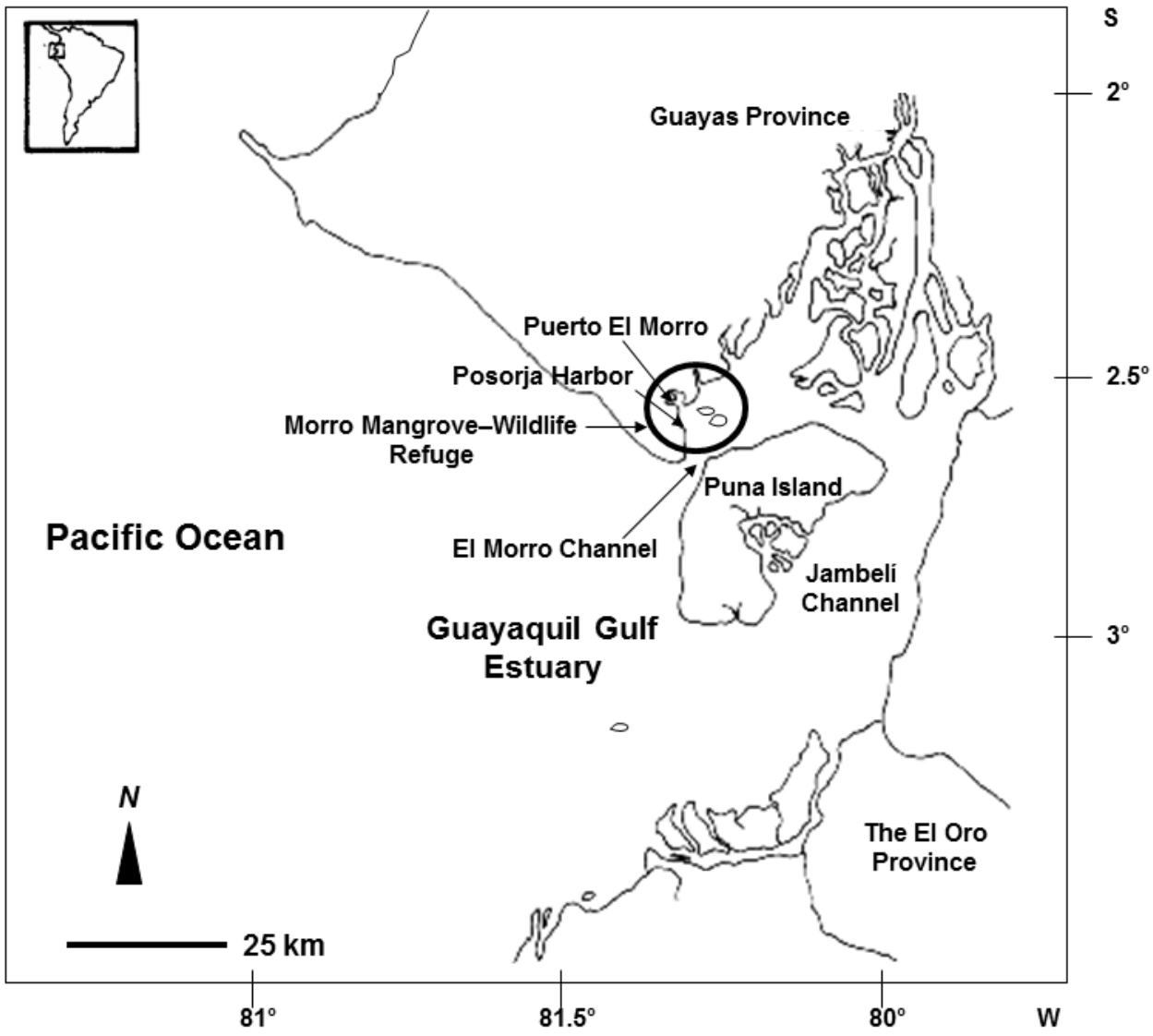

Figure 1. Map illustrating the geographical context and sites of the study area in the Estuary of the Gulf of Guayaquil, Ecuador.

watching, as an alternative, non-consumptive (*i.e.* sustainable) way of life to generate jobs (Jiménez and Alava, 2014).

The coastal ecotype of the bottlenose dolphin is commonly found to inhabit the Guayaquil Gulf Estuary; however, its behavioral and feeding ecology have been scarcely studied (Félix, 1994). To the best of our knowledge, behaviors resembling strand-feeding by bottlenose dolphins have been described very briefly without supporting photos in the inner estuary of the Gulf of Guayaquil (Félix, 1994). As a part of a long-term field study (2001-2011) on photo-identification, population ecology and monitoring of the bottlenose dolphin in the El Morro Mangrove and Wildlife Refuge, we provide some insights on its conservation, and photo-documented the occurrence of strand-feeding as a recurrent behavioral foraging tactic in this region of South America.

Field surveys were conducted from September 2009 to April 2011, using 5.5m fiberglass boats as observation platforms in the El Morro Mangrove and Wildlife Refuge (02°S, 80°W; Figure 1). This refuge is part of the National System of Protected Areas and encompasses 1304 x 10^4m^2 of mangrove forests, 700 x 10^4m^2 of mudflats and 8000 x 10^4m^2 of water area. Two Bushnell binoculars (10x42mm and 12x42mm) and two digital reflex cameras (Canon, EOS REBEL T1i, 15 megapixels), with 18-55mm and 70-300mm zoom lenses, were used for observation and photo-identification. A total of 60 surveys accounting for 240h of observations were conducted. Geographical coordinates were recorded whenever strand-feeding was observed, along with environmental information such as prey, vegetation type, and tidal state.

Strand-feeding was recorded in 10% of the surveys, including 10h of observation. It occurred at very low tides (*i.e.* during full moon cycle) in the interior channels of the surveyed mangroves areas (*i.e.* 02°31'54"S, 80°09'42"W; 02°35'46"S, 80°13'02"W). We observed that extreme low

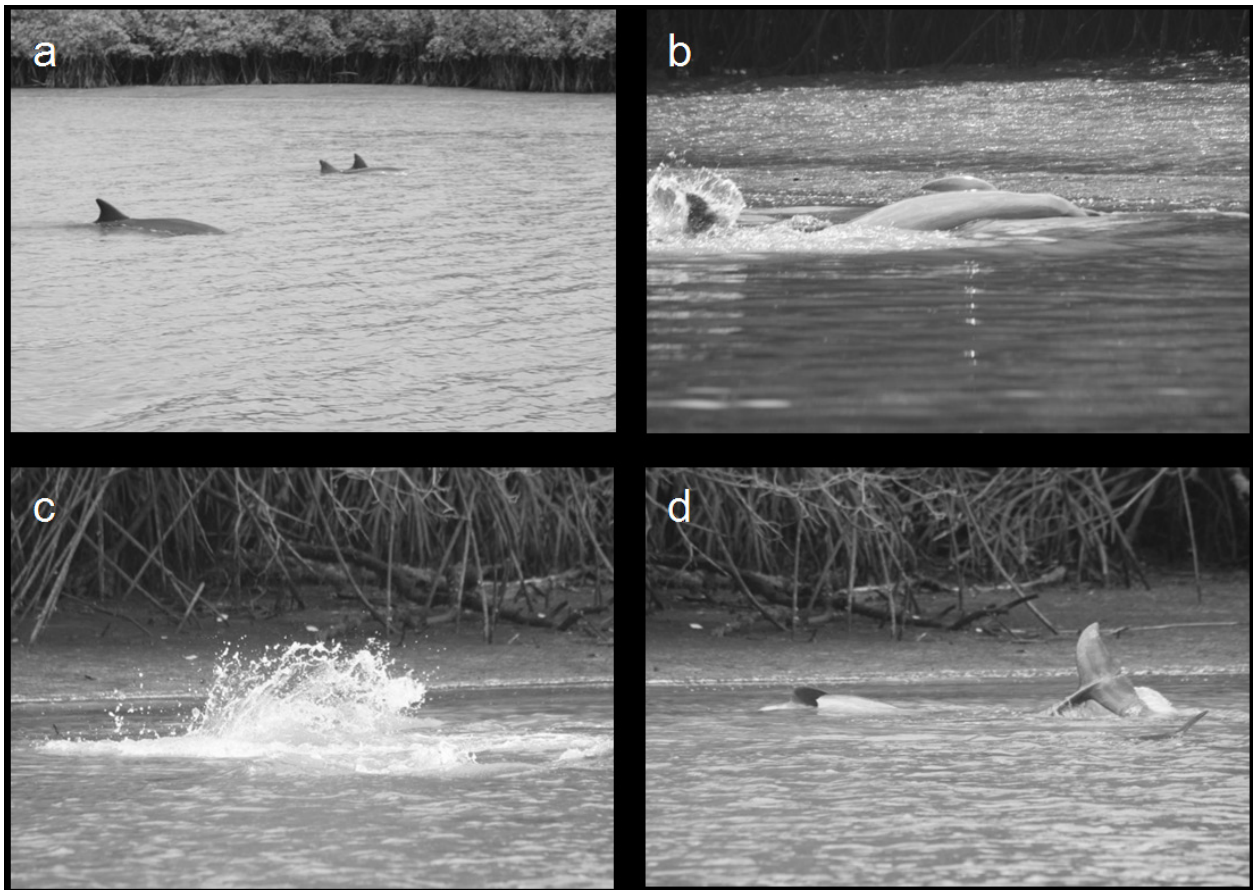

Figure 2. Foraging activities and strand-feeding behavior of bottlenose dolphins in an estuarine mangrove area of the El Morro Mangrove and Wildlife Refuge, Gulf of Guayaquil, Ecuador: (a) cooperative feeding by bottlenose dolphins targeting fish inhabiting brackish waters of mangrove areas; (b, c) individual bottlenose dolphins rushing up and splashing in low tide when chasing a fish in shallow waters adjacent to the intertidal mudflat zone; and, (d) stranded bottlenose dolphin in shallow water (30-40cm deep), lying over its right side displaying the left flipper and waving up its flukes after capturing prey (*e.g.* mullet) in close proximity to the shore and mangrove roots (*Rhizophora* sp.). Photographs by P.J. Jiménez.

tides during marked tidal regimes uncover wide mudflat beaches, creating suitable conditions for strand-feeding activities. Groups of bottlenose dolphins, ranging from two to eight individuals, were generally observed first very active and targeting fish in the middle of the channel and nearby mudflats and mangroves (Figure 2a); then they started approaching and chasing their prey, trapping them against the mud banks onto which at least one or two dolphins stranded each time and captured the prey successfully (Figure 2b, c). Dolphins washed ashore either partially or entirely over either side, forcing themselves by shaking the flukes and oscillating their bodies to move towards and onto the mudflats (Figure 2d). This behavior occurred in close proximity to mangroves, where dolphins often strand close to and underneath the aerial roots of red mangroves (*Rhizophora* spp.; where *R. harrisonii* is the most abundant species, accounting for 95% of mangrove species in the El Morro Refuge), which were used as natural barriers to trap fish. During strand-feeding events, we also observed 'cooperative escorting' in which the dolphin, a juvenile or subadult, washing ashore was accompanied by two or three individuals swimming on both sides presumably to offer assistance during the learning or training process for this foraging activity, which might be transmitted from one generation to another. Presumably, these escorts also try to catch fish when they are closer to the mudflats.

Bottlenose dolphins were observed feeding mainly on small fish. Confirmation on fish taxonomy was accomplished through direct comparisons with the landings from artisanal fishermen at Puerto El Morro and surrounding areas, using a field guide for marine fish of Ecuador (Jiménez and Béarez, 2004), as well as earlier data by Félix (1994). The main prey was the mullet (*Mugil* spp.), whereas secondary species were also exploited such as anchovies (*Anchoa* sp.; *Cetengraulis mysticetus*), croakers (*Cynoscion* sp.) and catfish (*Arius* sp.) (Félix, 1994). Based on our data and field observations elsewhere (Hoese, 1971; Rigley *et al.,* 1981; Dos Santos and Lacerda, 1987; Silber and Fertl, 1995; Torres and Read, 2009), we suggest that strand-feeding is an occasional foraging strategy of coastal bottlenose dolphins inhabiting estuarine waters in mangrove habitats of the Gulf of Guayaquil, and a

preferred feeding activity exhibited during certain times of the month, which occurs at low tides during the full moon cycle.

A different feeding pattern has been observed in a nearby area of the El Morro Refuge contrasting sharply with the strand-feeding behaviour reported in mangrove channels; dolphins schools consisting of 10 or 25 individuals were observed hunting cooperatively in sites close to decks and landing zones (Posorja Harbor, 02°42'S, 80°14'W), where discards and leftovers from fishing activities are disposed. At these locations, dolphins form subgroups of three or more individuals to pursue rushing fish, by diving, chasing and forcing them against the sea bottom (P. Jiménez, pers. obs., 2010).

Bottlenose dolphins are important predators and may have a significant ecological impact on fish populations; for instance, 3.2-6.8% of the total annual primary production in the North Inlet salt marsh creek system of South Carolina (US) is estimated to be needed to maintain an average population of only six bottlenose dolphins, which can consume up to 11.0-14.0t of fish (wet weight) each year (Young and Phillips, 2002). Therefore, the annual intake of fish by the coastal bottlenose dolphin population of the Guayaquil Gulf Estuary was estimated to be at least 925t of various fish (*e.g.* mullets, drums and anchovies) (Alava, 2009). Other apex predators feeding on similar prey items and residing in the mangrove ecosystem of the Guayaquil Gulf are aquatic birds, including snowy egrets (*Egretta thula*), great white egrets (*Ardea alba*), night herons (*Nycticorax nycticorax; Nyctanasa violacea*), brown pelican (*Pelecanus occidentalis*) and frigatebirds (*Fregata*), as well as the American crocodile (*Crocodylus acutus*)[2] (Carvajal *et al.,* 2005; Carvajal and Alava, 2007; Jimenez, 2009). In fact, feeding competition is very common in the study area, where frigatebirds and especially brown pelicans can take advantage of the fish driven ashore by chasing or stranding dolphins. Moreover, feeding frenzy activities were observed when bottlenose dolphins were foraging in the water or while beach-hunting in close interaction with brown pelicans[2] (P. Jiménez, pers. obs., 2010).

Though the conservation and status of this particular dolphin population in the El Morro Mangrove Wildlife Refuge has scarcely been assessed, approximately 100 individuals have been photo-identified in the refuge and the surrounding areas since 2005[3] (P. Jiménez, unpub. data). However, the El Morro population is potentially threatened and could be declining in abundance due to several anthropogenic impacts, including habitat loss and degradation, pollution, bycatch in artisanal fisheries and unsustainable dolphin watching tourism (Jiménez *et al.,* 2011). For instance, the number of stranded and dead dolphins associated to human activities (*e.g.* fisheries interaction) ranges from one to three individuals per year[4]. In addition to these environmental stressors, density dependent factors involving predation, migration, food shortages, inter- and intra-specific competition for quality and quantity of prey can also influence the number of dolphins present in the area. Competition can be even more pronounced during the El Niño Southern Oscillation (ENSO) events when sea surface temperature increases and lower marine productivity drastically affects sea birds and marine mammals by reducing prey abundance in this equatorial zone.

Like other specialized foraging techniques, strand-feeding may be socially learned either maternally, by vertical transmission or otherwise, a horizontal or oblique learning that may occur among individuals frequenting this coastal habitat (Mann and Sargeant, 2003; Sargeant et al., 2005; Weiss, 2006).

As more research is needed to elucidate the evolutionary and ecological consequences of the foraging strategies described here, we conclude that strand-feeding is a widespread feeding behavior developed by bottlenose dolphins on both hemispheres, and more common than previously reported.

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[4]Jiménez, P. (2010) Situación actual del bufeo costero *Tursiops truncatus* en un sector del Canal del Morro, Golfo de Guayaquil. Presentation *in 1er Simposio Latinoamericano de Biodiversidad Marina* y Costera de Latinoamérica y El Caribe, y *2do Simposio Ecuatoriano de Biodiversidad Marino Costera.* Ministerio del Ambiente; Grupo de Trabajo sobre Biodiversidad Marino y Costera del Ecuador. 9–12 Diciembre, 2010, Manta, Ecuador.

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