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Short Note

First Direct Evidence of a Galapagos Sea Lion (*Zalophus wollebaeki*) Predated by a Galapagos Shark (*Carcharhinus galapagensis*)

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The Galapagos sea lion (*Zalophus wollebaeki*) is an endemic species found across the Galapagos Archipelago (Trillmich, 1986), breeding and maintaining rookeries between the months of September and January (Trillmich et al., 2016; Riofrío-Lazo et al., 2017). As a result of endemism, this marine mammal has developed specific features such as a reduced body size and non-migratory behavior (Trillmich, 1990; Wolf et al., 2008). Moreover, the sea lion population of the Galapagos Islands has been declining from an estimated 40,000 individuals in 1977-1978 (Trillmich, 1979) to no more than 16,000 individuals in 2001 (Alava & Salazar, 2006). The main cause of this population reduction being the extreme El Niño events during 1982-1983 and 1997-1998 (Trillmich et al., 1991; Alava & Salazar, 2006). Furthermore, the high vulnerability of Galapagos sea lion populations to climatic changes, coupled with anthropogenic disturbances, such as marine pollution, habitat loss, and fishing gear entanglements (Denkinger et al., 2015; Páez-Rosas & Guevara, 2017), have resulted in this otariid being recognized as "Endangered" in the International Union for Conservation of Nature's (IUCN) *Red List* (Trillmich, 2015).

The majority of existing studies on Galapagos sea lions have focused on their behavior and foraging ecology (Trillmich, 1990; Villegas-Amtmann et al., 2008). However, very little has been published on attacks by potential predators, with limited references in relation to the role of Galapagos sharks (*Carcharhinus galapagensis*), tiger sharks (*Galeocerdo cuvier*), and oceanic white-tip sharks (*Carcharhinus longimanus*) as potential consumers of this species (Barlow, 1972; Riedman, 1990). While tiger sharks have been documented to feed upon Galapagos sea lion pups (Beebe, 1924/2012), the predatory role of Galapagos sharks upon sea lions of any age has yet to be directly confirmed (Table 1). For instance, stomach content analyses conducted during the 1898-1899 Hopkins-Stanford Galapagos Expedition revealed that fish, Galapagos fur seals (*Arctocephalus galapagoensis*), and Galapagos sea lions accounted for a great portion of Galapagos sharks' diet (Snodgrass & Heller, 1905). As a result, Snodgrass & Heller (1905) concluded that Galapagos sharks may have scavenged the pinniped carcasses left by the sealers that killed thousands of animals at the Galapagos Archipelago during the 19th century (Thornton, 1971). Also, Barlow (1972) described harassment behavior by a Galapagos shark towards juvenile Galapagos sea lions, as well as the apparent intervention of a group of adult males to protect their rookeries. However, to our knowledge, no direct evidence yet exists on the predatory role of Galapagos sharks upon Galapagos sea lions.

The Galapagos shark is a common species of tropical waters with a preference for isolated oceanic islands and seamounts (Compagno, 1984). Knowledge of its feeding habits has been limited to diet studies in which several species of pelagic fish and cephalopods have been reported as their main prey (Edwards & Lubbock, 1982; Wetherbee et al., 1996). However, recent studies have demonstrated that this species is a versatile predator capable of feeding on a wide spectrum of prey, including pinnipeds, batoids, and other sharks (Papastamatiou et al., 2006). Still, there are no previous studies on the Galapagos shark diet in the Galapagos Marine Reserve. In this note, we

provide the first unequivocal direct evidence of a Galapagos shark attacking and killing a Galapagos sea lion near Santa Cruz Island, Galápagos.

The event took place at South Plaza islet, Santa Cruz Island (-0.5833°, -90.1634°), on 6 November 2018. It was around 1500 h when a patch of blood was observed on the water surface near shore, followed by an abrupt splash motion (Figure 1a). Immediately after, a juvenile sea lion of undetermined sex breached out of the water onto shore, and a large dorsal fin broke the surface behind the sea lion (Figure 1b). Based on the morphology of the dorsal and caudal fins, grey coloration with no distinct markings, and relatively long and slender caudal fin with the tip shape broadly pointed and a straight rear edge, the shark was identified as a large Galapagos shark, measuring 2.5 to 3 m in total length (Grace, 2001; Compagno et al., 2005; C. Meyer, pers. comm., 6 June 2019). The attacked sea lion, bleeding profoundly, was missing the lower portion of its body, including its hind flippers (Figure 1c). As the sea lion continued to move inshore away from the water, the shark swam near the rocks and kept patrolling the area (Figure 1d).

Table 1. Evidence of carcharhinid sharks as predators of Galapagos sea lions in the Galapagos Islands

Location	Event	Date	Reference
Darwin, Wolf, Fernandina, and Isabela Islands	Presence of fur seal and sea lion in Galapagos sharks' stomach contents	1898-1899	Snodgrass & Heller, 1905
Guy Fawkes islet, Santa Cruz Island	Tiger shark predation upon sea lion pup	1924	Beebe, 1924
Champion islet, Floreana Island	Shark-mobbing behavior toward juvenile sea lions around rookeries	Feb. 1967	Barlow, 1972
South Plaza islet, Santa Cruz Island	Galapagos shark strike on juvenile sea lion	Nov. 2018	This study

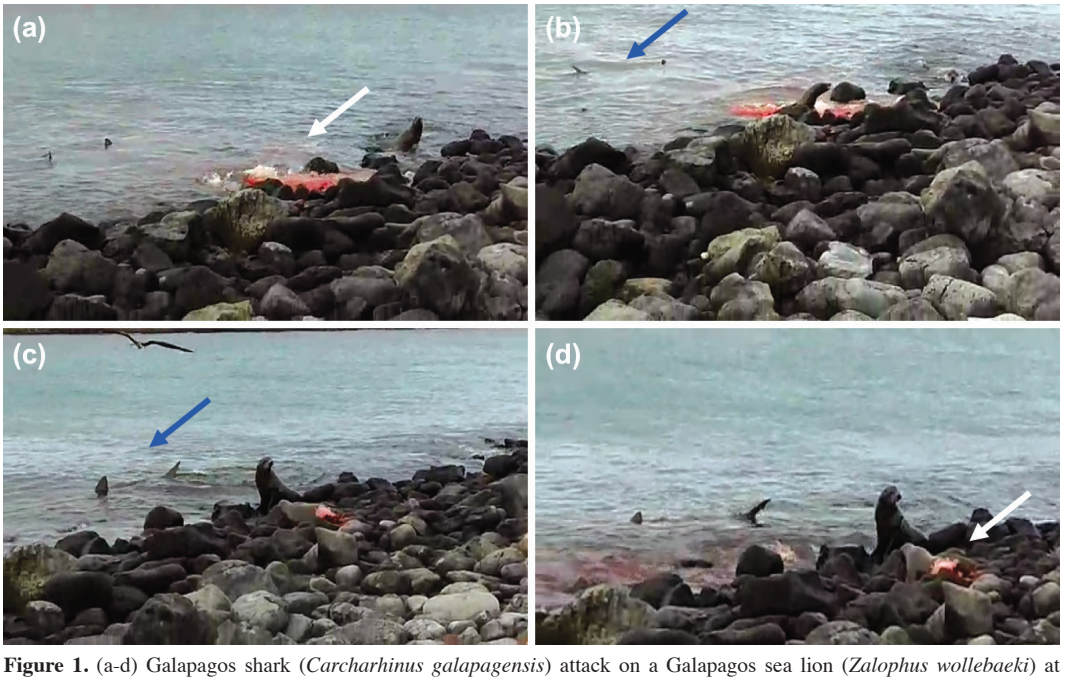

Figure 1. (a-d) Galapagos shark (*Carcharhinus galapagensis*) attack on a Galapagos sea lion (*Zalophus wollebaeki*) at South Plaza islet (-0.5833°, -90.1634°), east of Santa Cruz Island. Blue arrow shows the shark, and white arrow shows the injured sea lion. Images are chronological as described in the text.

While this event was taking place, a subadult male sea lion approached the site and entered the water. The shark appeared to swim towards it, but a second attack was not observed. The entire event lasted for approximately 3 min. Given that this occurred at a highly protected area where tourists are not allowed to stay on site for too long, the death of the sea lion could not be recorded. However, we estimate that the injured sea lion died within a few hours after the attack. (The link for the video footage of this interaction can be found on the *Aquatic Mammals*' Supplemental Material page: https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147).

This is the first unequivocal evidence of a Galapagos shark attacking a Galapagos sea lion. It is not yet clear whether such attacks are restricted to juveniles or whether this occurs year-round. Likewise, it is currently unknown how frequently these events occur near rookeries during the breeding season of Galapagos sea lions. Otariids are income breeders, and females alternate breeding season with the birth of their pups and suckling periods (Riedman, 1990). The lactation period of Galapagos sea lions is much longer (up to 3 y; Trillmich & Wolf, 2008) than that of most otariids, allowing juveniles to remain at their rookeries for longer periods. This behavior is based on the seasonal-productivity hypothesis, which predicts an inverse correlation between latitude and lactation length in pinnipeds (Schulz & Bowen, 2005). These characteristics are related to an extended rutting period in Galapagos sea lions of approximately 6 mo (Trillmich, 1986), which is reflected by a weak reproductive synchrony of females that may give birth and come into estrus at any time from August to January (Páez-Rosas, 2011). This trait also gives consequence to a greater animal presence on the rookeries during these months (Montero-Serra et al., 2014) and probably a greater opportunity for their predators.

Early studies reported Galapagos sharks closely patrolling the shores of the Galapagos Islands, specifically near sea lion haulout sites (Barlow, 1972; Bonner, 1984). Similarly, since 1997, Galapagos sharks have been observed in the Sotavento Islands, patrolling and attacking Hawaiian monk seal (*Monachus schauinslandi*) pups during their nursing period or days after weaning (Gobush & Farry, 2012). This near-shore patrolling behavior in the vicinity of rookeries is observed in many shark species such as the great white shark (*Carcharhinus carcharias*) and tiger shark, and it allows them to intercept sea lions and seals that depart and return to the rookeries (Klimley et al., 2001; Gobush & Farry, 2012). Therefore, the prolonged lactation period in Galapagos fur seals and sea lions (Trillmich & Wolf, 2008) could reduce encounters with predators patrolling near the surface (Lucas & Stobo, 2000).

In the Galapagos Marine Reserve, there are two genetically distinct Galapagos shark populations (Pazmiño et al., 2017). Hence, in addition to the climatic and anthropogenic pressures that Galapagos sea lions currently face, predation by Galapagos sharks should also be included as a source of natural mortality for this species. For example, shark attacks are one of the main causes of mortality in Hawaiian monk seals at the Sotavento Islands (Gobush, 2010); and recently, non-lethal methods are being developed to mitigate predation and deter sharks from monk seal breeding sites (Gobush & Farry, 2012). We hope our observations contribute to the understanding of potential predators and further natural threats for this endangered species while also highlighting the importance of protecting the rookeries and inshore habitats of the Galapagos Islands.

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Literature Cited

Alava, J. J., & Salazar, S. (2006). Status and conservation of otariids in Ecuador and the Galapagos Islands. In A. W. Trites, S. K. Atkinson, D. P. DeMaster, L. W. Fritz, T. S. Gelatt, L. D. Rea, & K. M. Wynne (Eds.), *Sea lions of the world: Conservation and research in the 21st century* (pp. 495-519). Alaska Sea Grant College Program. https://doi.org/10.4027/slw.2006.31

Barlow, G. W. (1972). A paternal role for bulls of the Galapagos Islands sea lion. *Evolution*, *26*(2), 307-310. https://doi.org/10.1111/j.1558-5646.1972.tb00196.x

Beebe, W. (2012). *Galapagos: World's end*. Courier Corporation. (Originally published in 1924)

Bonner, W. N. (1984). Seals of the Galapagos Islands. *Biological Journal of the Linnean Society*, *21*(1-2), 177-184. https://doi.org/10.1111/j.1095-8312.1984.tb02060.x

Compagno, L. J. V. (1984). *FAO species catalogue. Vol. 4: Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2 – Carcharhiniformes* (FAO Fisheries Synopsis No. 125[4/2], 251-655). Food and Agriculture Organization of the United Nations (FAO).

Compagno, L. J. V., Dando, M., & Fowler, S. (2005). *Sharks of the world*. Princeton University Press.

Denkinger, J., Gordillo, L., Montero-Serra, I., Murillo, J. C., Guevara, N., Hirschfeld, M., Fietz, K., Rubianes, F., & Dan, M. (2015). Urban life of Galapagos sea lions (*Zalophus wollebaeki*) on San Cristobal Island, Ecuador: Colony trends and threats. *Journal of Sea Research*, *105*, 10-14. https://doi.org/10.1016/j.seares.2015.07.004

Edwards, A. J., & Lubbock, H. R. (1982). The shark population of Saint Paul's Rocks. *Copeia*, *1982*(1), 223-225. https://doi.org/10.2307/1444304

Gobush, K. S. (2010). *Shark predation on Hawaiian monk seals: Workshop II & post-workshop developments* (NOAA Technical Memorandum NMFS-PIFSC-21). National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Gobush, K. S., & Farry, S. C. (2012). Non-lethal efforts to deter shark predation of Hawaiian monk seal pups. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *22*(6), 751-761. https://doi.org/10.1002/aqc.2272

Grace, M. (2001). *Field guide to requiem sharks (Elasmobranchiomorphi: Carcharhinidae) of the Western North Atlantic* (NOAA Technical Report NMFS 153). National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Klimley, A. P., Le Boeuf, B. J., Cantara, K. M., Richert, J. E., Davis, S. F., Van Sommeran, S., & Kelly, J. T. (2001). The hunting strategy of white sharks (*Carcharodon carcharias*) near a seal colony. *Marine Biology*, *138*(3), 617-636. https://doi.org/10.1007/s002270000489

Lucas, Z., & Stobo, W. T. (2000). Shark-inflicted mortality on a population of harbour seals (*Phoca vitulina*) at Sable Island, Nova Scotia. *Journal of Zoology*, *252*(3), 405-414. https://doi.org/10.1111/j.1469-7998.2000.tb00636.x

Montero-Serra, I., Páez-Rosas, D., Murillo, J. C., Vegas-Vilarrúbia, T., Fietz, K., & Denkinger, J. (2014). Environment-driven changes in terrestrial habitat use and distribution of the Galapagos sea lion. *Endangered Species Research*, *24*(1), 9-19. https://doi.org/10.3354/esr00573

Páez Rosas, D. (2011). *Ecología trófica de los pinnípedos de las Islas Galápagos: Análisis espacial y temporal* [Trophic ecology of the pinnipeds of the Galápagos Islands: Spatial and temporal analysis] (Doctoral dissertation). Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, La Paz, BCS, México.

Páez-Rosas, D., & Aurioles-Gamboa, D. (2010). Alimentary niche partitioning in the Galapagos sea lion, *Zalophus wollebaeki*. *Marine Biology*, *157*(12), 2769-2781. https://doi.org/10.1007/s00227-010-1535-0

Páez-Rosas, D., & Guevara, N. (2017). Management strategies and conservation status of Galapagos sea lion populations at San Cristóbal Island, Galapagos, Ecuador. In J. J. Alava (Ed.), *Tropical pinnipeds: Bio-ecology, threats and conservation* (pp. 159-175). CRC Press/Taylor & Francis Group. https://doi.org/10.1201/9781315151588-10

Papastamatiou, Y. P., Wetherbee, B. M., Lowe, C. G., & Crow, G. L. (2006). Distribution and diet of four species of carcharhinid shark in the Hawaiian Islands: Evidence for resource partitioning and competitive exclusion. *Marine Ecology Progress Series*, *320*, 239-251. https://doi.org/10.3354/meps320239

Pazmiño, D. A., Maes, G. E., Simpfendorfer, C. A., Salinas-de-León, P., & van Herwerden, L. (2017). Genome-wide SNPs reveal low effective population size within confined management units of the highly vagile Galapagos shark (*Carcharhinus galapagensis*). *Conservation Genetics*, *18*(5), 1151-1163. https://doi.org/10.1007/s10592-017-0967-1

Riedman, M. (1990). *The pinnipeds: Seals, sea lions, and walruses* (Vol. 12). University of California Press.

Riofrío-Lazo, M., Arreguín-Sánchez, F., & Páez-Rosas, D. (2017). Population abundance of the endangered Galapagos sea lion *Zalophus wollebaeki* in the southeastern Galapagos archipelago. *PLOS ONE*, *12*(1), e0168829. https://doi.org/10.1371/journal.pone.0168829

Schulz, T. M., & Bowen, W. D. (2005). The evolution of lactation strategies in pinnipeds: A phylogenetic analysis. *Ecological Monographs*, *75*(2), 159-177. https://doi.org/10.1890/04-0319

Snodgrass, R., & Heller, E. (1905). Papers from the Hopkins Stanford Galápagos Expedition, 1898-1899. XVII. Shore fishes of the Revillagigedo, Clipperton, Cocos and Galápagos Islands. *Proceedings of the Washington Academy of Sciences*, *6*, 333-427.

Thornton, I. W. (1971). *Darwin's islands: A natural history of the Galapagos*. American Museum of Natural History.

Trillmich, F. (1979). Galápagos sea lions and fur seals. *Noticias de Galápagos*, *29*.

Trillmich, F. (1986). Attendance behaviour of Galapagos sea lions. In R. L. Gentry & G. L. Kooyman (Eds.), *Fur seals: Maternal strategies on land and at sea* (pp. 196-208). Princeton University Press. https://doi.org/10.1515/9781400854691.196

Trillmich, F. (1990). The behavioral ecology of maternal effort in fur seals and sea lions. *Behaviour*, *114*(1-4), 3-20. https://doi.org/10.1163/156853990X00022

Trillmich, F. (2015). *Zalophus wollebaeki*. In International Union for Conservation of Nature (Ed.), *The IUCN red list of threatened species 2015* (e.T41668A45230540). https://doi.org/10.2305/IUCN.UK.20152.RLTS.T41668A45230540.en

Trillmich, F., & Wolf, J. B. W. (2008). Parent–offspring and sibling conflict in Galápagos fur seals and sea lions. *Behavioral Ecology and Sociobiology*, *62*(3), 363-375. https://doi.org/10.1007/s00265-007-0423-1

Trillmich, F., Meise, K., Kalberer, S., Mueller, B., Piedrahita, P., Pörschmann, U., Wolf, J. B. W., & Krüger, O. (2016). On the challenge of interpreting census data: Insights from a study of an endangered pinniped. *PLOS ONE*, *11*(5), e0154588. https://doi.org/10.1371/journal.pone.0154588

Trillmich, F., Ono, K. A., Costa, D. P., DeLong, R. L., Feldkamp, S. D., Francis, J. M., Gentry, R. L., Heath, C. B., Le Boeuf, B. J., Majluf, P., & York, A. E. (1991). The effects of El Niño on pinniped populations in the eastern Pacific. In *Pinnipeds and El Niño* (pp. 247-270). Springer. https://doi.org/10.1007/978-3-642-76398-4_27

Villegas-Amtmann, S., Costa, D. P., Tremblay, Y., Salazar, S., & Aurioles-Gamboa, D. (2008). Multiple foraging strategies in a marine apex predator, the Galapagos sea lion *Zalophus wollebaeki*. *Marine Ecology Progress Series*, *363*, 299-309. https://doi.org/10.3354/meps07457

Wetherbee, B. M., Crow, G. L., & Lowe, C. G. (1996). Biology of the Galapagos shark, *Carcharhinus galapagensis*, in Hawai'i. *Environmental Biology of Fishes*, *45*(3), 299-310. https://doi.org/10.1007/BF00003099

Wolf, J. B. W., Harrod, C., Brunner, S., Salazar, S., Trillmich, F., & Tautz, D. (2008). Ecological, morphological and genetic divergence of Galapagos sea lion populations as a model for tracing early stages of species differentiation. *BMC Evolutionary Biology*, *8*, 150. https://doi.org/10.1186/1471-2148-8-150