Aquatic Mammals 2022, *48*(6), 737-745, DOI 10.1578/AM.48.6.2022.737

Cetacean Mortality Related to Ship Traffic in the Mexican Central Pacific

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Ship traffic can negatively affect marine wildlife, including cetaceans, especially in areas where these mammals carry out relevant ecological activities (Halliday et al., 2022). Specifically, ship strikes can be caused by several types of large vessels (e.g., cargo, tankers, cruise ships, and fishing boats), as well as by smaller recreational boats (~10 m). Cetacean mortality caused by ship strikes has been documented on stranded carcasses collected from beaches or the bow of a vessel upon arrival at a port (Laist et al., 2001; Jensen et al., 2004; Silber et al., 2010; Schoeman et al., 2020; Ransome et al., 2021). Sometimes, the impact may leave no external evidence and cause of death must be confirmed via necropsy (Laist et al., 2001; Panigada et al., 2006); however, the carcass must be fresh since an advanced state of decomposition masks the signs of a ship strike (Glass et al., 2009).

Cetacean mortality related to ship traffic is increasing since the co-occurrence of cetaceans and ships is becoming more widespread (Guzmán et al., 2013; Redfern et al., 2013; Thomas et al., 2016), which is likely due to increased ship traffic worldwide and the recovery of certain cetacean populations (e.g., *Eschrichtius robustus*, *Megaptera novaeangliae*, and *Balaenoptera musculus* from the Northeast Pacific; Calambokidis & Barlow, 2004; Punt & Wade, 2012).

The commercial port of Manzanillo is located in the Mexican Central Pacific (MCP) in the eastern tropical Pacific (Figure 1). It is the most important port in the country with ship traffic capacity over 2.1 million cargo containers or twenty-foot equivalent units (TEUs) annually (Secretaría de Comunicaciones y Transportes [SCT], 2014). In addition, two companies that store liquefied gas (Z Gas and KMS) are present in the southeast zone (Figure 1), and tourist and fishing activities are also common in the region (Secretaría de Turismo [SECTUR], 2014). Therefore, the MCP presents high maritime traffic where three species of mysticetes and 11 odontocetes have been recorded (Ortega-Ortiz et al., 2013). As a result, the MCP is an area where interactions between cetaceans and vessels are frequent and mortality events can occur.

The aim of this paper is to report the mortality of six individual cetaceans in the MCP caused by interactions with ships (Table 1). Data were obtained from an indirect monitoring program that we have been conducting since 2010. In each stranding event, data such as date, time, site, animal decomposition state (i.e., alive, fresh, early decomposition, advanced decomposition, and mummified), species, size class, sex, and evidence of human interactions (e.g., wounds by ship strikes; Moore et al., 2013) were recorded (ACCOBAMS, n.d.).

Two Events Involving Humpback Whales

The first event on 10 March 2013 occurred when a sport fishing boat closely approached a humpback (*Megaptera novaeangliae*) mother–calf pair at the entrance of Manzanillo Bay, Colima (Figure 1). During the sighting, the calf was jumping and, due to its proximity, fell on the boat's deck. It broke the bow's hatch glass (Figure 2) and caused a laceration to its ventral area as it slid into the water. On 12 March, personnel of the Secretaría de Marina (SEMAR) sighted the carcass floating in the middle of Manzanillo Bay, which later stranded in Playa Azul, Manzanillo Bay, with moderate decomposition (Figure 1, blue circle 1). The calf was a male with trauma to the ventral area and a ~50 cm cut on the left side of its abdominal area (Figure 2).

The second event on 11 March 2022 involved a carcass in advanced decomposition observed

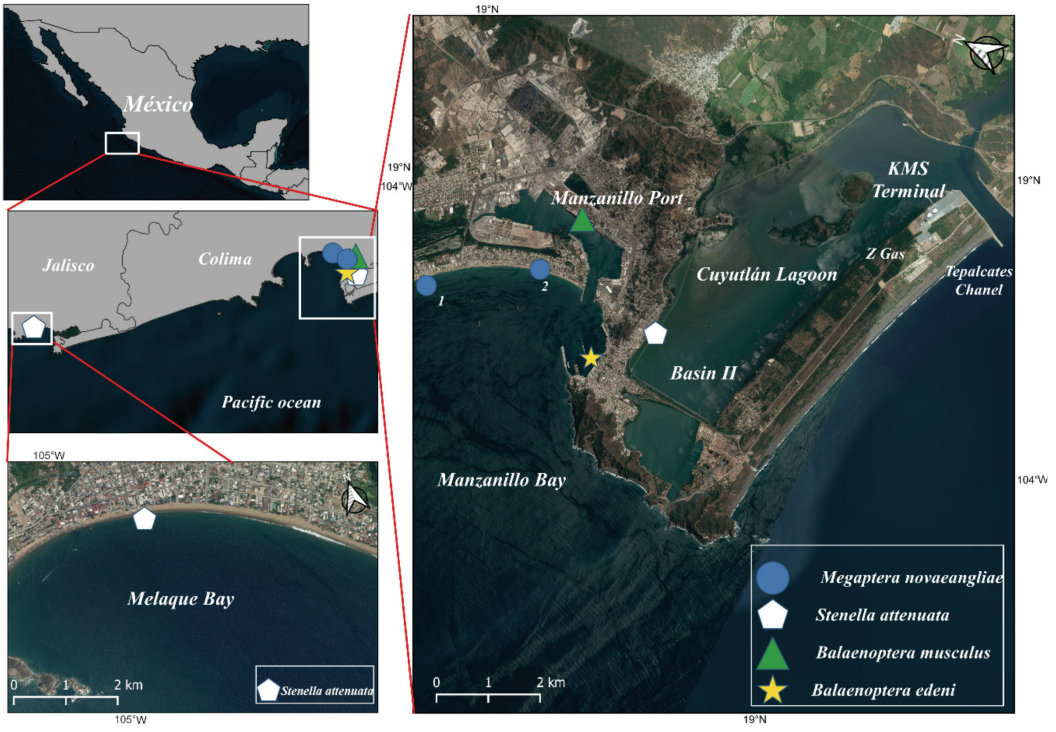

Figure 1. Locations of dead cetaceans related to ship strikes in the Mexican Central Pacific. In the map on the right, blue circle 1 indicates the humpback whale (*Megaptera novaeangliae*) calf stranding site of 12 March 2013, and blue circle 2 indicates the calf stranding site of 11 March 2022.

Table 1. Potential cetacean mortalities caused by ship strikes in the Mexican Central Pacific

Species	Event date	Location	Sex	Total length (m) and age class	Carcass decomposition state	Ship type
Megaptera novaeangliae	12 March 2013	-104.1926 W, 19.055 N	Male	4.7 calf	Moderate	Sport fishing boat
	11 March 2022	-104.3034 W, 19.0708 N	Female	4.6 calf	Advanced	Boat
Stenella attenuata	16 April 2013	- 104. 7051 W, 19. 2222 N	Female	~1.47 subadult	Moderate	Boat
	13 March 2014	-104.3048 W, 19.0466 N	Female	2.05 adult	Fresh	Gas tanker vessel
Balaenoptera musculus	23 April 2019	-104.2917 W, 19.0679 N	Male	~16.0 juvenile	Fresh	Container vessel
Balaenoptera edeni	24 October 2021	-104.3140 W, 19.0553 N	Male	11.3 subadult	Advanced	Vessel

Figure 2. Humpback whale calf stranded at Playa Azul, Manzanillo, Colima, on 12 March 2013: (A) injuries sustained in the ventral and peduncle area during the incident are indicated with red circles; and (B) sport fishing boat with damages to the glass of the bow hatch due to the impact of the calf's body falling on it. (Photos taken by Christian D. Ortega-Ortiz, Universidad de Colima)

floating in front of Manzanillo Bay, Colima, which stranded the same day on Las Brisas Beach (Figure 1, blue circle 2). It was a female calf with propeller lacerations on the dorsal peduncle and ventral flukes (Figure 3). Based on their shape, size, and position (4 to 8 cm apart), these injuries could have been from a strike by a small boat with a four-stroke engine.

Humpback whales are distributed in several coastal regions during winter–spring, engaging in breeding activities of the Mexican Distinct Population Segment (Baker et al., 2013; Bettridge et al., 2015; Ortega-Ortiz et al., 2022). Therefore, this species (both adults and calves) has the highest number of interactions with boats. Calves may die due to injuries caused by small tourist boats (Ransome et al., 2021). Whale-watching activities in México have increased (Urbán & Viloria-Gómora, 2021), even with a Mexican law (NOM-131-SEMARNAT-2010) that regulates this activity. However, few sites have certified companies, with most operating illegally. In addition, private non-tourist operators do not abide by the rules and speed limits. Currently, the Colima coasts are not official whale-watching sites, but the Manzanillo Bays have been identified as important areas for mother–calf pairs during February and March (Meza-Yañez, 2022). Calves spend more time at the surface, are less visible due to their small body size, and are more susceptible to vessel interaction because of their curious nature (Glockner & Venus, 1983; Laist et al., 2001; Lammers et al., 2013). Thus, humpback calves in the MCP are affected by boat collisions and likely other anthropogenic activities (Valencia-González, 2014; Arroyo-Salazar, 2017; Llamas-González, 2019).

Two Events Involving Spotted Dolphins

The first mortality of a spotted dolphin (*Stenella attenuata*) occurred on 16 April 2013 at Melaque Beach, Jalisco (Figure 1). The female subadult carcass had moderate decomposition, and the following injuries were evident: two deep lacerations and an abrasion on the dorsal area proximal to the peduncle. One laceration was rhomboid-shaped with loss of a large section of skin and subdermal tissue as well as tearing of the outer muscle layers without clear

Figure 3. Humpback whale calf stranded at Las Brisas Beach, Manzanillo, Colima, on 11 March 2022: (A) injuries from the collision with the propeller of a small boat, with wounds on the peduncle; and (B) injuries in the ventral region of the flukes. (Photos taken by Raziel Meza-Yañez, Universidad de Colima)

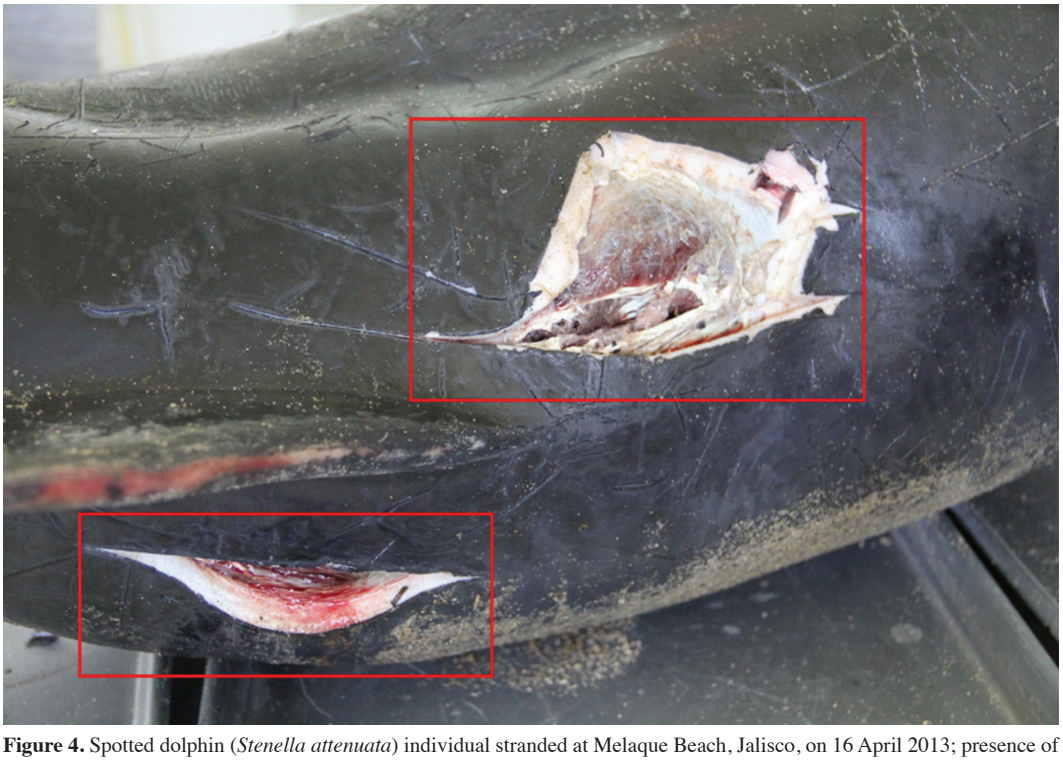

Figure 4. Spotted dolphin (*Stenella attenuata*) individual stranded at Melaque Beach, Jalisco, on 16 April 2013; presence of lacerations in the dorsal area near the peduncle: rhomboidal wound with loss of skin and subdermal tissue, with tearing of the outer muscle layers (upper box), and diffuse subcutaneous hematoma ~3 cm deep with muscle tearing, potentially caused by a propeller incision (bottom box). (Photo taken by Christian D. Ortega-Ortiz, Universidad de Colima)

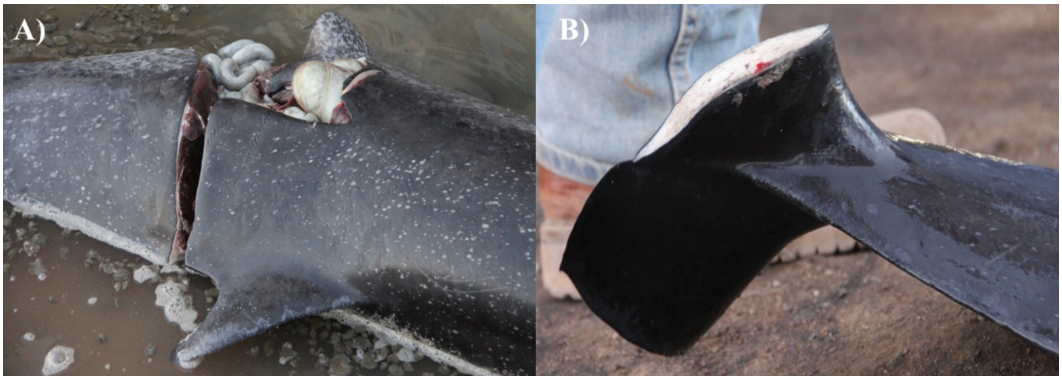

Figure 5. Spotted dolphin individual stranded at Basin II of Cuyutlán lagoon, Colima, on 13 March 2014. Injuries due to collision with a gas tanker vessel are shown in (A) left flank, with a clean cross-section and some organs extruding from the body; and (B) flukes, with wounds on both lobes. (Photos taken by Tadashi Kono Martínez, Universidad de Colima)

evidence of hematoma or inflamed wound edges. The second laceration was ~3 cm deep showing a diffuse subcutaneous hematoma with muscle tear. Cause was not identified, but the laceration might have been caused by a propeller (Figure 4).

The second event was an adult female that stranded inside the Cuyutlán lagoon, Colima (northwest of Basin II), on 13 March 2014 (Figure 1). The carcass was fresh and showed two large, deep transverse cuts in the middle of the body posterior to the dorsal fin, which exposed viscera and the vertebral column, as well as a mutilated fluke. The severity of the wounds was compatible with a large vessel propeller (Figure 5). The dolphin could have been struck by a vessel inside the lagoon or near the entrance of the Tepalcates channel. Coincidentally, the gas tanker *Sevilla* arrived at the KMS terminal at 0700 h that day. It is hypothesized that, based on the direction of the pattern of surface currents in the lagoon (SEMAR, 2013), the carcass was displaced into Basin II.

The spotted dolphin is the most dominant species in the area; its distribution is mainly associated with prey availability (Juárez-Ruiz, 2014; Kono-Martínez et al., 2017; Díaz-Torres et al., 2022). During winter coastal surveys, at least three sightings of spotted dolphin individuals in the Cuyutlán lagoon were recorded (20 March, 21 April, and 12 May 2016; unpub. data provided by Alejandro Reyes, Director of Environment of the Municipal Council of Manzanillo, Colima, México). This area might be a feeding ground for this dolphin species since there is a considerable abundance of fish in the lagoon in winter (Cabral-Solís, 2011). This explanation coincides with the high number of fish found in its stomach, which was observed during an impromptu necropsy on the carcass.

These two spotted dolphin mortalities likely involved two vessel types that caused different types of damage. However, both carcasses presented extensive injuries in the lumbar–caudal region that were fatal (Long et al., 1997).

One Event Involving a Blue Whale

On 23 April 2019, the *Rotterdam Express*, a container vessel from Long Beach, California, arrived at the commercial port of Manzanillo, Colima (Figure 1). Upon docking, workers notified port and environmental authorities that a whale was on the vessel's bulb. The carcass was identified as a male blue whale (*Balaenoptera musculus*) in fresh condition; hemorrhage was visible in some body parts (Figure 6).

The Northeast Pacific subpopulation of blue whales migrates each winter–spring to the coasts of the Baja California Peninsula, the Gulf of California, and the Costa Rican Dome for breeding activities (Gendron, 2002). Given that sightings of this species have not been documented in the MCP coastal region, it is presumed that its transit to the Costa Rican Dome must occur through oceanic zones. Trajectories of large cargo vessels also use oceanic regions where the blue whale was presumably encountered ("wrapped" on the bow). Examination of one baleen plate allowed assessment of its isotopic ratio that suggested that this whale came from the Dome (Blevins et al., 2022); thus, its vessel interaction likely occurred during its northward migration.

This blue whale subpopulation has shown recovery from the commercial overexploitation of the last century (Calambokidis & Barlow, 2004); however, this species may be vulnerable to anthropogenic stressors seasonally due to its migratory patterns. Collisions with vessels have historically affected blue whales in Californian (Redfern et al., 2013) and Mexican (Ransome et al., 2021)

Figure 6. (A) Blue whale (*Balaenoptera musculus*) individual struck and hooked on the bulb (see red circle) of the container vessel *Rotterdam Express*, which arrived on 23 April 2019 at the port of Manzanillo, Colima; and (B) hemorrhages in some parts of the body, mainly in the mid-section, were present where an apparent fracture due to the impact was also observed (red circles). (Photos taken by Luis M. Bautista-Moreno, Secretaría de Marina [SEMAR])

waters. Vessel collision is currently considered the main cause of death for blue whales on the United States' west coast due to high maritime traffic between the ports of Long Beach/Los Angeles and San Francisco (Monnahan & Branch, 2015; Carretta et al., 2016; Hazen et al., 2016).

One Event Involving Bryde's Whale

On 24 October 2021, the carcass of a Bryde's whale (*Balaenoptera edeni*) was reported under the tourist dock of Manzanillo, Colima (Figures 1 & 7). This species was identified through morphological characteristics (e.g., small pectoral fins, absence of fluke coloration, and presence of three longitudinal ridges on the head). Although the carcass showed advanced decomposition, there were areas of trauma on the head, the peduncle (next to the dorsal fin), and the ventral region. All wounds could be linked to a likely vessel strike or possibly to the pressure exerted between the sea and a vessel's bulb that might have transported the carcass into Manzanillo Port.

Like blue whales, this species is usually distributed in oceanic environments of the Mexican Pacific (Villegas-Zurita et al., 2016), and it is unlikely that it was struck or hooked by a vessel in the local area. Also because of its oceanic distribution, this species is one of the least studied baleen

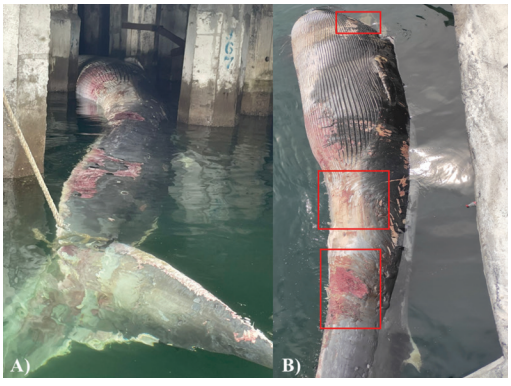

Figure 7. (A) Bryde's whale (*Balaenoptera edeni*) carcass trapped in the pillars of the dock in Manzanillo, Colima, on 24 October 2021, with injuries potentially caused by a collision with a vessel; and (B) possible vessel impact wounds on the peduncle, the side of the dorsal fin, and the ventral part of the abdominal area indicated by red boxes. (Photos taken by Javier Martínez-Rivera, Procuraduría Federal de Protección al Ambiente [PROFEPA-Colima])

whales; it is protected by national (NOM-059-SEMARNAT-2010) and international (International Union for Conservation of Nature [IUCN], 2020) laws.

Ship strikes involving Bryde's whales are rare, assumed so because of their fast swimming and smaller size compared to other more frequently affected baleen species (Félix & Van Waerebeek, 2005). Despite this, there are three reports of interactions between Bryde's whales and vessels in the Pacific Ocean. An example of one is a whale stuck on the bow of a boat in Ecuador. The animal was removed ventrally, still fresh, showing diffuse bruises, suggesting the animal was alive at collision (Félix, 2009; Ransome et al., 2021). This is the first observation of a Bryde's whale likely struck by a vessel in the Mexican Pacific.

Herein, we report on the only six cetacean mortality events related to ship strikes observed in the MCP during 12 years of monitoring. Our count might be an underestimate as similar events could be masked by (1) the inability to observe lesions in specimens with advanced stages of decomposition, (2) the lack of systematic necropsies by specialists, and (3) events in which struck animals sink and do not beach strand (Alzueta et al., 2001; Laist et al., 2001; Van Waerebeek et al., 2007; Silber et al., 2012). The high maritime traffic in the MCP undoubtedly represents a threat to cetaceans that use the region for ecological purposes. Traffic will likely increase in the coming years with the expansion of the port area towards Basin II of the Cuyutlán lagoon (Administración Portuaria Integral [API], 2019). This expansion will allow for the arrival of more

offshore vessels, which could increase the number of cetaceans affected.

Currently, there are no mitigation measures in place for this region. Mitigation measures for this problem are difficult to establish due to the complexity of all contributing factors. Nonetheless, certain ship restrictions such as the following could reduce negative cetacean encounters: (1) reduced speed, (2) traffic separation devices, (3) restricted navigation areas, (4) a mandatory vessel notification system, and (5) establishment of natural protected areas (without navigation) (Silber et al., 2012; Guzmán et al., 2013). In this regard, monitoring should be increased in areas of potential interaction between ships and cetaceans, mainly to gather enough information to carry out a local or regional mitigation plan prepared by all the institutions involved to reduce the probability of collisions.

Acknowledgments

We thank the Facultad de Ciencias Marinas and Centro Universitario de Investigaciones Oceanológicas (U de C) for their logistical support. The Secretaría de Medio Ambiente y Recursos Naturales via the Dirección General de Vida Silvestre México provided the field sampling permits. We thank the staff of the Procuraduría Federal de Protección al Ambiente (PROFEPA) and the Secretaría de Marinao as well as the volunteers and students of the Grupo Universitario de Investigación de Mamíferos Marinos (GUIMM) of the U de C for their assistance during strandings. Special thanks to the Director of Environment of the Municipal Council of Manzanillo, Ezequiel Alejandro Reyes Herrera, and his staff, for the logistical support during the last strandings.

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