

Short Note

Impacts of Fishing Entanglement on the Bottlenose Dolphin Society in the Gulf of Guayaquil, Ecuador

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The common bottlenose dolphin (*Tursiops truncatus*) is a cosmopolitan species inhabiting tropical and temperate waters. Some populations of coastal bottlenose dolphin (both *T. truncatus* and *Tursiops aduncus*) are among the better studied cetacean societies. Living within semi-discrete population units, both species organize in fission-fusion societies where kinship, age, sex, reproductive status, and ecological features modulate the interactions among their members (Wells et al., 1987; McHugh, 2019; Connor et al., 2000). Long-term studies have attempted to decode the complex bottlenose dolphin societies in different parts of the world by monitoring known animals at different life stages; this has provided details of the diverse roles individuals play within dolphin society (Wells, 2014; Connor et al., 2019). Adult females play an important role within the bottlenose dolphin society that is not limited to their reproductive phase but probably extends into senescence when their experience and knowledge would become valuable societal assets, similar to other long-lived mammals (e.g., McComb et al., 2001; Foster et al., 2012). For some populations, male bottlenose dolphins maintain long-lasting associations with other males to improve status and access to receptive females (Wells et al., 1987; Connor et al., 1992). In such complex societies, effective bonds created in early development likely exceed those benefits associated with defense, food procurement, and reproduction (Stanton & Mann, 2012).

Sudden changes in dolphin social dynamics are generally associated with ecological disturbances, such as disease outbreaks or harmful algal blooms (Van Bressem et al., 2014; Fire et al., 2015), or changes in productivity and prey availability (Sprogis et al., 2017). But some human activities could also cause unexpected changes in group social dynamics if key animals are

suddenly removed by unnatural causes, particularly in small populations (Williams & Lusseau, 2006). Entanglement in fishing gear is undoubtedly the main cause of stress, injury, and mortality of marine mammals (Read et al., 2006; Wells et al., 2008; Reeves et al., 2013; Brownell et al., 2019). Injuries in bottlenose dolphins may also affect temporal sociality (Greenfield et al., 2020). However, rarely are disruptions to sociality considered when evaluating human impacts or informing management (Smith et al., 2016). Measuring changes in group social structure along a temporal scale requires statistical methods that incorporate the high variability in different association and dissociation mechanisms such as constant companionship, temporal feeding/breeding associations, ephemeral relationships, immigration/emigration, and death (Whitehead, 1995; Greenfield et al., 2020).

Changes in association patterns over time of bottlenose dolphins that had become entangled in fishing gear in two different social groups were assessed in the Gulf of Guayaquil, Ecuador (centered at 3° S, 80° 32' W; Figure 1). This study is part of an effort over the last decade to identify threats and define alternatives with the goal of halting the decreasing abundance trend experienced by this population (Jiménez & Álava, 2014; Félix et al., 2017; Félix & Burneo, 2020). The studied animals are part of a metapopulation (*sensu* van Nouhuys, 2016) composed of small resident population subunits referred to as communities with well-defined home ranges and strong bonds between their members (Félix, 1997; Félix et al., 2017; Félix & Burneo, 2020). In the last decade, effort has concentrated in an area of 150 km² in the western inner estuary where two dolphin communities distribute. These areas are referred to as Posorja and El Morro (Félix & Burneo, 2020). Both dolphin communities are conservation targets of a

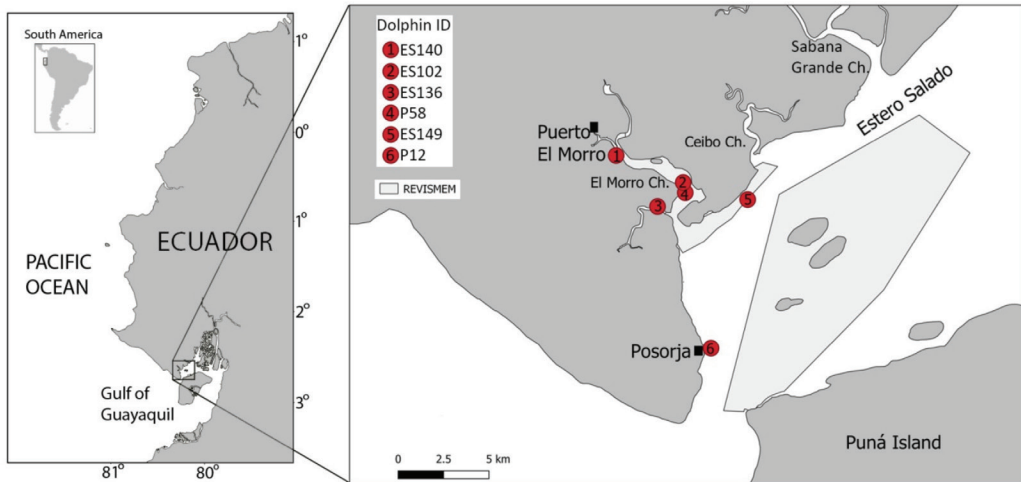


Figure 1. The study area on the western inner estuary of the Gulf of Guayaquil. Dots indicate sites where bottlenose dolphins (*Tursiops truncatus*) entangled or towing gear were recorded for the first time. The numbers inside the dots indicate the ID code of the animals. The two light gray polygons indicate the limits of the El Morro Mangrove Wildlife Refuge (REVISMEM), a marine protected area.

marine protected area named El Morro Mangrove Wildlife Refuge (REVISMEM) located within the study area. From February 2011 to December 2019, 253 surveys were conducted and 13,684 km traveled, with 8,834 h of survey effort and 3,488 h of dolphin sightings. During the surveys, 445 dolphin groups were recorded in which 147 different animals were identified by natural marks. A pair-wise association index (AI) was estimated for all members of the two dolphin communities using the half-weight index as described in Félix et al. (2017). Male ranking within the society was assigned according to the average AI with the core of adult females in the community: the higher the AI with adult females, the higher the rank of a male within the community (Félix et al., 2019).

Entanglement Cases

Six cases of dolphins entangled in fishing gear occurred from January 2017 to December 2019. In four cases, animals were released by fishers and officials of the Ministry of Environment, one animal released itself from the gear, and the 6th dolphin remained entangled and towed the gear until the last time it was seen. Figure 1 shows the sites where each entangled animal was initially observed.

Case 1: Individual ID# ES140—A subadult of unknown sex was found entangled alone on 3 January 2017 in a secondary branch of the El Morro Channel (Figure 2A). A heavy piece of gear was entangled around the tail, which kept its body in an inclined position with the tail down and head at or above the water surface.

This individual had been seen only once before in the area, in June 2016, as part of a group of five dolphins of the El Morro community. When the animal was released, it gradually recovered its ability to swim. It was followed for 15 min more, and then the observations were discontinued. This individual was not seen again during this study.

Case 2: Individual ID# ES102—An adult male of the El Morro community was caught in a surface nylon monofilament gillnet of 2-inch mesh within the El Morro Channel on 14 January 2017 and released alive by fishers (Figure 2B). The dolphin was seen again 11 times after this entanglement until August 2018 and then not seen again until the end of the study. This was a male with a high rank within the El Morro community until 2016. Interestingly, the last 11 records of this dolphin were not within the El Morro dolphin community home range but within the Posorja dolphin community home range, where he remained for almost a year as a low- to mid-ranked male. He was last observed in this study area 14 mo later in October 2019. ID# ES102 was recorded again at Naranjal River, 50 km away on the other side of the estuary.

Case 3: Individual ID# ES136—A subadult female of the El Morro community was observed entangled in a longline on 21 January 2017 (Figure 2C). The individual was swimming alone in a secondary branch of the El Morro Channel. The dolphin was seen again two times in April 2017 with a group of mothers with offspring: she appeared to be recovered from the entanglement. On 1 July 2017, ID# ES136 was seen with her body covered with long

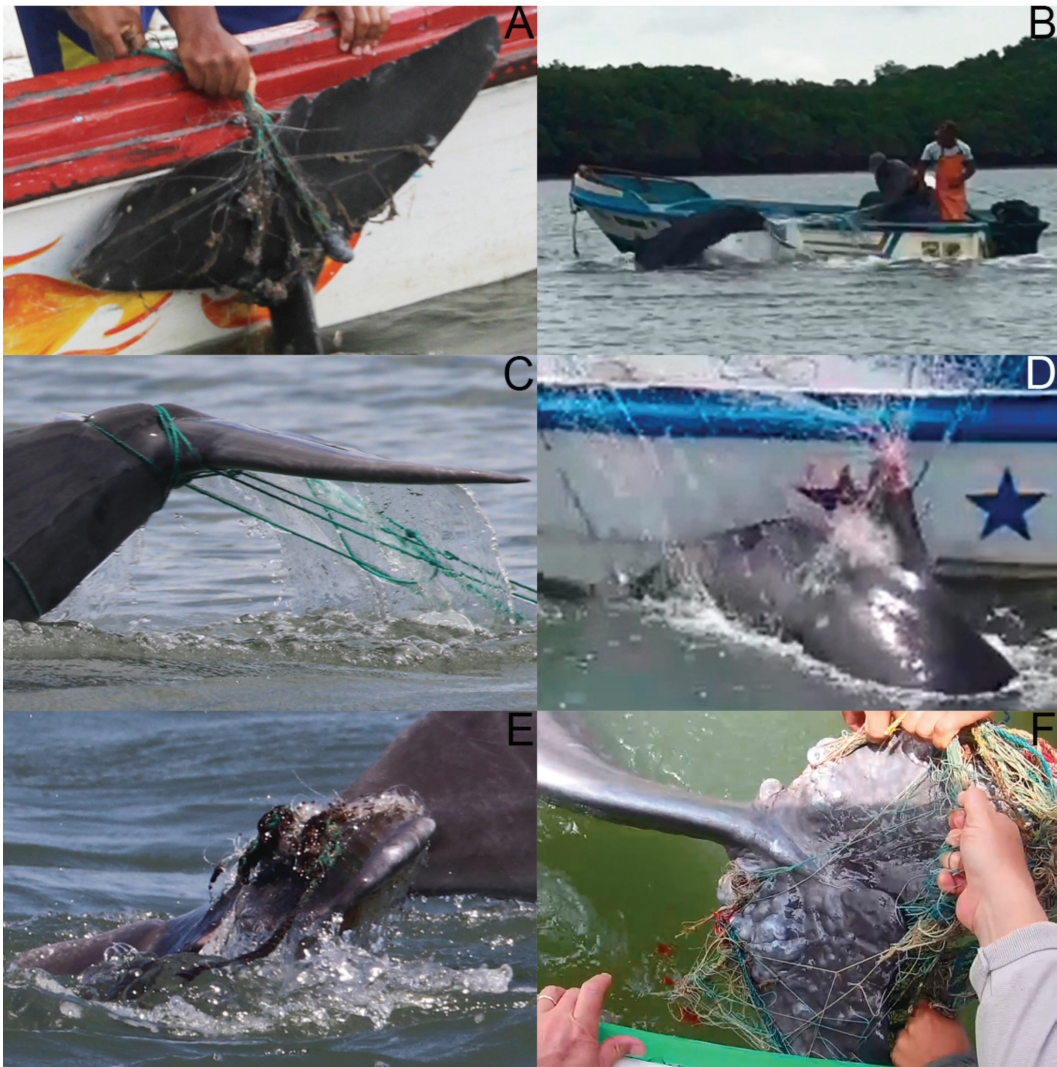


Figure 2. Six identified bottlenose dolphins found entangled in different fishing gear in the study area between 2017 and 2019: Case 1 (A), Case 2 (B), Case 3 (C), Case 4 (D), Case 5 (E), and Case 6 (F). Photographs in (B) and (C) were provided by REVISEMEM officials.

wounds, presumably from a second entanglement. This female reintegrated into the group of mothers with offspring in the El Morro dolphin community after 3.5 mo in October 2017. Since then, she has been seen regularly with females and their offspring.

Case 4: Individual ID# P58—An adult male of the Posorja community was caught in a 2.5-inch mesh nylon monofilament surface gillnet on 12 September 2017 and released by fishers (Figure 2D). This dolphin was usually found associated with another adult male, ID# P60, but always maintained a low rank within the community. This male pair was recorded 13 times between April 2011 and October 2018,

either as a pair or within larger groups of mostly females with offspring. ID# P58 was seen six more times between September and October 2018—twice alone, three times with P60, and only once as part of another group—after which time he emigrated. Since October 2018, his partner, ID# P60, was seen twice in 2019 but not associated to another adult male. ID# P58 was found dead in October 2020, some 40 km northwest of Posorja within the home range of another neighbor community, confirming his emigration and the end of a 7-y male–male association with ID# P60 2 y earlier.

Case 5: Individual ID# ES149—An adult dolphin of the El Morro community, presumed to be male because it was not seen associated with a calf nor other adult females, was first observed on 30 June 2018 (Figure 2E). This dolphin barely lifted its tail, which was wrapped with remains of a nylon monofilament net and polypropylene ropes. It was observed nine times between June 2018 and November 2019—on two occasions alone and seven times in groups that varied in size between two and 13 animals. During these group observations, only on one occasion did this dolphin seem well integrated into the group, interacting with young animals. In other sightings, however, ID# ES149 was observed on the periphery of these groups, with low or no interaction with other animals. The animal towed gear for at least 18 mo.

Case 6: Individual ID# P12—An adult male from the Posorja dolphin community was found entangled on 16 February 2019 with remains of a 6-inch mesh cotton gillnet around his tail (Figure 2F). ID# P12 had a high status within the community since 2014. He formed an association with ID# P69 and maintained high association levels with adult females between February 2017 and August 2018. From August 2018, ID# P12 was not observed until he was found entangled. ID# P69, ID# P12's associate, was seen three times during the 6 mo when ID# P12 was not observed, with ID# P69's last observation on 22 September 2018 when he had apparently emigrated. Once the gear was removed, ID# P12 was seen regularly again at Posorja and was integrated within the adult groups as before. A few weeks later, ID# P12 formed an association with another adult male (ID# P25). The new association was maintained to the end of the study.

Changes in the Social Dynamics

Overall, there were three cases of dolphins that abandoned or emigrated from the area after entanglement—two of them immediately (ID#s ES140 and ES102) and a third individual 1 y later (ID# P58). Thus, by the end of 2019, only three of the six entangled dolphins continued to be observed regularly in the study area. Five entangled animals were alone when observed (ID#s ES140, ES102, P136, P58, and P12). In two cases, the reduction in their level of sociality extended months while animals towed gear (ID#s ES136 and ES149). In one case, a high-ranked male lost status while entangled (ID# P12), although he recovered his status about 6 mo after the gear was removed and joined another adult male. For ID# P12, his entanglement also ended his association with male ID# P69 who seemed to emigrate from the area. Male association disruption also occurred for ID# P58 who separated from his 7-y partner (ID# P60). Of

the six entanglement cases, two were subadults (ID#s ES140 and female ES136), and four were adults. Of the four adults, three were confirmed males (ID#s ES102, P58, and P12), and the fourth (ID# ES149) was also likely a male but requires confirmation.

Observations of six entangled dolphins in a critically threatened dolphin population facilitated a better understanding of how the physical impacts of entanglement affect their social behavior, including association patterns, distribution, and behavioral interaction. The changes observed in surviving animals following an entanglement included a reduction in their level of sociality, potential emigration, changes in social status, and male association pattern disruption. Such impacts could affect the social and population dynamics of these two small dolphin communities, especially if individuals with high reproductive potential or with relevant cultural knowledge were affected (Whitehead et al., 2004; Cantor & Whitehead, 2013). These findings are consistent with a reduction in preferred associations found in injured bottlenose dolphins in Florida (Greenfield et al., 2020). Since these six observed entangled dolphins represented 15% of the current population, the impact of gear entanglement on both the individual and groups should be considered an additional contributing factor to the steady deterioration of these dolphin communities (Félix et al., 2017; Félix & Burneo, 2020).

Two of the six entangled dolphins (subadult ID# ES140 and adult ID# ES102) seemed to emigrate from the area immediately after their entanglement event. This value is higher than the estimated annual rate of mortality/emigration in the Posorja (6.4%) and El Morro (3.1%) communities (Félix & Burneo, 2020). In a stable bottlenose dolphin community in Florida, the annual immigration/emigration rate was estimated as 3% (Wells & Scott, 1990). Thus, entanglements would contribute to an increasing emigration rate, although due to the relatively short study period (8 y: 2011 to 2019), it is not possible to establish whether emigration was temporary or permanent. In one case, ID# P58, found dead in 2020, that emigration was not reversible. While dispersal may favor other more distant dolphin communities and contribute to the gene flux within the metapopulation (Manlik et al., 2018), the impact on some source communities such as Posorja and El Morro could be significant. The trauma caused by entanglement could be the reason why subadult ID# ES140 had not returned to the study area 3 y after being released from the gear. For subadult female ID# ES136, she had two short periods away from the study area while entangled, then returned to the groups of mothers with offspring. As segregation by sex occurs naturally in some bottlenose

dolphin groups during adolescence (Wells et al., 1987; Stanton & Mann, 2012), entanglement could delay the recruitment of young animals.

A reduction of sociability was evident in ID#s P12, ES136, and ES149 during the time when they towed gear. It is unknown if such a change in their social patterns was because they could not keep up with the movement of other animals and therefore were less useful during group activities such as chasing fish or defense or if it was because the entangled dolphins were actively avoided by other dolphins due to their condition. The deviation from normal social and spatial patterns has also been reported for bottlenose dolphins affected by injuries (Greenfield et al., 2020) and skin lesions (Murdoch et al., 2008; Daura-Jorge & Simões-Lopes, 2011). The temporal absence and/or entanglement of ID# P12 could be why his former partner ID# P69 abandoned the area, extending the problem to individuals not involved in the entanglement. Strong association patterns between males have been documented in several common coastal bottlenose dolphin groups; these associations are formed between males of similar ages and often last until one of the members dies (Connor et al., 1992; Wells, 2000). Since male bottlenose dolphins rely on these strong associations to be created at a young age (Wells et al., 1987; Stanton & Mann, 2012), disruption of these pair bonds may have severe fitness consequences for males. Male bottlenose dolphins may form new associations at different levels, in part as a mating strategy (Connor et al., 1992; Wiszniewski et al., 2012); thus, a male entangled in and towing gear is probably a less preferred partner. The social cost for adult males would be high if they cannot maintain operational associations with other males while towing gear. For ID# P12, after being released from the gear and physically recovered, he associated with a different adult male (ID# P25) who had also lost his partner, which might not have been possible without intervention of gear removal. This was not the case for ID# P60, who, after losing his partner (ID# P58) due to entanglement, was unable to form an association with another male of the Posorja community. ID#s P60 and P69 also offer an example of how demography may exacerbate the problem when males need to restart strong associations or alliances. Thus, entanglement is seen to potentially accelerate changes in the male hierarchy structure within the bottlenose dolphin society in the Gulf of Guayaquil.

Different aged and sexed dolphins experienced variable risks of entanglement. Subadult and adult male dolphins are most affected by fishing gear in the Gulf of Guayaquil. For subadults, entanglement might be related to inexperience as reported

elsewhere (Wells & Scott, 1994; Mann et al., 1995; Wells et al., 1998) and also could affect both sexes. But for adults, the situation might be different. Since the dolphin communities of El Morro and Posorja show a marked bias towards males, 2:1 and 3:1, respectively (Bayas-Rea et al., 2018; Félix & Burneo, 2020), it is not clear whether the high proportion of entangled adult males might simply reflect this existing demographic reality. On the other hand, as males often have a wider distribution than females (Wells et al., 1987; Connor et al., 2017; Félix et al., 2019), the propensity of males to become entangled more frequently than females could be related to male exploratory behavior when searching for receptive females in nearby communities, which would expose adult males more often than other age/sex groups to different fishing activities. An entanglement rate biased towards males has also been reported in Laguna, Brazil, where researchers attributed this problem to the sex bias towards females found in this population (Fruet et al., 2015). For adult females, the protective instinct of mothers with calves would likely make them more alert to different threats than males. Females also might concentrate activities in smaller home ranges where activities to be avoided are better known. The bias of entanglement towards adult males, either by mortality/emigration or male association/alliance disruption in bottlenose dolphins, may be similar to that caused by poaching in the society of African elephants (*Loxodonta africana*). Poaching disrupts kin-based association patterns, reduces the age of peak reproduction for males, and increases male reproductive skew (Archie & Chiyo, 2012). A better understanding of these impacts on the bottlenose dolphin society in the Gulf of Guayaquil is necessary to develop tailored conservation strategies. However, quantifying the impact of human threats in terms of fitness, genetic structure, and population trajectory requires time and knowledge of multiple demographic and environmental variables.

Most entangled dolphins were observed alone. The absence of other dolphins near the entangled individual(s) indicates that there was no ongoing attempt of assistance after entanglement, leaving the affected animals to their fate, at least during the periods of observation by this author. Bottlenose dolphins and other cetacean species are known for offering epimeletic or caregiving behavior to either stressed or dead conspecifics, particularly with mothers towards their dead offspring (Félix, 1994; Bearzi et al., 2018). Distress sounds are produced by animals needing assistance (Kuczaj et al., 2015), which seems to also alert other dolphins of the danger or to call others to help. Since entanglements occur with frequency in this study

area, dolphins might perceive entangled animals as a menace and avoid approaching them. For both subadults (ID#s ES140 and ES136), the entanglement also seemed to motivate their potential need to look for a safe place while towing gear as both subadults were found inside secondary branches of the El Morro Channel and stayed there for hours. Moving to shallow channels would reduce risk from predation and vessel collisions. The use of those secondary channels is rather rare compared with other areas regularly used by the El Morro dolphins (Félix & Burneo, 2020). Fleeing to shallow waters is an anti-predation tactic used by some marine mammals (Srinivasan, 2019).

Many types of fishing gear, including surface and bottom gillnets and longlines, affect bottlenose dolphins in the Gulf of Guayaquil, and those effects are likely underestimated if social impacts are not considered. An effective conservation strategy with strong management commitment is needed to address the problem and to reduce the impact of fisheries on this population. The presence of a marine protected area (REVISMEM) in the study area constitutes a strength to enhance fishing management and to support dolphin research on social and demographic modeling. In previous reports, recommendations were made to improve fishing management in this zone such as to shift fishing gear and to create fishing-free areas where dolphins concentrate their activities and corridors to allow the transit of dolphins between the different channels along the Estero Salado (Félix et al., 2017; Félix & Burneo, 2020). Dolphins' social dynamics is a new element to be incorporated into the management equation to reduce the risk of population extirpation and should be part of future monitoring to determine whether management measures were effective. This should also be considered for other populations of social odontocetes impacted by fisheries in coastal areas elsewhere. Fishers could play a significant role in supporting such a strategy in the long-term and should be included in the decision-making process.

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