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First Confirmed Record of the Longfin Mako Shark (*Isurus paucus*) for Puerto Rico

Antonio A. Mignucci-Giannoni[1,2,*], Daritzel Cintrón-Nieves[1], Glorimar Franqui-Rivera[3], Raimundo Espinoza[4], Juan M. Orcera-Iglesias[1], Pedro J. Rivera-Ilarraza[1], Carla I. Rivera-Pérez[1,2], and Grisel Rodríguez-Ferrer[3,5]

Abstract - *Isurus paucus* (Longfin Mako) is a mesopelagic shark inhabiting tropical and subtropical waters. While records of Longfin Makos have been documented for the Western North Atlantic, only a few records exist for the Caribbean. On 3 March 2019, a large shark was found stranded off Barceloneta, Puerto Rico. We thoroughly examined the carcass and identified it as a 333-cm adult female shark with diagnostic characteristics consistent with that of a Longfin Mako. We analyzed collected skin for species identification, which confirmed the identification genetically. Longfin Makos are subjected to extensive fishing, both commercially and recreationally. Thus, they are of conservation concern due to their sparse distribution, low abundance, and external threats. International conservation measures need to be implemented to protect this squalid.

Isurus paucus Guitart Manday (Longfin Mako) is a lamnid mesopelagic shark known in Spanish by different vernacular names: Dientuso Prieto (Cuba), Marrajo Carite (Nicaragua, Spain), Marrajo de Aleta Larga (Chile), Marrajo Dientuso (Spain), Tiburón Carite Ojón (Venezuela), Tiburón Mako Aleta Larga (Colombia), and Tiburon Mako Aletón (Mexico) (Bustamante et al. 2009, Cervigón and Alcalá 1999, Gámez Barrera et al. 2012, Guitart Manday 1966, Moreno and Morón 1992, Page et al. 2013, Sánchez 1997). It inhabits tropical and subtropical waters around the globe (Compagno 2001). In the Western North Atlantic, it is observed seasonally off Florida and is considered a resident in The Bahamas and Cuba (Castro 2011). Whereas Longfin Makos have been more frequently documented for the Western North Atlantic (Queiroz et al. 2008), only a few records exist for the Caribbean (Table 1). This dearth of reported sightings in the region may be due to the difficulties in distinguishing this species from the similar *Isurus oxyrinchus* Rafinesque (Shortfin Mako), which is commonly observed and captured in the Caribbean, including Puerto Rico, as part of recreational and sport fisheries (Mollet et al. 2000). Elsewhere, the shark is considered rare, and its occurrence poorly known (Compagno 2001, Hueter et al. 2016, Stevens and Scott 1995). The International Union

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for the Conservation of Nature (IUCN) has classified its population as decreasing and its status as endangered (Rigby et al. 2019).

This report is the first full documentation of a Longfin Mako in Puerto Rico, based on the salvage, necropsy, and genetic identification of a stranded specimen off the north coast of Puerto Rico.

Case report. Early in the morning of 3 March 2019, a local biologist, Hector Y. López-Pelet, found a large dead shark (Fig. 1) stranded on a beach, 1.7 km ESE of Punta Palmas Alta in Barceloneta, PR (18°29.20'N, 66°32.88'W). According to fishermens' reports, they saw a live shark days before the stranding. Officials from Puerto Rico's Department of Natural and Environmental Resources confirmed the stranding event and alerted the rescue and stranding team of the Puerto Rico Manatee Conservation Center at Inter American University to document the case.

Table 1. Published records of Longfin Mako shark in the Caribbean. ? indicates data not reported. M = male, F = female, and U = Unidentified.

Date	Location	Sex	TL (cm)	Source
?	Off Cojimar, Cuba	F	195.5	Guitart Manday 1966
?	Off Cojimar, Cuba	M	203	Guitart Manday 1966
?	Off Cojimar, Cuba	F	226	Guitart Manday 1966
1971	Off Cojimar, Cuba	~ 33U	?	Guitart Manday 1975
1972	Off Cojimar, Cuba	~ 34U	?	Guitart Manday 1975
1973	Off Cojimar, Cuba	F	?	Guitart Manday 1975
Jan 1983	Mona Passage, between Dominican Republic and Puerto Rico	F	330	Casey 1986
?	North of Playa Verde, Maiquetía, Venezuela	F	146	Cervigón and Alcalá 1999
?	North of Playa Verde, Maiquetía, Venezuela	F	198	Cervigón and Alcalá 1999
1994–2003	~38 km W of Aruba, Netherland Antilles	U	?	Tavares Viscaya 2005
1994–2003	~42 km E of Chichiriviche, Falcón, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~60 km NE of Bonaire, Netherland Antilles	U	?	Tavares Viscaya 2005
1994–2003	~58 km NW of Isla los Roques, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~85 km N of Isla los Roques, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~38 km NE of Isla la Orchila, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~160 km NNE of Isla la Blanquilla, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~80 km NNW of Isla la Blanquilla, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~47 km NW of Isla la Blanquilla, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~65 km W of Isla la Blanquilla, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~170 km SW of Isla de Aves, Venezuela	U	?	Tavares Viscaya 2005
1994–2003	~46 km SSW of Isla de Aves, Venezuela	U	?	Tavares Viscaya 2005
8 Jul 2009	140 km NNE of Santa Marta, Colombia	F	177	Gámez Barrera et al. 2012
12 Aug 2009	170 km NNE of Santa Marta, Colombia	M	218	Gámez Barrera et al. 2012
8 Apr 2010	Bahía Concha, Santa Marta, Colombia	M	306	Gámez Barrera et al. 2012
2010–2011	Off Cojimar, Playa or Plaza, Cuba	16F, 7M	?	Aguilar et al. 2014
14 Feb 2015	13 km NNW of Santa Cruz del Norte, Cuba	M	190	Hueter et al. 2016
3 Mar 2019	1.7 km ESE of Punta Palmas Alta, Barceloneta, PR	F	330	This paper

We thoroughly examined the carcass on 4 March 2019 and identified it as an adult female shark measuring 333 cm in total length and 315 kg in weight that was gravid with 17 embryos in her reproductive tract.

Diagnostic characteristics correctly placed the specimen in the family Lamnidae (mackerel sharks) and within the genus *Isurus*, based on Compagno (1984). We also documented characteristics diagnostic of the Longfin Mako, including: broad-tipped pectoral fins as long as the head and over 23% of shark's total length; a narrow to blunt-pointed, but not acute, snout, with no reversed tip teeth; lunate caudal fin with a long lower lobe; eyes relatively large; and dark blue dorsal and white ventral coloration, with dusky markings around its mouth, as described in Bass (1986) and Compagno (1998, 2001). We took complete morphometrics (Table 2, Fig. 2), which correspond to proportions of total length known for the species (Cervigón and Alcalá 1999, Compagno 2001, Gámez Barrera et al. 2012).

The necropsy revealed no signs of ante-mortem human interaction. The gastrointestinal system was empty and we found no metazoan parasites. Due to its state of decomposition (moderate to advanced) at the time of necropsy, histopathology tissues did not yield a possible cause of death. Samples of skin, muscle, teeth, embryos, and gills were collected and preserved in 70% ethanol. Other remains were properly disposed in a sanitary landfill.

We genetically analyzed collected skin from the dorsal fin to identify the species. We extracted genomic DNA from ~25 mg of the dorsal fin tissue using the QIAGEN DNeasy kit (QIAGEN Inc., Valencia, CA, USA). An approximate 1026-base pair (bp) fragment from the region of the NADH dehydrogenase subunit 2 (ND2) was amplified with the polymerase chain reaction (PCR) using the primer set ILEM (5′-AAA GAG CAG TTT GAT AGA GT-3′), and ASNM (5′-AAC GCT TAG CTG TTA ATT AA-3) (Naylor et al. 2012). The amplified product was purified with ExoSAP-IT™ and sequenced in both directions at the Sequencing Facilities of

Figure 1. Photographic documentation of a Longfin Mako shark stranded in Puerto Rico on 3 March 2019. Photographs © Héctor Y. López-Pelet.

Table 2. Morphometrics of a Longfin Mako shark stranded in Puerto Rico on 3 March 2019.

Measurement	Abbreviation	2019 Puerto Rico specimen (cm)	% of TL	% of TL from literature*
Total length	TL	333.0	100.0	100
Fork length	FL	297.0	89.2	90–93
Precaudal length	PCL	277.0	83.2	78–85
Preanal fin length	PAL	247.6	74.4	75–79
Predorsal fin 1 length	PDF1L	114.0	34.2	32–39
Prepectoral fin length	PP1L	78.8	23.7	19–26
Prepelvic fin length	PP2L	193.5	58.1	20–61
Head length (HL)	HL	76.0	22.8	20–26
Preorbital length	POL	12.3	16.2§	19–34§
Dorsal fin 1 width	DF1W	30.0	9.0	8–12
Dorsal fin 1 height	DF1H	32.0	9.6	9–11
Dorsal fin 2 width	DF2W	10.8	3.2	-
Dorsal fin 2 height	DF2H	6.0	1.8	1–2
Caudal fin height	CFH	82.6	24.8	-
Pectoral fin anterior length	P1AL	78.9	23.7	23–31
Pectoral fin posterior length	P1PL	70.9	21.3	-
Pelvic fin anterior length	P2AL	16.7	5.0	5–6
Pelvic fin posterior length	P2PL	9.0	2.7	3–8
Eye diameter	ED	6.0	7.9§	8–13§

*Guitart Manday (1966), Cervigón and Alcalá (1999), Compagno (2001), Gámez Barrera et al. (2012).
§ = % of HL rather than % of TL.

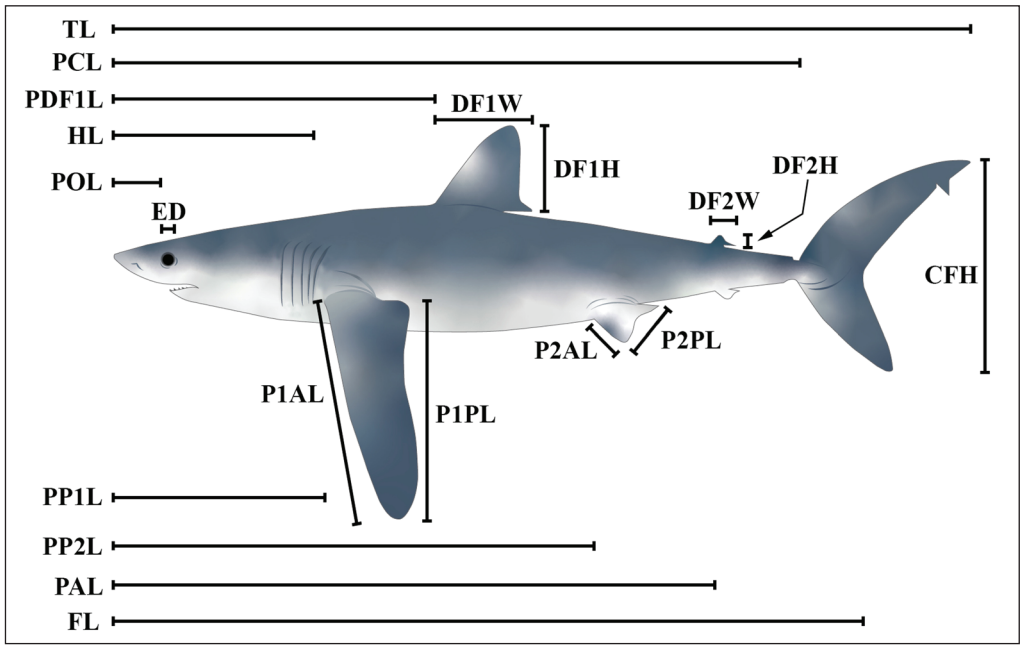

Figure 2. Morphometric guide for Table 2 of a Longfin Mako shark stranded in Puerto Rico. Illustration © Vanessa Méndez-Gallardo.

the University of Puerto Rico, Río Piedras Campus. Species identity was verified by querying the National Center for Biotechnology Information (NCBI) through BLAST. The ND2 sequences (1026 bp) from the shark specimen from Puerto Rico matched 99.7% (3 C-T transitions difference) with the ND2 sequence of an Indian Ocean Longfin Mako from Sri Lanka (Accession Number MK335360; Fernando et al. 2019). Thus, we assigned the Puerto Rico specimen genetically to *Isurus paucus*.

Scientific and conservation significance. The Longfin Mako is a relatively unknown species of laminid shark reported from several locations throughout the Indian and North and South Pacific oceans (Compagno et al. 2005, Garick 1967, Killiam and Parsons 1986). Pacific records are available from California (Ebert 2001), Japan (Nakaya and Shirai 1984), Taiwan (Shen et al. 1993), Mexico (Ruiz-Campos et al. 2010), Chile (Bustamantes et al. 2009), Fiji (Seeto and Baldwin 2010), and northeast of Micronesia, between Solomon and Nauru Islands, south of the Johnston Islands, near Phoenix Island, and north of Hawaiian Islands (Compagno 2001, Mundy 2005). Atlantic records include the North Atlantic (Mucientes et al. 2013, Queiroz et al. 2008), the Gulf of Mexico (Hueter et al. 2016, Killam and Parsons 1986, Wakida-Kusunoki and Anda-Fuente 2012), off Guyana, Surinam and French Guiana (Tavares Vizcaya 2005), off southern Brazil (Amorim et al. 1998), and Morocco and off the Iberian Peninsula (Moreno and Morón 1992). In the Caribbean, only a few records exist, except for northern Cuba (Florida Straits) where they are commonly captured in recreational and longline fishing year-round (Aguilar et al. 2014; Guitart Manday 1966, 1975; Ramos Díaz 2016). Aside from this report, only 18 other records exist for Caribbean waters, 12 from Venezuela (Cervigón 2005, Cervigón and Alcala 1999, Tavares Vizcaya 2005), 2 from the Netherland Antilles (Tavares Vizcaya 2005), 3 from Colombia (Gámez Barrera et al. 2012), and 1 in the Mona Passage between Dominican Republic and Puerto Rico (Casey 1986). Other records of occurrence of the Longfin Mako shark in the Caribbean may have gone unreported or may have been miss-identified as the very similar Shortfin Mako (Bonfil 1994, 1997; Castro 1993; Castro et al. 1999; Compagno 2001; Shivji et al. 2002).

Longfin Mako sharks, as well as other Caribbean shark species, are subjected to extensive fishing, both commercially (longline) and recreationally (Rigby et al. 2019). Some of this fishing targets this species and in other instances represent by-catch (Adams et al. 2015, Mucientes et al. 2013). Its sister species, the Shortfin Mako, is an important longline and gillnet fishery species around the world due to its high-quality meat and is a prime game fish prized by sport fishermen. People use its meat for human food, its oil for vitamins, its fins for shark-fin soup, and its hide for leather (Compagno 2001). Longfin Makos, on the other hand, are taken primarily in tropical pelagic longline fishing, particularly in northeastern Cuba (Aguilar et al. 2014, Ramos Díaz 2016), and as bycatch in tuna or swordfish fisheries (Frédou et al. 2015). They also are taken during sport fishing as well as in anchored gill nets (Compagno 2001). Because their meat is considered of lower quality, they are finned and discarded at sea, contributing to the lack of biological knowledge and known distribution of the species (Adams et al. 2015, Brooks et al. 2012, Cramer et al. 1997, NMFS 1999).

Longfin Makos are a species of conservation concern, due apparently to its low abundance, low reproduction rate (complicated by lecithotropic vivipary with oophagy and uterine cannibalism), and current environmental and anthropogenic threats. Such threats have led to its classification as endangered (Campagno 2001, Gilmore 1993, Rigby et al. 2019). The Shortfin Mako, though presently heavily harvested, shows an intrinsic high rebound potential (Smith et al. 1998), which may not be characteristic of the Longfin Mako. International conservation measures need to be implemented, particularly research and monitoring actions that allow us to better understand their population abundance trends, distribution, life history, ecology, and harvest threats (Rigby et al. 2019). This expanded knowledge, in turn, will allow for the conservation of the species through protection of areas essential to the species' survival, as well as providing for public education and awareness.

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