

MARINE RECORD

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# Southernmost record of the Giant Manta Ray *Mobula birostris* (Walbaum, 1792) in the Eastern Pacific

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## Abstract

**Background:** Manta rays (Mobulidae), *Mobula birostris* and *Mobula alfredi*, are widely distributed in tropical and temperate waters. Still, little is known about their movements and their ecological interactions (e.g. behavior and diet). In Peru, *M. birostris* has only been reported along the northern shore within the Tropical East Pacific Marine Province. No official reports exist from central or south Peru within the Warm Temperate Southeastern Pacific Marine Province.

**Methods:** On December 22nd 2015, a rare sighting of a ~4 m disc width mobulid ray was recorded as video footage near the Palomino Islets, Lima, Peru.

**Results:** In situ observations and subsequent analysis of the footage confirmed that this single mobulid was a *M. birostris* with a melanistic color morph.

**Conclusions:** This sighting could be explained by the warm El Niño, primary (chl-a), and secondary (zooplankton) productivity events during that same period. This represents the southernmost record of *M. birostris* in the southeastern Pacific (12°S) and the first report of this species in the Warm Temperate Southeastern Pacific Marine Province and in the Humboldt Current Large Marine Ecosystem.

**Keywords:** Sighting, El Niño, Peru, Southeastern Pacific, Marine province

## Background

Until recently, manta rays belonged to the genus *Manta* which formally comprised two re-described species: the Giant Manta Ray (*M. birostris*) and the Coastal Manta Ray (*M. alfredi*). In addition to these, the putative species *M. cf. birostris* (suggested as *M. giorna* by Marshall et al., 2009) was consistent with the recent publication of the potential species of Yucatán manta ray (Hinojosa-Alvarez et al., 2016). White et al. (2017) have updated the taxonomic arrangement of the Mobulidae family nesting the members of the genus *Manta* within the *Mobula* species. Manta rays (referring now to *M. birostris* and *M. alfredi*) are pelagic planktivores, the largest batoid fishes in the world (Marshall et al., 2011) and reported to occur circumglobally in tropical and temperate waters (Couturier

et al., 2012). *M. birostris* is considered the more widely distributed member of the genus as it is broadly spread in the Pacific, Atlantic and Indian oceans (Marshall et al., 2009) while *M. alfredi* is absent from the Eastern Pacific (Couturier et al., 2012; Lawson et al., 2017). Several biological traits (i.e. slow growth, late sexual maturation and low fecundity) of these species make them prone to over-exploitation (Dulvy et al., 2008; Deakos et al., 2011). In addition, two of the most direct threats are by-catch and the high demand for its gill rakers by the Asian market (White et al., 2006). Therefore, the International Union of the Conservation of Nature (IUCN) has assessed the conservation status of both manta ray species as vulnerable to extinction (Marshall et al., 2011, IUCN Red List). Moreover, The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) included *M. birostris* species in appendix II; while the Commission of Migratory Species (CMS) included *M. birostris* in appendices I and II.

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Five species of the Mobulidae family have been officially reported in northern Peru (up to 6°S): *M. birostris*, *M. mobular*, *M. munkiana*, *M. tarapacana*, and *M. thurstoni* (Chirichigno & Cornejo, 2001). However, *M. birostris* is commonly allocated in distribution maps that extend its occurrence to southern Peruvian limits (e.g. Marshall et al., 2011; Lawson et al., 2017). Peruvian waters present two marine provinces (MP) (Spalding et al., 2007; <http://www.marineregions.org/sources.php>): 1) the Tropical East Pacific (TEP–MP), characterized by the Equatorial Current; and 2) the Warm Temperate Southeastern Pacific (WTSP–MP), characterized by the Humboldt Current and the associated upwelling of cold nutrient-rich waters. From these two marine provinces, *M. birostris* have only been reported in the TEP–MP; moreover, this species has not been reported in the Humboldt Current Large Marine Ecosystem (HC–LME). Therefore, the aim of this study is to report and establish the southernmost record of *M. birostris* in the southeastern Pacific and its first report in the WTSP–MP and HC–LME.

## Methods

On December 22nd 2015, one of the authors (BM) performed a diving excursion to the Palomino Islets which are located on Peruvian central coast, 8.9 km away from La Punta, Callao (Fig. 1). The Palomino Islets are located 2.6 km from Cavinzas Island and together they comprise a Natural Protected Area covering 5146 ha (Sernanp, 2009). BM was carrying an action-cam GoPro Hero2 model, a compass and a Cressi Leonardo dive computer, which measured depth and water temperature. For the approximate identification of the mobulid, individual visible diagnostic characteristics (excluding dentition) described by Marshall et al. (2009) and Hinojosa-Alvarez et al. (2016) were used (Table 1). The distinctive features included: terminal mouth, large and unfurl cephalic fins, ventral spot pattern clustered around lower abdominal region, trailing underside edge of pectoral fins usually shaded black, gill covers often with black shading/flaring, and white shoulder markings form two mirror image right angled triangles which creates the letter T in black across the top of the head. Both *M. birostris* and *M. alfredi* show a melanistic form, described as entirely black on the dorsal surface and predominantly black on the ventral surface (Marshall et al., 2009).

## Results

During the dive an unusual encounter with a large mobulid individual was registered on video nearby the Palomino Islets (Fig. 1), 12°07'37.01''S; 77°13'50.76''W. The sighting was registered at a depth of 16 m, where temperature was 18 °C (SST: 19 °C), water was turbid (~6 m visibility), greenish, and the bottom sediment at 18 m was composed of sand and deposits of broken shells.

Mouth position was the first morphological observation to discriminate between all possible *Mobula* species. The sighted mobulid had a terminal mouth which is a key trait to restrict it to the larger *Mobula* species (Table 1). Also, it had ~4 m disc width (DW) and long unfurled cephalic fins. Based on the dorsal coloration it was a melanistic morph of manta ray, with a centered white ventral pattern (Fig. 2).

Eleven sucker fish (*Remora* sp.) were counted below the ventral zone, and one above the dorsal zone next to the dorsal fin. Although remoras were located in the gill area, gill slits covered with black shading could be observed. Based on the diagnostic traits (Table 1), *M. alfredi* was less likely as the expected body and mouth coloration differed from the observed individual and there was no embedded caudal spine. Both Yucatán manta ray and *M. birostris* presented the same diagnostic traits as the sighted individual.

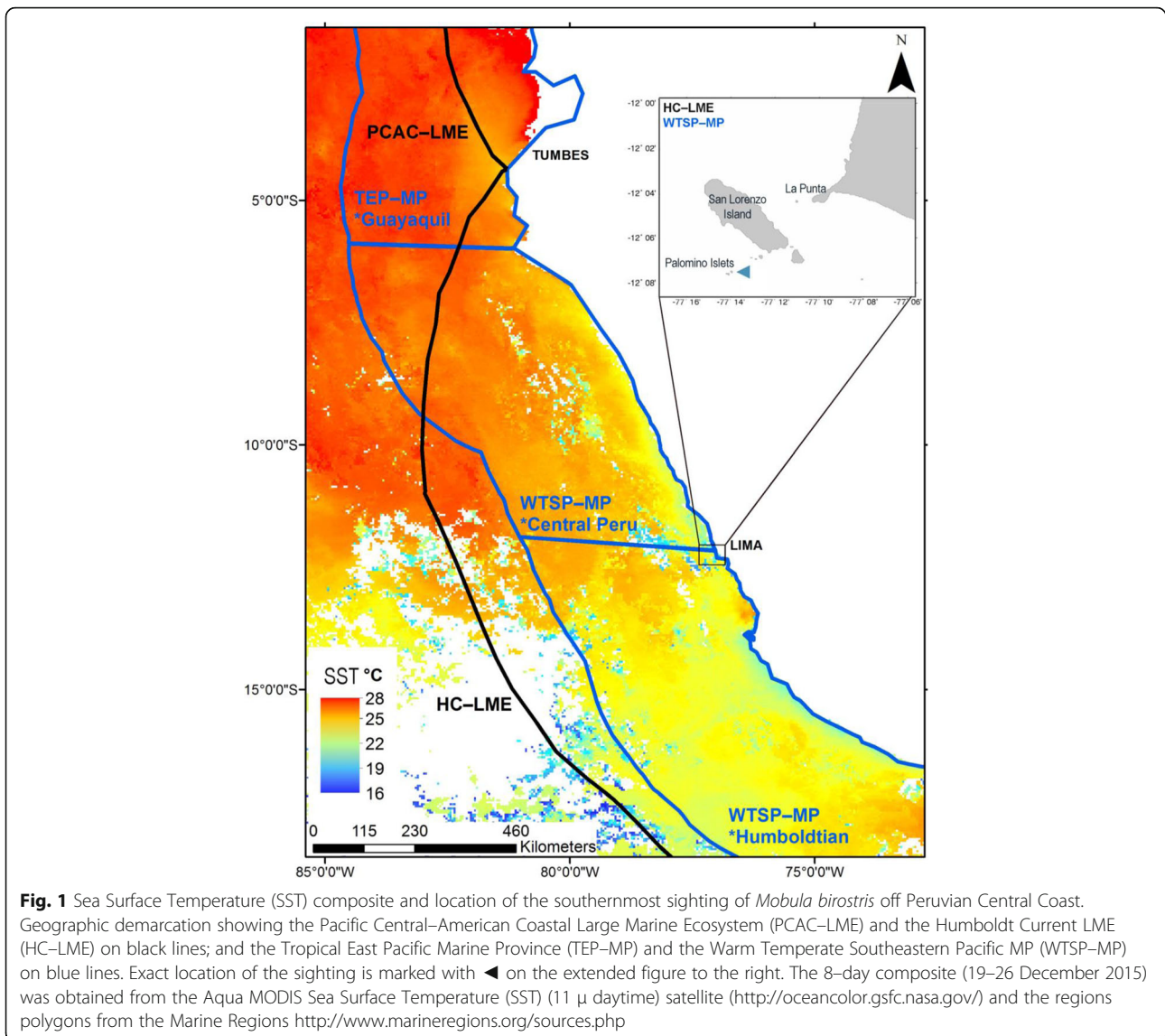
The cephalic fins were closed while swimming across the water column 2 m above the seafloor, suggesting a non-feeding behavior (Ari & Correia, 2008). The widening of the branchial gills could not be assessed because of the presence of sucker-fishes below them, which impeded the determination of a definite feeding behavior. Additional observations include dense mats of red squat lobsters (*Pleuroncodes monodon*) on the surface and several dozen siphonophores in the water column.

Video footage of the sighting is available at <https://vimeo.com/150842390> (Peruvian Dark Angel).

## Discussion

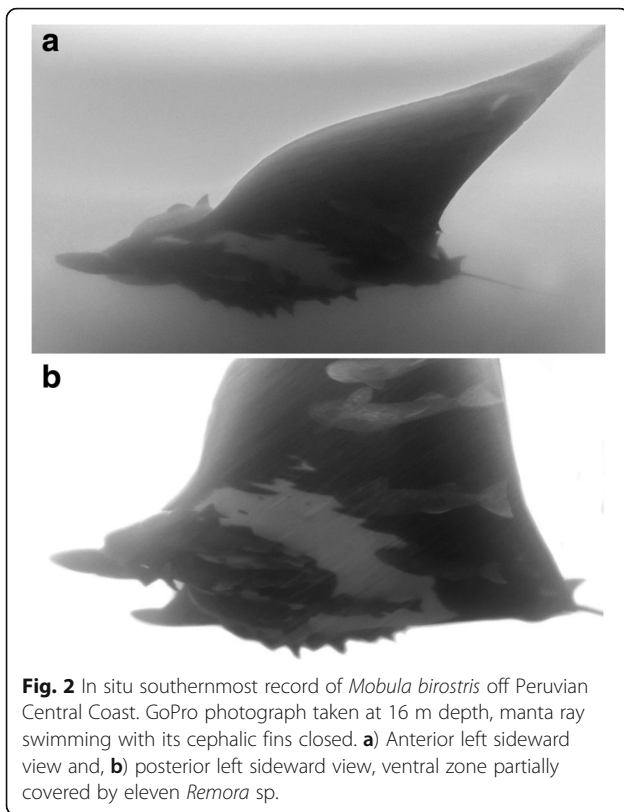
Due to similarities in their body size and external appearance, mobulids are often confused in the field (Couturier et al., 2012). Location of the mouth is a key diagnostic characteristic between manta rays and devilrays, being terminal and subterminal respectively. Based on the terminal mouth, body size and coloration patterns, the sighted mobulid was undoubtedly a manta ray. The largest representatives of the *Mobula* genus (White et al., 2017), commonly known as manta rays, have two officially defined species: *M. birostris* and *M. alfredi*, which have many morphological characters in common and close similarities at the molecular level (Kashiwagi et al., 2012). Their evolutionary divergence is thought to be relatively recent (1 Ma), in contrast to e.g. *M. rochebrunei* and *M. munkiana* (2.59 Ma) (Poortvliet et al., 2015).

The IUCN Red List states that historical reports of both *M. birostris* and *M. alfredi* are often mixed since the re-description and separation of the species was published in 2009; therefore, reports and distribution ranges should acknowledge this. Also, relying only on color morphologies could be a possible source of error resulting in misidentifications (Visser et al., 2004). One hybrid (*M. birostris* x *M. alfredi*) has been reported through



**Table 1** Diagnosis traits comparison chart (modified from Hinojosa et al., 2016) between the sighted individual, *M. birostris*, *M. alfredi*, and the putative additional species off Yucatán (Hinojosa et al., 2016). Present: 1; absent: 0

Visible diagnosis traits	Sighted <i>Mobula sp</i>	<i>M. birostris</i>	<i>M. alfredi</i>	Yucatán manta ray
Mouth color (white:0; black:1)	1	1	0	0; 1
Black dorsal surface	1	1	1	1; brown
Triangular-shaped shoulder patches in supra-branchial region (Unless melanistic form)	melanistic	1; melanistic	0	1; melanistic
Dark spots between the five gill slits or pectoral fins	0	0	1	0
Calcified mass with an embedded spine on the dorsum of tail immediately posterior to dorsal fin	1	1	0	1



**Fig. 2** In situ southernmost record of *Mobula birostris* off Peruvian Central Coast. GoPro photograph taken at 16 m depth, manta ray swimming with its cephalic fins closed. **a**) Anterior left sideward view and, **b**) posterior left sideward view, ventral zone partially covered by eleven *Remora* sp.

genetic analysis by Walter et al. (2014) even though it was initially identified as a *M. alfredi* in the field. Similarly, in Kashiwagi et al. (2012) several specimens that were visually identified as *M. alfredi* ended up separating out genetically as *M. birostris*. These facts highlight the need for molecular tools to confirm and validate whether an individual is one species or another -or a hybrid- especially in individuals occurring in sympatry (Marshall et al., 2009; Kashiwagi et al., 2011). Recently, by using molecular tools, a third potential species of manta has been suggested from a resident population in the Yucatán Peninsula. This latter has been hypothesized to have genetically diverged from *M. birostris* between 0.028–0.056 Ma (Hinojosa-Alvarez et al., 2016) and it poses a challenge as it shows morphological similarities to both *M. alfredi* and *M. birostris* (Table 1).

Non-invasive techniques were performed to identify the observed individual, and as such, statements at the species level cannot be conclusive. Nevertheless, potential paths of arrival should also be considered. Rare and seasonal sightings (Duffy & Abbott, 2003; Luiz et al., 2009) together with broad-scale movements >1000 km (Rubin et al., 2008) suggest a notable seasonal migration for *M. birostris*. However, this hypothesis has recently been challenged by Stewart et al. (2016) using three complementary techniques to conclude that the species appears to exhibit restricted movements and fine-scale

population structure in three different locations (i.e. Revillagigedo Islands and Baja California in Mexico, and Raja Ampat in Indonesia). Regardless, *M. birostris* is thought to be a more oceanic and migratory species than *M. alfredi* as the latter has usually been re-sighted in aggregation sites (Marshall et al., 2011; Braun et al., 2015). Thus, *M. alfredi* is considered to have a smaller habitat range and to be more resident in tropical waters (Marshall et al., 2009) with seasonal migrations up to 500 km (Couturier et al., 2012). Moreover, the Eastern Pacific Barrier (Ekman, 1953) could pose a spatial (*ca* 5000 km) and environmental (i.e. low-productivity) barrier to the colonization of *M. alfredi* from southeast-Polynesian populations towards the Eastern Pacific region (Cowman & Bellwood, 2013). Additional to this, the current report is from the southeastern Pacific, strongly suggesting an allopatric separation from Yucatán manta rays as these are thought to be resident -and potentially endemic- in the Caribbean (Hinojosa-Alvarez et al., 2016) and some parts of the Western Atlantic (Marshall et al., 2009). The sighted individual is likely to belong to one of the world's largest populations of *M. birostris* in Ecuador that usually migrates south towards tropical Peruvian waters (Andrea Marshall pers. comm.).

According to Chirichigno & Cornejo (2001), Marshall et al. (2009), Avila et al. (2014) and anecdotal sightings (Daniel Cáceres pers. comm.), Piura (northern Peru) is the southernmost distribution of *M. birostris* in Peru which is located in the TEP–MP. Only three *Mobula* species have been reported in Chile (none of these was *M. birostris*), but these are either rarely collected specimens or dubious record of the species (Bustamante et al., 2014). Central and southern Peru share the same marine province as Chile, the WTSP–MP, and the same large marine ecosystem, the HC–LME. Yet, *M. birostris* is commonly allocated in distribution maps that extend its occurrence to southern Peruvian limits (Marshall et al., 2011; Couturier et al., 2012) and northern Chile (Lawson et al., 2017). The sources of these distribution ranges remains unclear as they are not based on official reports. Therefore this sighting represents the southernmost record of *M. birostris* in the eastern Pacific and the first report of this species in the WTSP–MP and HC–LME.

The distribution of manta rays in tropical and subtropical waters suggest an apparent preference for water temperature of 20–26 °C (Dewar et al., 2008; Marshall et al., 2011). In northern Peru the regular SST on summer is between 20 and 23 °C; yet during this warm El Niño event the SST rose up to 28 °C. In central Peru, the month of December, 2015 presented positive anomalies according to two El Niño indices: +4.5 for the Coastal El Niño Index (acronym in Spanish, ICEN) which is a coastal index representative at a local scale (Takahashi et al., 2014), and +3.7 for the Peruvian Oscillation Index

(POI) which is a large scale index representative of the central Pacific Ocean (Purca et al., 2000), and at the time of the sighting 19 °C SST was registered in situ, representing a + 3 °C SST anomaly (Enfen, 2015). Hence, this sighting could be explained as a consequence of a warm El Niño event. Warming in the Peruvian Central Coast waters could have induced this individual to migrate south as northern Peru presented SST above its range preference, which is considered a biological impact of El Niño 2015–16 (Enfen, 2015). The occasional occurrence of certain ichthyofauna species at higher latitudes of the southeastern Pacific Ocean are usually related to warm El Niño events (Hooker, 1998; Espino, 1999). For example, the occurrence of *M. tarapacana* and *M. mobular* in northern Chile has been associated with El Niño (Sielfeld et al., 2010; Bustamante et al., 2014).

This sighting may not only be linked to oceanographic processes like warming waters by climate-driven changes (Bigelow & Schroeder, 1953) but also to local productivity events that boost the abundance of zooplankton providing foraging opportunities (Sampson et al., 2010; Jaime et al., 2014) as these have been considered important causes for movement behavior of elasmobranchs (Dewar et al., 2008; Luiz et al., 2009; Sleeman et al., 2010). The concentration of chlorophyll-a has varied spatially and temporally in central Peru; in December 2015 the concentration was high (15 mg/m<sup>3</sup>), compared to offshore areas (2 mg/m<sup>3</sup>) and December 2014 (4 mg/m<sup>3</sup>) (Imarpe, 2016). In addition, during the sighting we observed a dense mat of *P. monodon* and several dozen siphonophores; these groups have been associated with productive upwelling zones (Gasca & Suarez, 1991; Gutierrez et al., 2008). Thus, we suggest that *M. birostris* was preying on *P. monodon*. Even though the observed individual was seen with its cephalic fins closed at 16 m deep, suggesting a non-feeding behavior (Ari & Correia, 2008) and recent work has found that *M. birostris* mainly feeds on deep-water zooplankton (Burgess et al., 2016; Stewart et al., 2016), the possibility that this muninid crustacean could be a prey of *Mobula* spp. shall not be completely discarded as few studies have determined that zooplankton, shrimps, crabs and small fishes are key items on giant manta rays diet (Bigelow & Schroeder, 1953; Couturier et al., 2012; Rohner et al., 2017).

This sighting is unique because this individual might have migrated ca 1000 km south from eutropical populations. Also, the observed individual was seen alone, with no other members travelling and feeding in schools as it has usually been reported and filmed elsewhere (Couturier et al., 2012). A recent study has shown that *M. birostris* exhibited restricted movements and fine-scale population structure (Stewart et al., 2016). Thus, the origin of this individual and causes for its migration remains unknown. Also, because of the similar morphological characters between *M. alfredi* and *M. birostris*, we recommend to

validate the presence of the latter in Peruvian marine ecosystem by using molecular tools.

## Conclusions

This sighting represents the southernmost record of *M. birostris* in the southeastern Pacific (12°S). Although molecular confirmation is lacking, the observations strongly suggest that the manta ray belonged to *M. birostris*, additionally, this sighting represents the first report of this species in the WTSP–MP and HC–LME. This species is commonly allocated in distribution maps that extend its occurrence to southern Peruvian limits and northern Chile. Yet, this should be revised as this study suggests that the southeastern Pacific distribution of *M. birostris* limits with central Peru. This record is important to hypothesize migration patterns, biological impacts, and contribute with the knowledge of distribution patterns in order to advise decision makers, stakeholders and national fishing authorities.

## Abbreviations

DW: Disc width; Enfen: Comité Multisectorial encargado del Estudio Nacional del Fenómeno El Niño; ENSO: El Niño Southern Oscillation; HC–LME: Humboldt Current Large Marine Ecosystem; ICEN: El Niño Coastal Index; MP: Marine Province; POI: Peruvian Oscillation Index; SST: Sea Surface Temperature; TEP: Tropical East Pacific; WTSP: Warm Temperate Southeastern Pacific

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## Authors' contributions

BM registered the sighting, wrote the paper, prepared figures, and reviewed the drafts of the paper. AGP wrote the paper and reviewed the drafts of the paper. Both authors read and approved the final manuscript.

## Ethics approval and consent to participate

Not applicable.

## Consent for publication

Not applicable.

## Competing interests

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