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Short Note

Evidence of a Predatory Interaction of a Cookiecutter Shark (*Isistius brasiliensis*) on Galapagos Fur Seals (*Arctocephalus galapagoensis*)

Andrés Moreira-Mendieta,[1] Diego O. Urquía,[1, 2] Pacarina Asadobay,[1] and Diego Páez-Rosas[1, 3]

[1]*Universidad San Francisco de Quito (USFQ), Galapagos Science Center, Avenida Alsacio Northia s/n, Isla San Cristóbal, Islas Galapagos, Ecuador*
E-mail: dpaez@usfq.edu.ec
[2]*University of North Carolina at Chapel Hill, Department of Biology, Chapel Hill, NC 27599, USA*
[3]*Dirección Parque Nacional Galapagos, Unidad Técnica Operativa San Cristóbal, Isla San Cristóbal, Islas Galapagos, Ecuador*

Predation events typically refer to the lethal consumption of individuals of one species (prey) by another (predator), yet this is not always true as there are several events which do not involve lethality for the prey (Wirsing et al., 2008). Predation risk or sublethal effects may have consequences on the fitness of the prey due to anti-predator behaviors, which may limit energy fluxes in marine trophic webs, thus altering the composition and dynamics of these communities (Cresswell, 2008; Heithaus et al., 2008; Wirsing et al., 2008, Liu et al., 2018). Furthermore, certain cases of ectoparasitism (i.e., predators that feed on the tissue or blood of their prey—or host—causing damage but not lethality to the animal) can also be considered as sublethal predatory interactions, highlighting those caused by two species of sharks commonly known as cookiecutters (*Isistius* spp.; Gallo-Reynoso & Figueroa-Carranza, 1992; Widder, 1998; Papastamatiou et al., 2010; Dwyer & Visser, 2011; Feunteun et al., 2018).

There are two widely distributed, but poorly understood, cookiecutter shark species grouped within the *Isistius* genus: (1) *I. brasiliensis* and (2) *I. plutodus* (Ebert et al., 2021). The former is a small squaloid (up to 42 cm length in males; 56 cm in females), which is distributed in deep-oceanic waters in the tropics, especially near islands, but can extend to higher latitudes if warm currents are present (Jahn & Haedrich, 1987; Ebert et al., 2021). *I. brasiliensis* individuals are characterized by performing vertical diel migrations from deep waters up to the surface (i.e., from 2,000 to 3,000 m deep to 0 m) usually at night (Wenzel & López Suárez, 2012; Ebert et al., 2021) and for exhibiting dignathic heterodonty—upper teeth are lanceolate, small, and arranged in quincunxes, whereas lower teeth are distributed in a row of triangular, erect, and interconnected plates, being significantly larger in size than the former (Shirai & Nakaya, 1992; Ebert et al., 2021). Dentition morphology, coupled with a modified pharynx, stealthy behavior, and luminescent photophores, allows *I. brasiliensis* to ambush significantly larger prey by digging their sharp lower teeth into the skin, then rotating in a circle to extract a piece of flesh attached to the upper teeth (Widder, 1998; Ebert et al., 2021). Therefore, *I. brasiliensis* is considered to be an ectoparasitic predator that feeds on species in a wide range of sizes, including significantly larger prey (e.g., marine mammals; Feunteun et al., 2018; Carlisle et al., 2021).

Predatory interactions between *Isistius* spp. and marine mammals have been mostly reported for cetaceans (e.g., Wenzel & López Suárez, 2012; Feunteun et al., 2018), with evidence suggesting that wounds caused by this group could lead to strandings in some species of delphinids (Souto et al., 2007). For pinniped species, there are fewer published reports of *Isistius* spp. bites (see Table 1).

During June of 2023, at Cape Douglas, Fernandina (Galapagos Islands), we opportunistically encountered an adult female Galapagos fur seal (*Arctocephalus galapagoensis*; GFS) with a relatively fresh and circular wound (approx. 10 cm in diameter) in the central portion of the dorsum (Figure 1). The wound was deep enough so that all dermal layers were absent, although some fibrin layers were apparent, showing early signs of cicatrization. We determined that *I. brasiliensis*

Table 1. Predatory interactions reported between *Isistius* spp. and pinnipeds

Common name	Species	No. of individuals	Location	Bite site	Suspected lethality	Reference
Galapagos fur seal	*Arctocephalus galapagoensis*	1	Galapagos, Ecuador	Dorsum	No	This study
Hawaiian monk seal	*Neomonachus schauinslandi*	Multiple	Hawaii, USA	Dorsum; rest not specified	Not specified	Villalobos, 2021
		1	Pearl and Hermes Reef, Hawaii, USA	Not specified	No	Aguirre, 1998
		Multiple	Hawaii, USA	Not specified (13 wounds)	Not specified	Hiruki et al., 1993
New Zealand fur seal	*Arctocephalus forsteri*	1	Sydney, Australia	Not specified	No	Shaughnessy & Goldsworthy, 2020
		1	Norfolk Island, Australia	Ventrum, front flippers	No	Shaughnessy & Christian, 2016
		2	Teewah, New Zealand	Not specified	No	Meager, 2013
California sea lion	*Zalophus californianus*	1	Gleneden Beach, Oregon, USA	Not specified	No	El-Mallakh & Hartman, 2018
Southern elephant seal	*Mirounga leonina*	1	Espírito Santo, Brazil	Dorsum	No	Mayorga et al., 2017
Subantarctic fur seal	*Arctocephalus tropicalis*	2	Bahia, Brazil	Front flippers, dorsum	Yes	Souto et al., 2009
		Multiple (< 10)	Bahia and Sergipe, Brazil	Anterior fin (n = 1); rest not specified	Not specified	Velozo et al., 2009
Guadalupe fur seal	*Arctocephalus townsendi*	1	Guadalupe Island, Mexico	Right shoulder	Not specified	Gallo-Reynoso & Figueroa-Carranza, 1992
Crabeater seal	*Lobodon carcinophaga*	1	Cape Point, South Africa	Ventrum	No	Klages & Cockcroft, 1990
Northern elephant seal	*Mirounga angustirostris*	20	Mexico	Front flippers, ventrum, dorsum, neck, head	Not specified	Le Boeuf et al., 1987

created this bite mark based on the before-mentioned characteristics of the wound and that this is the only *Isistius* spp. recorded around the tropical Galapagos Islands, specifically at the northwestern side of the archipelago (Morris, 1891; Le Boeuf et al., 1987). This GFS individual did not show any apparent abnormal behavior or altered mobility, and it was even observed nursing a pup. The individual left shortly after the observation, so it was not possible to track any progression of wound healing.

GFSs are the smallest otariids in the world, endemic to the Galapagos Islands; they establish their main reproductive rookeries on the western and northern regions, namely on Fernandina, Isabela, and Pinta Islands (Páez-Rosas et al., 2021; Riofrío-Lazo & Páez-Rosas, 2021). The western region of the Galapagos Islands is characterized by unusually cold waters for a tropical ecosystem, having steep slopes on the continental shelf (over 1,000 m in depth) (Johnson et al., 1976; Palacios et al., 2006; Harpp & Geist, 2018). GFSs are known to carry out long nocturnal foraging trips in both time (mean of 18.8 h) and distance from the coast (mean of 20.6 km), diving down to 87.8 m depth to seek vertically migrating prey overnight in the pelagic zone (Horning & Trillmich, 1997; Villegas-Amtmann et al., 2013). These conditions make this otariid susceptible to predation by several deep-diving species (Dellinger & Trillmich, 1999; Trillmich, 2021), such as *I. brasiliensis* since this shark is prone to attack marine mammals that feed on deep-scattering layer organisms (Heithaus, 2001). Therefore, evidence of the predatory interaction recorded herein between *I. brasiliensis* and a GFS might be explained partly by overlapping behaviours of the two species: the former migrate to the pelagic zone at night at the same time as the GFSs go out to forage.

Figure 1. Adult female Galapagos fur seal (*Arctocephalus galapagoensis*) with a bite mark in the dorsum from a cookiecutter shark (*Isistius brasiliensis*) (Photos provided by Pacarina Asadobay)

Nonetheless, environmental variability caused due to extreme climatic events may modify species distributions by altering temperature, primary productivity, and chemical composition of the ocean, thus creating novel habitats for some species (Collins et al., 2010; Feng et al., 2022). Changes in the thermal profile of the water column and productivity patterns in elasmobranchs that exhibit diel vertical migrations may shape the use of vertical space, altering diurnal cycles (Vedor et al., 2021). Considering that *I. brasiliensis* has been suggested to occur in association with warm currents (Jahn & Haedrich, 1987), we hypothesize that temperature shifts in the western Galapagos Islands linked to the recent El Niño Southern Oscillation (Climate Prediction Center, 2023) might generate favorable conditions for *I. brasiliensis*, increasing their relative abundance and thus the probability of encounters with novel prey such as the GFS. Survival and health status of the endangered GFS populations could possess an additional threat with the presence of novel predators, especially considering that wounds from these animals have been suggested to be lethal if they are near key mobility zones in pinnipeds (e.g., front flippers; Souto et al., 2009). Emergence of additional novel stressors (i.e., lethal and sublethal predation) may be a factor that influences GFS population declines during important warming events in the region.

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Literature Cited

Aguirre, A. A. (1998). *Hawaiian monk seal health assessment and disease status studies: A progress report* (SWFSC Administrative Report H-98-10). National Marine Fisheries Service. https://repository.library.noaa.gov/view/noaa/4226

Carlisle, A. B., Allan, E. A., Kim, S. L., Meyer, L., Port, J., Scherrer, S., & O'Sullivan, J. (2021). Integrating multiple chemical tracers to elucidate the diet and habitat of cookiecutter sharks. *Scientific Reports*, *11*(1), 11809. https://doi.org/10.1038/s41598-021-89903-z

Climate Prediction Center. (2023, September). *El Niño Southern Oscillation (ENSO) diagnostic discussion*. National Oceanic and Atmospheric Administration. https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.shtml

Collins, M., An, S. I., Cai, W., Ganachaud, A., Guilyardi, E., Jin, F. F., Jochum, M., Lengaigne, M., Power, S., Timmermann, A., Vecchi, G., & Wittenberg, A. (2010). The impact of global warming on the tropical Pacific Ocean and El Niño. *Nature Geoscience*, *3*(6), 391-397. https://doi.org/10.1038/ngeo868

Cresswell, W. (2008). Non-lethal effects of predation in birds: Non-lethal effects of predation risks. *Ibis*, *150*(1), 3-17. https://doi.org/10.1111/j.1474-919X.2007.00793.x

Dellinger, T., & Trillmich, F. (1999). Fish prey of the sympatric Galápagos fur seals and sea lions: Seasonal variation and niche separation. *Canadian Journal of Zoology*, *77*(8), 1204-1216. https://doi.org/10.1139/z99-095

Dwyer, S., & Visser, I. (2011). Cookie cutter shark (*Isistius* sp.) bites on cetaceans, with particular reference to killer whales (orca) (*Orcinus orca*). *Aquatic Mammals*, *37*(2), 111-138. https://doi.org/10.1578/AM.37.2.2011.111

Ebert, D. A., Dando, M., & Fowler, S. (2021). *Sharks of the world: A complete guide*. Princeton University Press. https://press.princeton.edu/books/hardcover/9780691205991/sharks-of-the-world; https://doi.org/10.2307/j.ctv1574pqp

El-Mallakh, R. S., & Hartman, M. (2018). The curious case of the missing face: Death of California sea lion by Dungeness crab trap. *International Journal of Aquatic Biology*, *6*(4), 198-201. https://doi.org/10.22034/ijab.v6i4.517

Feng, Z., Yu, W., Zhang, Y., Li, Y., & Chen, X. (2022). Habitat variations of two commercially valuable species along the Chilean waters under different-intensity El Niño events. *Frontiers in Marine Science*, *9*, 919620. https://doi.org/10.3389/fmars.2022.919620

Feunteun, A., De Schrevel, C., Verhaegen, M., Chevallier, D., Duchemin, M., Ziani, N., & De Montgolfier, B. (2018). First evaluation of the cookie-cutter sharks (*Isistius* sp.) predation pattern on different cetacean species in Martinique. *Environmental Biology of Fishes*, *101*(5), 749-759. https://doi.org/10.1007/s10641-018-0735-1

Gallo-Reynoso, J. P., & Figueroa-Carranza, A. L. (1992). A cookiecutter shark wound on a Guadalupe fur seal male. *Marine Mammal Science*, *8*(4), 428-430. https://doi.org/10.1111/j.1748-7692.1992.tb00060.x

Harpp, K. S., & Geist, D. J. (2018). The evolution of Galápagos volcanoes: An alternative perspective. *Frontiers in Earth Science*, *6*, 50. https://doi.org/10.3389/feart.2018.00050

Heithaus, M. R. (2001). Predator–prey and competitive interactions between sharks (order Selachii) and dolphins (suborder Odontoceti): A review. *Journal of Zoology*, *253*(1), 53-68. https://doi.org/10.1017/S0952836901000061

Heithaus, M. R., Wirsing, A. J., Thomson, J. A., & Burkholder, D. A. (2008). A review of lethal and non-lethal effects of predators on adult marine turtles. *Journal of Experimental Marine Biology and Ecology*, *356*(1-2), 43-51. https://doi.org/10.1016/j.jembe.2007.12.013

Hiruki, L. M., Gilmartin, W. G., Becker, B. L., & Stirling, I. (1993). Wounding in Hawaiian monk seals (*Monachus schauinslandi*). *Canadian Journal of Zoology*, *71*(3), 458-468. https://doi.org/10.1139/z93-066

Horning, M., & Trillmich, F. (1997). Ontogeny of diving behaviour in the Galápagos fur seal. *Behaviour*, *134*(15-16), 1211-1257. https://doi.org/10.1163/156853997X00133

Jahn, A. E., & Haedrich, R. L. (1987). Notes on the pelagic squaloid shark *Isistius brasiliensis*. *Biological Oceanography*, *5*(4), 297-309.

Johnson, G. L., Vogt, P. R., Hey, R., Campsie, J., & Lowrie, A. (1976). Morphology and structure of the Galapagos Rise. *Marine Geology*, *21*(2), 81-120. https://doi.org/10.1016/0025-3227(76)90052-9

Klages, N. T. W., & Cockcroft, V. G. (1990). Feeding behaviour of a captive crabeater seal. *Polar Biology*, *10*, 403-404. https://doi.org/10.1007/BF00237828

Le Boeuf, B. J., McCosker, J. E., & Hewitt, J. (1987). Crater wounds on northern elephant seals: The cookiecutter shark strikes again. *Fishery Bulletin*, *85*, 387-392. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/fishbull/leboeuf_0.pdf

Liu, Z., Kariya, M. J., Chute, C. D., Pribadi, A. K., Leinwand, S. G., Tong, A., Curran, K. P., Bose, N., Schroeder, F. C., Srinivasan, J., & Chalasani, S. H. (2018). Predator-secreted sulfolipids induce defensive responses in *C. elegans*. *Nature Communications*, *9*(1), 1128. https://doi.org/10.1038/s41467-018-03333-6

Mayorga, L. F. S. P., Bhering, R. C. C., Hurtado, R., & Vanstreels, R. E. T. (2017). Recurrent sightings of a southern elephant seal (*Mirounga leonina*) on the southeast coast of Brazil, 2012–2017. *Latin American Journal of Aquatic Mammals*, *12*(1-2), 53-58. https://doi.org/10.5597/00237

Meager, J. J. (2013). *Marine wildlife stranding and mortality database annual report 2012. II. Cetacean and pinniped* (Conservation Technical and Data Report

2013, 2). 38 pp. https://www.qld.gov.au/__data/assets/pdf_file/0015/202335/cetacean-and-pinniped-2012.pdf

Morris, P. J. (1891). Isistius brasiliensis *occurrence dataset* (GBIF-863075879) [Dataset]. Museum of Comparative Zoology, Harvard University. https://doi.org/10.15468/p5rupv

Páez-Rosas, D., Torres, J., Espinoza, E., Marchetti, A., Seim, H., & Riofrío-Lazo, M. (2021). Declines and recovery in endangered Galapagos pinnipeds during the El Niño event. *Scientific Reports*, *11*(1), 8785. https://doi.org/10.1038/s41598-021-88350-0

Palacios, D. M., Bograd, S. J., Foley, D. G., & Schwing, F. B. (2006). Oceanographic characteristics of biological hot spots in the North Pacific: A remote sensing perspective. *Deep Sea Research Part II: Topical Studies in Oceanography*, *53*(3-4), 250-269. https://doi.org/10.1016/j.dsr2.2006.03.004

Papastamatiou, Y. P., Wetherbee, B. M., O'Sullivan, J., Goodmanlowe, G. D., & Lowe, C. G. (2010). Foraging ecology of cookiecutter sharks (*Isistius brasiliensis*) on pelagic fishes in Hawaii, inferred from prey bite wounds. *Environmental Biology of Fishes*, *88*(4), 361-368. https://doi.org/10.1007/s10641-010-9649-2

Riofrío-Lazo, M., & Páez-Rosas, D. (2021). Galapagos sea lions and fur seals, adapted to a variable world. In C. Campagna & R. Harcourt (Eds.), *Ethology and behavioral ecology of otariids and the odobenid* (pp. 643-661). Springer International Publishing. https://doi.org/10.1007/978-3-030-59184-7_30

Shaughnessy, P. D., & Christian, M. (2016). Seals (Pinnipedia) at Norfolk Island, south-west Pacific. *Australian Mammalogy*, *38*(2), 234-236. https://doi.org/10.1071/AM15035

Shaughnessy, P. D., & Goldsworthy, S. D. (2020). Dispersion of long-nosed fur seals (*Arctocephalus forsteri*) determined by tagging. *Australian Journal of Zoology*, *67*(3), 173-179. https://doi.org/10.1071/ZO20032

Shirai, S., & Nakaya, K. (1992). Functional morphology of feeding apparatus of the cookie-cutter shark, *Isistius brasiliensis* (Elasmobranchii, Dalatiinae). *Zoological Science*, *9*, 811-821. https://biostor.org/reference/117331

Souto, L. R. A., Abrão-Oliveira, J. G., Maia-Nogueira, R., & Dórea-Reis, L. W. (2009). Interactions between subantarctic fur seal (*Arctocephalus tropicalis*) and cookiecutter shark (*Isistius plutodus*) on the coast of Bahia, northeastern Brazil. *Marine Biodiversity Records*, *2*, e123. https://doi.org/10.1017/S1755267209000992

Souto, L. R. A., Abrão-Oliveira, J. G., Costa, J. de A., Maia-Nogueira, R., & Sampaio, C. (2007). Análise das mordidas de tubarões-charuto, *Isistius* spp. (Squaliformes: Dalatiidae) em cetáceos (Mammalia: Cetacea) no litoral da Bahia, nordeste do Brasil [Analysis of the bites of cookiecutter sharks, *Isistius* spp. (Squaliformes: Dalatiidae) on cetaceans (Mammalia: Cetacea) off the coast of Bahia, northeast Brazil]. *Biotemas*, *20*(1), 19-25. https://periodicos.ufsc.br/index.php/biotemas/article/view/20775

Trillmich, F. (2021). Galápagos fur seal (*Arctocephalus galapagoensis,* Heller 1904). In G. Heckel & Y. Schramm (Eds.), *Ecology and conservation of pinnipeds in Latin America* (pp. 31-50). Springer International Publishing. https://doi.org/10.1007/978-3-030-63177-2_3

Vedor, M., Mucientes, G., Hernández-Chan, S., Rosa, R., Humphries, N., Sims, D. W., & Queiroz, N. (2021). Oceanic diel vertical movement patterns of blue sharks vary with water temperature and productivity to change vulnerability to fishing. *Frontiers in Marine Science*, *8*, 688076. https://doi.org/10.3389/fmars.2021.688076

Velozo, R. S., Schiavetti, A., & Dórea-Reis, L. W. (2009). Analysis of subantarctic fur seal (*Arctocephalus tropicalis*) records in Bahia and Sergipe, north-eastern Brazil. *Marine Biodiversity Records*, *2*, e117. https://doi.org/10.1017/S1755267209000980

Villalobos, C. I. (2021). *Monitoring the Hawaiian monk seal population on Hawai'i island* (Master's thesis). University of Hawaii. http://hdl.handle.net/10790/7164

Villegas-Amtmann, S., Jeglinski, J. W. E., Costa, D. P., Robinson, P. W., & Trillmich, F. (2013). Individual foraging strategies reveal niche overlap between endangered Galapagos pinnipeds. *PLOS ONE*, *8*(8), e70748. https://doi.org/10.1371/journal.pone.0070748

Wenzel, F., & López Suárez, P. (2012). What is known about cookiecutter shark (*Isistius* spp.) interactions with cetaceans in Cape Verde seas? *Zoologia Caboverdiana*, *3*(2), 57-66. www.scvz.org/zoolcv/vol3no2/Wenzel%20&%20Lopez%20Suarez%20cookiecutter%20sharks.pdf

Widder, E. A. (1998). A predatory use of counterillumination by the squaloid shark, *Isistius brasiliensis*. *Environmental Biology of Fishes*, *53*(3), 267-273. https://doi.org/10.1023/A:1007498915860

Wirsing, A. J., Heithaus, M. R., Frid, A., & Dill, L. M. (2008). Seascapes of fear: Evaluating sublethal predator effects experienced and generated by marine mammals. *Marine Mammal Science*, *24*(1), 1-15. https://doi.org/10.1111/j.1748-7692.2007.00167.x