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Short Communication

Reef fish mortalities in the Mexican Caribbean: report of two cases

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ABSTRACT. This paper reports two events related to reef fish mortalities that occurred off the Mexican Caribbean's west coast, specifically within the Puerto Morelos Reef National Park. The first event occurred in January and February 2021, affecting several reef fish species. The angelfish *Pomacanthus arcuatus* was particularly impacted. The second event in February 2023 corresponds to a mass mortality of the sharpnose pufferfish *Canthigaster rostrata*. This phenomenon has been recurring since 2008 across the western Caribbean basin, spanning from Mexico to Colombia, and appears to be related to the settlement of the species in reproductive habitats. These events could result from higher magnitude ecological disturbances in the coastal waters of the Caribbean.

Keywords: *Pomacanthus arcuatus*; *Canthigaster rostrata*; water quality; coral reef fish; epizootics; Puerto Morelos

Mass mortalities of reef fish are a common phenomenon on Atlantic coasts, including the Caribbean basin, affecting a wide diversity of species (Atwood 1981, Panek 2005). The main causes involved in the mortality events of coral reef fishes comprise toxin production from microalgae, cyanobacteria, and macroalgae, sudden temperature changes, episodes of hypoxia and anoxia, and a wide range of diseases caused by viruses, bacteria, and protozoa (Landsberg 1995, Ferguson et al. 2000, Williams & Bunkley-Williams 2000, Panek 2005, Overstreet & Hawkins 2017).

Depending on the period in which epizootics occur, mortality events can be classified as chronic or acute. The first is produced by sublethal agents that weaken during days or weeks organisms to death. Acute mortalities occur over short periods and can be caused by hypoxic events due to eutrophication or harmful algal bloom decay, as well as abrupt temperature changes (Gilmore et al. 1978, Genin et al. 2020, Aguilar-Medrano et al. 2023). As described above, the causes of epizootics are a well-identified group of etiological agents. However, it is sometimes impossible to determine the cause of death in a specific event because the conditions or causes led to it vanishing from the environment upon detecting deceased organisms (La & Cooke 2011) or due to the compromised tissue integrity of the collected samples, which hinders necropsy and histopathological analyses (George et al. 2016, Mitchell et al. 2023).

However, documenting these epizootics events is crucial because they constitute a sign of the condition of the ecosystem, reflected in the biodiversity inhabiting the zone. Historical records are essential to facilitate the identification of causal agents, as exemplified by two events recorded on the Mexican Caribbean coast of Puerto Morelos Reef National Park (PMRNP) in 2021 and 2023.

Case 1. During January and February 2021, an unusual mortality event was observed among marine fish species in the PMRNP. Anglers and tour operators reported the presence of dead fish stranded on the beach

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or floating in the reef lagoon. The gray angelfish (*Pomacanthus arcuatus*) was the most affected species. However, other species, such as *Acanthostracion quadricornis*, *Canthidermis sufflamen*, *Acanthurus coeruleus*, *Haemulon plumieri*, *Aluterus schoepfii*, and *Scarus coelestinus* were also affected. A field survey was conducted to collect specimens and gather information on the condition of the affected area. Stranded organisms were predominantly reported along a 15 km stretch of beach between Petempich Bay to the north and Punta Brava to the south, bordering the west side of the PMRNP polygon. Sightings of floating dead fish were most abundant near the sites known locally as La Pared (20°49'28"N; 86°52'33"W), Viveros (20°48'53"N; 86°52'33"W), and Fishmarket (20°48'43"N; 86°52'59"W) (Fig. 1). During the beach survey, numerous individuals were found stranded on the sand in an advanced state of decomposition.

Additionally, some hotel beach cleaners reported that during this period, they had to collect many dead fish, predominantly *P. arcuatus*, a situation they had never encountered. Despite efforts, no visibly diseased organisms were detected during field observations. Only two stranded dead specimens of *P. arcuatus* were collected for further analysis. These analyses included fish necropsies to assess the condition of internal organs, determine external parasite loads, and examine intestinal contents for potentially toxic algae.

The specimens exhibited lesions on their skin, along with reddish or pinkish spots, likely due to hemorrhaging (Fig. 2a,c). Caudal and anal fins were severely lacerated. Despite the specimens being in a state of decomposition, there was no evidence of malnutrition, as they retained a substantial proportion of muscle mass. Although the external parasite load was negligible, six metacercariae parasite cysts were detected in one specimen's heart. The stomachs of both specimens were filled with organic and plant matter, accompanied by algae and invertebrates. Benthic diatoms from genera such as *Licmophora* and *Navicula*, as well as macroalgae genera including *Halymenia*, *Dictyota*, *Dictyopteris*, *Stypopodium*, *Padina*, *Sargassum*, *Ceramium* and *Galaxaura* were observed. The intestines of one of the analyzed fish contained organic and plant matter. Closer to the urogenital pore, an accumulation of matter was observed, followed by exposure of the distal part of the intestine protruding outside of the fish (prolapse). Water samples from the area showed no evidence of potentially toxic microalgae proliferation. Furthermore, the analysis of epiphytic microalgae load revealed only diatoms and dinoflagellates of the genus *Ostreopsis*.

Case 2. During the initial days of January 2023, a significant mortality event of *Canthidermis rostrata* occurred along the coast of PMRNP. Before the field survey, reports were received from residents who observed numerous fish of this species stranded on the shore in varying stages of decomposition, with some of them still floating on the water. Three band transects, each 30 m long and 2 m wide, were established horizontally and parallel to the coastline to have a gross estimate of the impact on the population. The results revealed an average of 52 ± 22.6 fish per transect, equivalent to 0.9 organisms per m^2. The mean total length of the deceased fish was 3.5 ± 0.42 cm (n = 47) (Fig. 2d,f).

Reef fish mortalities are common in the Atlantic basin, including the Caribbean basin and affect a wide diversity of species (Atwood 1981, Pinheiro et al. 2010), among which are those reported in this work (Landsberg 1995, Williams & Bunkley-Williams 2000, Panek 2005, Jordán-Garza et al. 2009, Pinheiro et al. 2010, Piedra-Castro & Araya-Vargas 2018).

A similar case of reef fish mortality, including *P. arcuatus*, was documented by Landsberg (1995) off the southeast coast of Florida and in the Islamorada area between November 1993 and February 1994. This event primarily impacted species within the Pomacanthidae family, particularly *P. arcuatus*, *P. paru*, and *Holacanthus tricolor*, although at least eight other species were also affected. The analyzed specimens from this event exhibited skin injuries, ulcers, and fin necrosis and were covered in mucus. Skin wounds and gill swears revealed infestations of parasitic ciliates such as *Brooklynella hostilis*, *Uronema marinum*, and pathogenic bacteria. Furthermore, histological analysis of the intestines confirmed the presence of amoebae. Despite the evident impact of parasites on the health of the fish, the author hypothesizes that these were opportunistic infestations resulting from an underlying primary cause, which she suggests could have been phycotoxin poisoning such as ciguatoxins produced by the dinoflagellate *Gambierdiscus* spp. or caluerpins produced by the green algae *Caulerpa*.

However, unlike the extensive mortality Landsberg (1995) reported, the Puerto Morelos event was relatively localized, affecting some tens of individuals over approximately six weeks. Nevertheless, given that angelfish was prominently impacted in both cases, it is reasonable to assume a shared etiological agent between the two events related to diet. The reef ecosystems of Florida and the Mexican Caribbean harbor species of potentially toxic algae and micro-

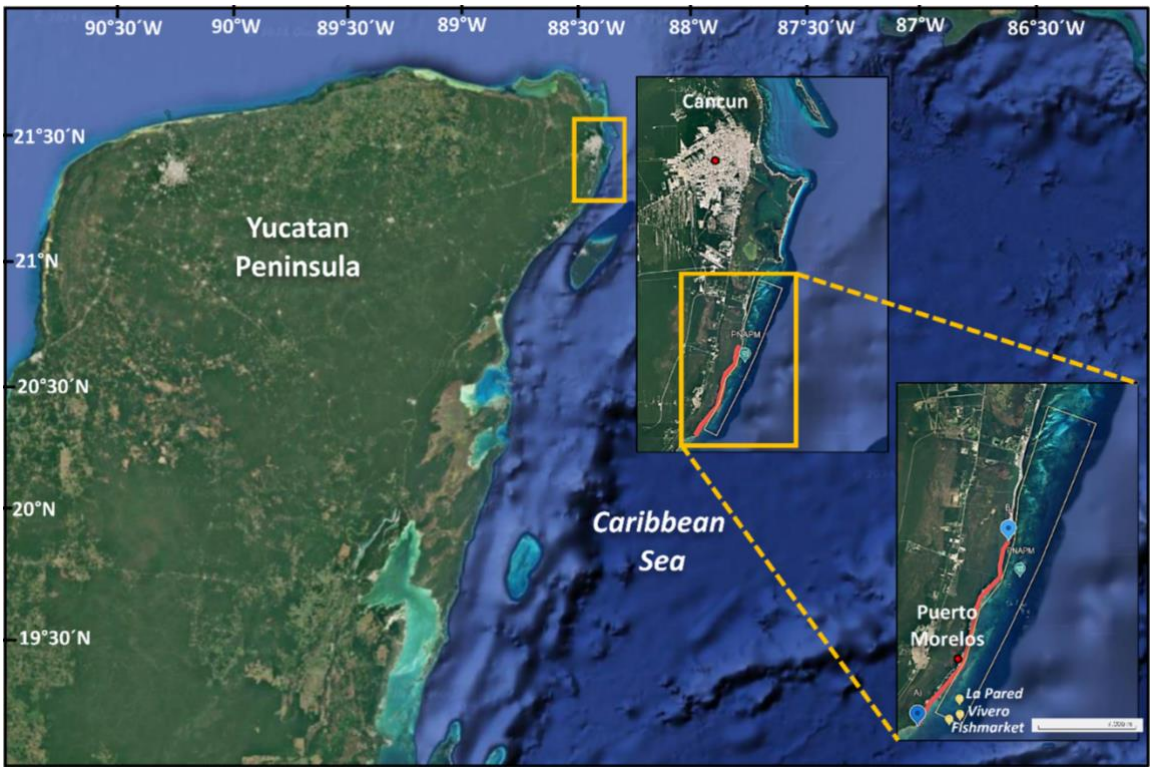

Figure 1. The study area shows the approximately 15 km stretch of coastline where most stranded fish were detected (red line). In the marine part, reef sites are shown where the largest number of reports of floating dead fish were located. The perimeter of the Puerto Morelos Reef National Park is shown delimited by the yellow line.

algae, which, according to Landsberg (1995), the ingestion of toxic algae like benthic dinoflagellates and *Caulerpa* could have a role in the fish die-off. In the Mexican Caribbean, remarkably within the PMRNP, populations of several *Caulerpa* species coexist alongside toxic benthic dinoflagellates populations such as *Gambierdiscus*, *Ostreopsis*, and *Prorocentrum*. However, given the absence of robust data, the hypothesis of death due to phycotoxin poisoning lacks evidence.

Contrary to the localized and relatively small number of affected individuals of *Pomacanthus* and other reef species, there is evidence that the phenomenon impacting the Caribbean sharpnose puffer *Canthigaster rostrata* is recurrent and occurs on a regional scale, spanning the western Caribbean basin from Mexico to Colombia. Although not all mortality events have been formally documented in scientific literature, several have been recorded through blogs, press reports, or indirectly due to the impact of other species' consumption of dead fish. That evidence shows the frequency of the cases (Barrientos et al. 2019, Brown et al. 2020).

Jordán-Garza et al. (2009) documented that the first event of *C. rostrata* mortality occurred in 2008 along the Mexican Caribbean coast, including the PMRNP. Subsequent mortalities were observed in Panama, Costa Rica, Honduras, and the San Andrés Archipelago, Colombia (Table 1).

Hypotheses related to these mortalities encompass factors such as rising sea temperatures, epidemic diseases, and recruitment events of juvenile organisms in reproductive habitats. Mortality events associated with increases in sea temperature can affect several species, which does not coincide with the mortalities of *C. rostrata* since this is the only species affected. Besides, the events have been recorded practically throughout the year, including January and December, corresponding to the cold season (Table 1). Epizootics caused by pathogenic bacteria have been reported in the Caribbean (Ferguson et al. 2000). However, the organisms examined during these events did not show signs of disease at a macroscopic level (Jordán-Garza et al. 2009), nor in histological analyses (Vázquez-Yeomans et al. 2023) so there is still no evidence to support that epidemic agents have caused these epizootics.

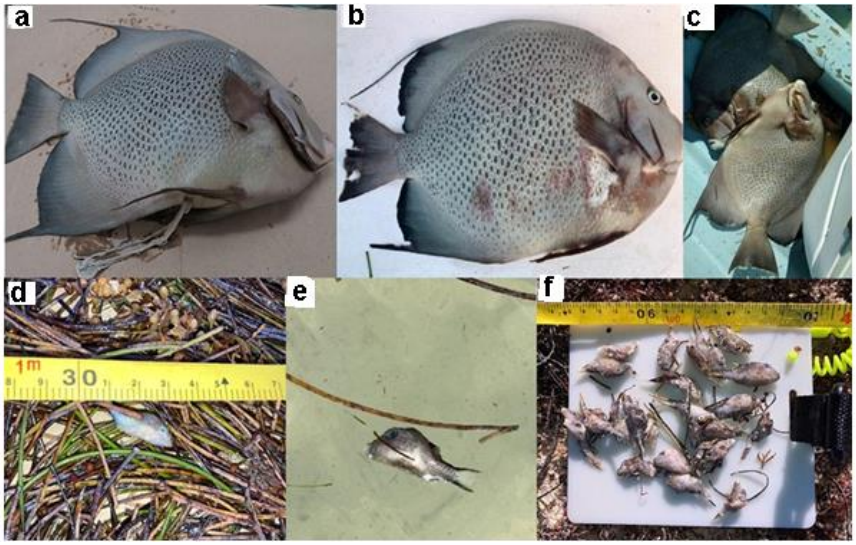

Figure 2. a) *Pomacanthus arcuatus* exhibiting intestinal prolapse, b) *P. arcuatus* with damage on the operculum, pectoral fins, head, and skin, resulting in scale loss in certain areas, c) specimens collected by fishermen from Puerto Morelos in the affected area (40-43 cm in total length), d-f) *Canthigaster rostrata* specimens found dead along transects and some floating in the water near the coast.

Table 1. Mortality events of *Canthigaster rostrata* recorded in the west Caribbean. 1) Jordán-Garza et al. (2009), 2) Vázquez-Yeomans et al. (2023), 3) Barrientos et al. (2019), 4) Piedra-Castro & Araya-Vargas (2018), 5) Ramírez-Vargas et al. (2023), 6) Castillo & Pérez (2014), 7) Bolaños-Cubillos (cited in Piedra-Castro & Araya-Vargas, 2018), 8) Brown et al. (2020), 9) This study. *Blog information. TL: total length, SL: standard length.

Country	Location	Date	Observation
Mexico	Akumal and Puerto Morelos	December 2008	[1]38 ± 2.6 mm TL.
	Puerto Morelos	February 2023	[9]35 ± 4.2 mm TL.
	Xkalak	September 2017	[2]26.7 ± 3.3 mm SL.
Costa Rica	Limon Province	September 2013	[3]Events related to green turtle intoxication by eating *C. rostrata* related to mass mortality event.
		May 2014	
	Gandoca-Manzanillo National Wildelife Refuge	April to May 2017	[4]36.73 ± 4.72 mm TL.
		November 2017	
		October 2020	[5]Mortality cause not specified. 40.59 ± 3.82 mm SL.
Panama	Guna Yala and Bocas del Toro	September to November 2014	[6]Hypothesize reproductive event. ~40 mm TL.
Colombia	*San Andres Archipelago, Providencia, and Santa Catalina	August 2013	[7]Hypothesize reproductive event.
Honduras	Utila Island	April 2020	[8]Event related to dog intoxication by eating *C. rostrata* related to mass mortality event.

The most reasonable hypothesis is that mortality could be related to the settlement of juveniles in reproductive habitats. Sikkel (1990) reports that the lower limits of the size range for reproductive adult males and females are approximately 36 and 37 mm, respectively, which closely aligns with the average sizes of stranded fish observed at several locations during this phenomenon (Table 1). Furthermore, territoriality (a social aspect of the species) can hinder the settlement of juveniles when reproductive habitats are already occupied and defended by established adults. Similar mortality events have been observed during the settlement of *C. bennetii*, a functionally analogous species to *C. rostrata* from the Tropical Pacific reefs (Vail & Sinclair-Taylor 2011). It is possible that the transition from breeding to reproductive habitat results in a proportion of dead individuals that, due to their small size and number, often go unnoticed. Settlement events are part of the life cycle of reef fishes. Predation mortality may account

for up to 50% of juvenile losses during this period (Alamany & Webster 2006). However, *C. rostrata* is a toxic species with concentrations of saxitoxin and tetrodotoxin, making it less susceptible to predation, which can be corroborated by the lack of scavengers eating the dead fish around the area and the poisoning reports of turtles and dogs after consuming stranded fish (Barrientos et al. 2019, Brown et al. 2020). Therefore, the recurrent mass mortalities observed in the Caribbean since 2008 may serve as a population control mechanism compensating for high reproduction and low predation rates.

Also, mass mortalities could be interpreted as signs of disturbances at the ecosystem level. One of the main factors of coral reef ecosystem decline is the deterioration of water quality. Recently, a mass coral mortality event known as the 'white plague' occurred in the Caribbean region, including the PMRNP (Álvarez-Filip et al. 2019). This event strongly affects stony coral colonies and does not affect fish species. While the exact cause of this disease remains elusive, declining water quality may play a significant role as a stress mechanism, rendering corals and other reef species more susceptible to pathogens that would not typically have a substantial impact. Water quality deterioration in the Mexican Caribbean has been documented in recent studies (Pérez-Gómez et al. 2020, Velázquez-Ochoa & Enriquez 2023). Still, it has been further exacerbated by the massive influx of pelagic *Sargassum* to the region (Rodríguez-Martínez et al. 2019). Therefore, mass mortalities of coral reef fish and other taxa could be a warning of the ecosystem's decline.

Credit author contribution

A. Almazán-Becerril: conceptualization, validation, methodology, formal analysis, writing-original draft, supervision, review; J.C. Peniche-Pérez & B. Delgado-Pech: methodology, formal analysis, writing-original draft, supervision, review, and editing; J.A. Caballero-Vázquez: review, and editing; M.C. García-Rivas: review, methodology, editing. All authors have read and accepted the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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