

Significance of stingrays (Chondrichthyes: Myliobatiformes) as prey of crocodilians (Reptilia: Crocodylia) in non-marine environments

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Stingrays (Myliobatiformes) co-occur with many crocodilians (alligators, caimans and crocodiles) in non-marine environments of tropical and subtropical regions. However, predation by crocodilians on stingrays is rare. Here, we report two predation attempts (one unsuccessful, one unknown) on *Potamotrygon motoro*, by a southern spectacled caiman, *Caiman yacare*, in Iberá Lake, Argentina. Based on these and other observations, we discuss the hypothesis that crocodilian predation is more common on sharks and shark-like batoids than on depressed batoids, due to the fusiform body shape of the former two and the flattened shape of the latter. Within the literature, all recorded predation events on sharks were successful; one out of two observed predation attempts on shark-like batoids resulted in consumption. No successful predation attempts on depressed batoids were recorded, although only one outcome was known out of the seven events observed. The prey/predator size ratio of one of our observed events (0.263) was similar to both the mean of all predatory events (0.312 ± 0.060) and only successful ones (0.298 ± 0.104), indicating that size was less important than prey shape in determining the outcome of the interaction. We reviewed the scientific literature on diet of South American crocodilians to quantify the prevalence of stingrays as prey. No stingray remains were found in any of the 7 species studied, based on 1339 samples. The low success rate of crocodilians preying on depressed batoids, the lack of stingray remains in diet studies of South American crocodilians, and the lack of rake-like marks consistent with caiman bites on living Neotropical freshwater stingrays indicate that predation by crocodilians on stingrays is very low. This should be taken as a working hypothesis in future assessments of predation on obligate freshwater elasmobranchs.

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Literature cited

- Adame, M. F., T. D. Jardine, B. Fry, D. Valdez, G. Lindner, J. Nadji & S. E. Bunn. 2018. Estuarine crocodiles in a tropical coastal floodplain obtain nutrition from terrestrial prey. *PLoS One*, 13: e0197159.
- Antelo, R., J. Ayarzagüena & J. Castroviejo. 2008. Biología del cocodrilo o caimán del Orinoco (*Crocodylus intermedius*) en la Estación Biológica El Frío, Estado Apure (Venezuela). Publicaciones de la Asociación Amigos de Doñana, Sevilla, i-xxxix + 286 pp.
- Barão-Nóbrega, J. A. L., B. Marioni, D. Dutra-Araújo, R. Botero-Arias, A. J. A. Nogueira, W. E. Magnusson & R. Da Silveira. 2016. Nest attendance influences the diet of nesting female spectacled caiman (*Caiman crocodilus*) in Central Amazonia, Brazil. *Herpetological Journal*, 26: 65-71.
- Blanco, R. E., W. W. Jones & J. Villamil. 2015. The 'death roll' of giant fossil crocodyliforms (Crocodylomorpha: Neosuchia): allometric and skull strength analysis. *Historical Biology*, 27: 514-524.
- Borteiro, C., F. Gutiérrez, M. Tedros & F. Kolenc. 2009. Food habits of the broad-snouted caiman (*Caiman latirostris*: Crocodylia, Alligatoridae) in northwestern Uruguay. *Studies on Neotropical Fauna and Environment*, 44: 31-36.
- Carvalho, M. R. 2016. Neotropical stingrays: family Potamotrygonidae. Pp. 619-655 in: P. R. Last, P. R., W. T. White, M. R. Carvalho, B. Séret, M. F. W. Stehmann & G. J. P. Naylor (eds.), *Rays of the world*. Cornell University Press, Ithaca.
- Chapman, D. D. & S. H. Gruber. 2002. A further observation of the prey-handling behavior of the great hammerhead shark, *Sphyrna mokarran*: predation upon the spotted eagle ray, *Aetobatus narinari*. *Bulletin of Marine Science*, 70: 947-952.
- Compagno, L. J. V. & S. F. Cook. 1995. The exploitation and conservation of freshwater elasmobranchs: status of taxa and prospects for the future. *Journal of Aquaculture and Aquatic Sciences*, 7: 62-90.
- Cott, H. B. 1961. Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (*Crocodylus niloticus*) in Uganda and Northern Rhodesia. *Transactions of the Zoological Society of London*, 29: 211-356.
- Cuvier, G. 1807. Sur les différentes espèces de crocodiles vivans et sur leurs caractères distinctifs. *Annales du Muséum National d'Histoire Naturelle*, 10: 8-86.
- Da Silveira, R. & W. E. Magnusson. 1999. Diets of spectacled and black caiman in the Anavilhanas Archipelago, Central Amazonia, Brazil. *Journal of Herpetology*, 33: 181-192.
- Dall, S. R. X., A. M. Bell, D. I. Bolnick & F. L. W. Ratnieks. 2012. An evolutionary ecology of individual differences. *Ecology Letters*, 15: 1189-1198.
- Daudin, F. M. 1802. Histoire naturelle, générale et particulière des reptiles; ouvrage faisant suite à l'Histoire naturelle générale et particulière, composée par Leclerc de Buffon, et rédigée par C. S. Sonnini, membre de plusieurs sociétés savantes. Tome second. L'Imprimerie de F. Dufart, Paris, 432 pp., pls. 16-28.
- Fish, F. E., S. A. Bostic, A. J. Nicastro & J. T. Beneski. 2007. Death roll of the alligator: mechanics of twist feeding in water. *Journal of Experimental Biology*, 210: 2811-2818.
- Frazzetta, T. H. 1988. The mechanics of cutting and the form of shark teeth (Chondrichthyes, Elasmobranchii). *Zoomorphology*, 108: 93-107.
- Freiberg, M. A. 1977. Reptilia Crocodylia o Loricata. Pp. 1-20 in: R. A. Ringuelet (ed.), *Fauna de agua dulce de la República Argentina, Volumen XLII: Reptilia*. Fundación para la Educación, la Ciencia y la Cultura, Buenos Aires.
- Giraud, A. R., A. Bortoluzzi & V. Arzamendia. 2006. Vertebrados tetrápodos de la Reserva y Sitio Ramsar "Esteros del Iberá" (Corrientes, Argentina): análisis de su composición y nuevos registros para especies amenazadas. *Natura Neotropicalis*, 37: 1-20.
- Grant M. I., P. M. Kyne, C. A. Simpfendorfer, W. T. White & A. Chin. 2019. Categorising use patterns of non-marine environments by elasmobranchs and a review of their extinction risk. *Reviews in Fish Biology and Fisheries*, 29: 689-710.
- Graves, M. L. 1819. Sur deux nouvelles espèces de crocodile. *Annales Générales des Sciences Physiques*, 2: 343-353.
- Grigg, G. & D. Kirshner. 2015. *Biology and evolution of crocodylians*. Cornell University Press, Ithaca, 649 pp.
- Heithaus, M. R. 2004. Predator-prey interactions. Pp. 487-521 in: J. C. Carrier, J. A. Musick & M. R. Heithaus (eds.), *Biology of sharks and their relatives*. CRC Press, Boca Raton.
- Hildebrand, S. F. & W. C. Schroeder. 1928. Fishes of Chesapeake Bay. *Bulletin of the Bureau of Fisheries*, 43: 1-366.
- Horna, J. V., R. Cintra & P. Vazquez Ruesta. 2001. Feeding ecology of black caiman *Melanosuchus niger* in a western Amazonian forest: the effects of ontogeny and seasonality on diet composition. *Ecotropica*, 7: 1-11.
- Hyvärinen, P. & A. Huusko. 2006. Diet of brown trout in relation to variation in abundance and size of pelagic fish prey. *Journal of Fish Biology*, 68: 87-98.
- Ingram, T., R. Costa-Pereira & M. S. Araújo. 2018. The dimensionality of individual niche variation. *Ecology*, 99: 536-549.
- Kirchhoff, K. N., T. Hauffe, B. Stelbrink, C. Albrecht & T. Wilke. 2017. Evolutionary bottlenecks in brackish water habitats drive the colonization of fresh water by stingrays. *Journal of Evolutionary Biology*, 30: 1576-1591.
- Kirchhoff, K. N., I. Klingelhöfer, H.-M. Dahse, G. Morlock & T. Wilke. 2014. Maturity-related changes in venom toxicity of the freshwater stingray *Potamotrygon leopoldi*. *Toxicon*, 92: 97-101.
- Kreff, G. 1873. Remarks on Australian crocodiles, and description of a new species. *Proceedings of the Zoological Society of London*, 1873: 334-335.

- Laurenti, J. N. 1768. Specimen medicum, exhibens synopsin reptilium emendatam cum experimentis circa venena et antidota reptilium austriacorum. Joan Thomae, Viennae [= Wien], 214 pp.
- Laverty, T. M. & A. P. Dobson. 2013. Dietary overlap between black caimans and spectacled caimans in the Peruvian Amazon. *Herpetologica*, 69: 91-101.
- Lesueur, C. A. 1824. Description of several species of the Linnaean genus *Raia*, of North America. *Journal of the Academy of Natural Sciences of Philadelphia*, 4 (Part 1): 100-121, pls. 4-6.
- Linnaeus, C. 1758. *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. Tomus I. Editio decima, reformata. Salvius, Holmiae, 824 pp.
- Loboda, T. S. & M. R. Carvalho. 2013. Systematic revision of the *Potamotrygon motoro* (Müller & Henle, 1841) species complex in the Paraná-Paraguay basin, with description of two new ocellated species (Chondrichthyes: Myliobatiformes: Potamotrygonidae). *Neotropical Ichthyology*, 11: 693-737.
- Loiselle, S. A., L. Bracchini, A. Cózar, A. M. Dattilo & C. Rossi. 2005. Extensive spatial analysis of the light environment in a subtropical shallow lake, Laguna Iberá, Argentina. *Hydrobiologia*, 534: 181-191.
- Lucifora, L. O., L. Balboni, P. A. Scarabotti, F. A. Alonso, D. E. Sabadin, A. Solari, F. Vargas, S. A. Barbini, E. Mabrugaña & J. M. Díaz de Astarloa. 2017. Decline or stability of obligate freshwater elasmobranchs following high fishing pressure. *Biological Conservation*, 210: 293-298.
- Lucifora, L. O., M. R. Carvalho, P. M. Kyne & W. T. White. 2015. Freshwater sharks and rays. *Current Biology*, 25: R971-R979.
- Lucifora, L. O., V. B. García, R. C. Menni, A. H. Escalante & N. M. Hozbor. 2009. Effects of body size, age and maturity stage on diet in a large shark: ecological and applied implications. *Ecological Research*, 24: 109-118.
- Magnusson, W. E., E. V. Silva & A. P. Lima. 1987. Diets of Amazonian crocodylians. *Journal of Herpetology*, 21: 85-95.
- Moldovan, P. D., T. M. Laverty, C. J. Emmans & R. C. Stanley. 2016. Diet, gastric parasitism, and injuries of caimans (*Caiman*, *Melanosuchus*, and *Paleosuchus*) in the Peruvian Amazon. *South American Journal of Herpetology*, 11: 176-182.
- Morgan, D. L., R. Somaweera, A. C. Gleiss, S. J. Beatty & J. M. Whitty. 2017. An upstream migration fought with danger: freshwater sawfish fending off sharks and crocodiles. *Ecology*, 98: 1465-1467.
- Müller, J. & F. G. J. Henle. 1838-1841. *Systematische Beschreibung der Plagiostomen*. Veit, Berlin, i-xxii + 200 pp., plus 60 unnumbered plates.
- Nair, T., J. B. Thorbjarnarson, P. Aust & J. Krishnaswamy. 2012. Rigorous gharial population estimation in the Chambal: implications for conservation and management of a globally threatened crocodylian. *Journal of Applied Ecology*, 49: 1046-1054.
- Neiff, J. J. & A. S. G. Poi de Neiff. 2006. Situación ambiental en la ecorregión Iberá. Pp. 177-184 in: A. Brown, U. Martínez Ortiz, M. Acerbi & J. Corcuera (eds.), *La situación ambiental argentina 2005*. Fundación Vida Silvestre Argentina, Buenos Aires.
- Nifong, J. C. & R. H. Lowers. 2017. Reciprocal intraguild predation between *Alligator mississippiensis* (American alligator) and Elasmobranchii in the southeastern United States. *Southeastern Naturalist*, 16: 383-396.
- Nilsson, P. A. & C. Brönmark. 2000. Prey vulnerability to a gape-size limited predator: behavioural and morphological impacts on northern pike piscivory. *Oikos*, 88: 539-546.
- Piña, C. I., P. Siroski, G. Príncipe & M. Simoncini. 2010. Populations status of *Caiman yacare* and *Caiman latirostris* in North Argentina. *Crocodylia*, 1: 1-15.
- Reynolds, N. 2007. Dietary competition between the black caiman (*Melanosuchus niger*) and the spectacled caiman (*Caiman crocodilus*) within the Lago Preto Reserve, Peru. BSc dissertation, University of Kent, Canterbury, 40 pp.
- Rosenblatt, A. E., J. C. Nifong, M. R. Heithaus, F. J. Mazzotti, M. S. Cherkiss, B. M. Jeffery, R. M. Elsey, R. A. Decker, B. R. Silliman, L. J. Guillette Jr., R. H. Lowers & J. C. Larson. 2015. Factors affecting individual foraging specialization and temporal diet stability across the range of a large "generalist" apex predator. *Oecologia*, 178: 5-16.
- Santos, S. A., M. S. Nogueira, M. S. Pinheiro, Z. Campos, W. E. Magnusson & G. M. Mourão. 1996. Diets of *Caiman crocodilus yacare* from different habitats in the Brazilian Pantanal. *Herpetological Journal*, 6: 111-117.
- Schneider, J. G. 1801. *Historiae Amphibiorum naturalis et literariae. Fasciculus secundus continens Crocodilos, Scincos, Chamaesauras, Boas, Pseudoboas, Elapes, Angues, Amphisbaenas et Caeciliae*. Frommann et Wesselhoeft, Jena, i-vi + 364 pp.
- Shine, R. & L.-X. Sun. 2003. Attack strategy of an ambush predator: which attributes of the prey trigger a pit-viper's strike? *Functional Ecology*, 17: 340-348.
- Silva, J. P. C. B. & T. S. Loboda. 2019. *Potamotrygon marquesi*, a new species of neotropical freshwater stingray (Potamotrygonidae) from the Brazilian Amazon Basin. *Journal of Fish Biology*, 95: 594-612.
- Speed, C. W., M. G. Meekan & C. J. A. Bradshaw. 2007. Spot the match - wildlife photo-identification using information theory. *Frontiers in Zoology*, 4: 2 (1-11).
- Spix, J. B. de. 1825. *Animalia nova sive species novae lacertarum quas in itinere per Brasiliam annis MDCCCXVII-MDCCCXX jussu et auspiciis Maximiliani Josephi I. Bavariae regis suscepto / collegit et descripsit Dr. J. B. de Spix.. Franc. Seraph. Hübschmanni, Monachii [= Munich], IV-26 pp., 28 pls.*
- Staton, M. A. & J. R. Dixon. 1975. Studies on the dry season biology of *Caiman crocodilus crocodilus* from the Venezuelan Llanos. *Memorias de la Sociedad de Ciencias Naturales La Salle*, 35: 237-266.

- Strong, W. R., F. F. Snelson & S. H. Gruber. 1990. Hammerhead shark predation on stingrays: an observation of prey handling by *Sphyrna mokarran*. *Copeia*, 1990: 836-840.
- Tamarack, J. L. 1993. *Alligator mississippiensis* (American alligator) diet. *Herpetological Review*, 24: 57.
- Thorbjarnarson, J. B. 1989. Ecology of the American crocodile, *Crocodylus acutus*. Pp. 228-259 in: P. Hall (ed.), *Crocodiles: their ecology, management, and conservation*. International Union for Conservation of Nature and Natural Resources, Gland.
- Thorbjarnarson, J. B. 1993. Diet of the spectacled caiman (*Caiman crocodilus*) in the Central Venezuelan Llanos. *Herpetologica*, 49: 108-117.
- Thorson, T. B. 1972. The status of the bull shark, *Carcharhinus leucas*, in the Amazon River. *Copeia*, 1972: 601-605.
- Vincent, S. E., B. R. Moon, R. Shine & A. Herrel. 2006. The functional meaning of "prey size" in water snakes (*Nerodia fasciata*, Colubridae). *Oecologia*, 147: 204-211.
- White, W. T. & E. Sommerville. 2010. Elasmobranchs of tropical marine ecosystems. Pp. 159-239 in: J. C. Carrier, J. A. Musick & M. R. Heithaus (eds.), *Biology of sharks and their relatives II: biodiversity, adaptive physiology, and conservation*. CRC Press, Boca Raton.
- Whitfield, A. K. & S. J. M. Blaber. 1979. Predation on striped mullet (*Mugil cephalus*) by *Crocodylus niloticus* at St. Lucia, South Africa. *Copeia*, 1979: 266-269.

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