CAMERA TRAP FOOTAGE OF ISLAND-ENDEMIC RINGTAIL CONSUMING NEUROTOXIC PORCUPINEFISH

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Source: The Southwestern Naturalist, 69(4) : 1-7

Published By: Southwestern Association of Naturalists

URL: https://doi.org/10.1894/0038-4909-69.4.8

Zuercher, M. E., Tzintzun Sánchez, C. L., Paredes de los Rios, F., Shier, D. M., & Grether, G. F. (2025). Camera trap footage of island-endemic ringtail consuming neurotoxic porcupinefish. *The Southwestern Naturalist*.

Notes

Camera Trap Footage of Island-Endemic Ringtail Consuming Neurotoxic Porcupinefish

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Keywords: trail camera, diet, scavenging, tetrodotoxin, Procyonidae, cacomixtle

The Southwestern Naturalist

ABSTRACT—The diets of ringtails (*Bassariscus astutus*) vary seasonally and vary widely across their extensive range. While studying an insular, endemic ringtail subspecies (*B. a. saxicola*) in Mexico, one of our camera traps recorded a ringtail consuming a porcupinefish (*Diodon holocanthus*). Fish have not been described in the diet of any other ringtail population. Our discovery was surprising, considering that porcupinefish contain a potent neurotoxin (tetrodotoxin) in their spines and some organs. To our knowledge, no mammal has evolved tetrodotoxin resistance. Further research is needed to determine whether this insular ringtail lineage evolved tetrodotoxin resistance for exploiting a novel protein source found on the islands.

RESUMEN—La dieta del cacomixtle norteño (*Bassariscus astutus*) varía estacionalmente y a lo largo de su extensa distribución. Durante el estudio de la subespecie insular y endémica del cacomixtle norteño (*B. a. saxicola*) en México, una de nuestras cámaras trampa capturó en video a un cacomixtle consumiendo un pez globo (*Diodon holocanthus*). No se han descrito peces en la dieta de ninguna otra población de la especie. Esta evidencia resulta sorprendente, considerando que los peces globo contienen una potente neurotoxina (tetrodotoxina) en algunos órganos y espinas. Hasta donde tenemos conocimiento, no existe evidencia de resistencia a tetrodotoxina en mamíferos. Se requiere más investigación para determinar si el linaje insular del cacomixtle norteño ha desarrollado resistencia a la toxina, lo que le permitiría aprovechar una nueva fuente de proteína disponible en las islas.

Describing animal diets is critical for understanding species' ecosystem roles (Klare et al., 2011). Mammal diets are typically described from analysis of the hair, tissues, feces, or gut contents. Manual dissection, DNA metabarcoding, and stable isotope analysis are all common methods of quantifying a species' dietary breadth and trophic position (Codron et al., 2007; Klare et al., 2011; Middleton et al., 2021; Monterroso et al., 2019; Mowat et al., 2023). Camera traps—remote cameras that are triggered to capture photos or videos of wildlife—are frequently used to describe other aspects of species' life histories, but also provide unique insights into animal foraging behaviors (Cove et al., 2017; Wagnon & Serfass, 2017). Here we present camera trap documentation of an island-endemic carnivore consuming a neurotoxic fish.

We used Cuddeback E2 and Cuddeback G5017 motion-activated wildlife cameras (Non Typical Inc, Green Bay, WI) to collect occurrence and behavioral data on an endemic subspecies of ringtail (*Bassariscus astutus saxicola*) on Isla Espíritu Santo and Isla Partida in the Gulf of California, Mexico (Fig. 1), from May 2022 through September 2023. The camera traps were baited every 1-4 months with 142 g strawberry preserves and 57-85 g canned tuna.

The Spanish name for the ringtail is the "cacomixtle" and this subspecies, the Espíritu Santo Island ringtail, is known locally as the "babisuri." This region experiences high precipitation during the summer rainy season (July through October), followed by low precipitation during the winter rainy season (November through February), then minimal precipitation during the dry season (March through June) (Sansores Sánchez, 2016).

Ringtail diets vary widely by season and site across their extensive range. Previous analyses of ringtail feces and gut contents show that their diets are primarily composed of fruits and other plant parts, insects, arthropods, birds, small mammals, amphibians, and reptiles (Ackerson & Harveson, 2006; Alexander et al., 1994; Brody & Koch, 1983; Harrison, 2012; Poglayen-Neuwall & Toweill, 1988; Rodríguez-Estrella et al., 2000; Taylor, 1954). However, they have also been shown to opportunistically consume carrion and anthropogenic food sources, including trash (Castellanos Morales, 2006; Rodríguez-Estrella et al., 2000; Taylor,

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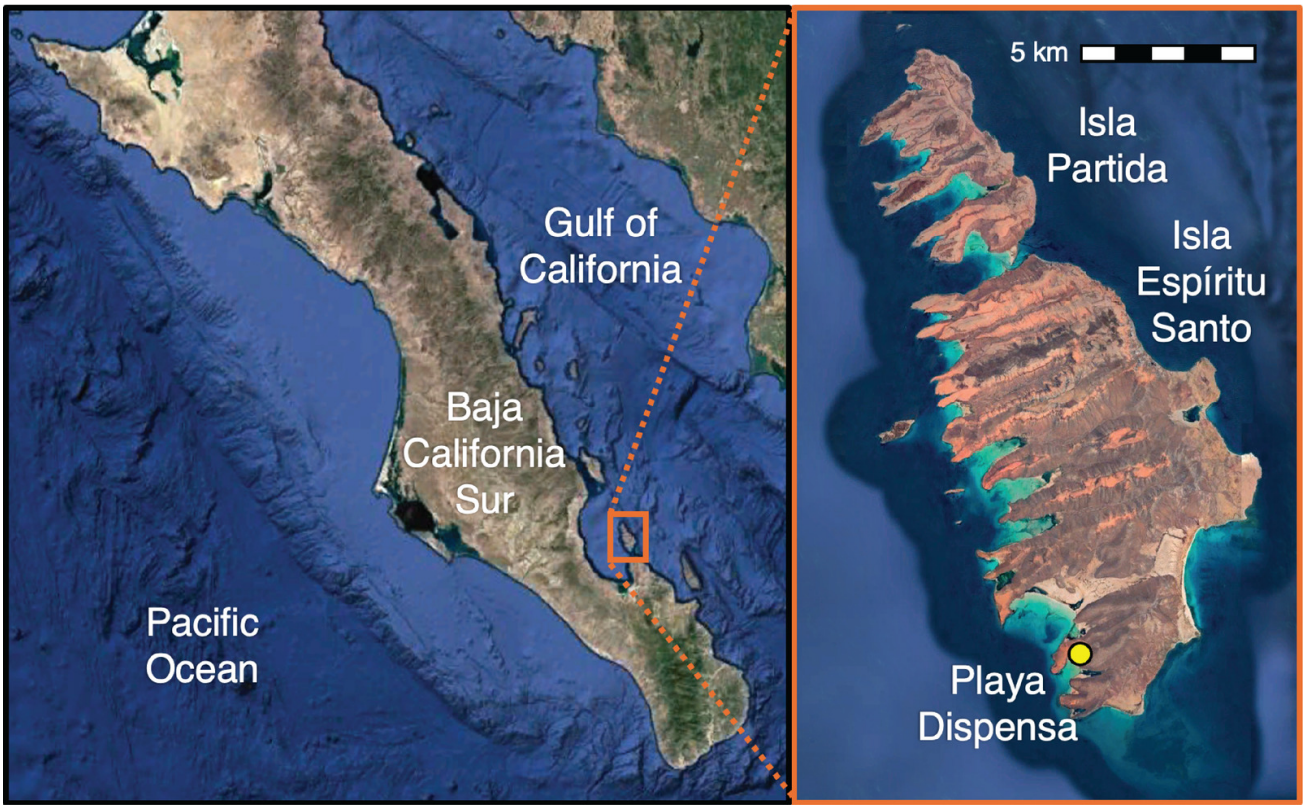

FIG. 1. The study location, the Espíritu Santo archipelago, is magnified from a satellite map of Baja California Sur, Mexico. The site of the camera on the northern edge of Playa Dispensa is noted by a circle. Satellite imagery credit: Google Earth Pro 7.3.6.9796.

1954). One study of ringtail diets on Isla San José, a neighboring island to the Espíritu Santo Archipelago, demonstrated that the insular ringtail population consumed more reptiles and invertebrates than reported in other studies (Rodríguez-Estrella et al., 2000). On Isla Espíritu Santo, two studies have documented the presence of fish bones and scales in ringtail feces (Calderón Vega, 2002; Sansores Sánchez, 2016). The fish species were unidentified, and it is unknown if the fish were hunted, scavenged, or anthropogenically sourced. One study identified fish scales in only two of 167 scat samples, one during the dry season and one during the summer rainy season (Sansores Sánchez, 2016). Another study identified fish scales in 20 of 974 scat and latrine samples, though the fish scales were only found in scats from January through May (Calderón Vega, 2002). Despite the breadth of the ringtail diet and the consumption of fish by other procyonids (Rulison et al., 2012), no studies have reported fish being part of the diet of any other ringtail populations.

We recorded footage of a ringtail consuming a recently deceased porcupinefish, likely *Diodon holocanthus* (Fig. 2a-e, Supplementary Video 1). The camera was located at the northern end of Playa Dispensa on Isla Espíritu Santo, approximately 10 m from the shoreline. The observation was recorded during the winter rainy season on 15 January 2023 from 0515-0518 h. On that day, the sun rose at 0706 h and high and low tides were at approximately 0158 h and 1100 h, respectively. The ringtail arrived at the camera carrying the porcupinefish, which it had presumably scavenged along the shore. We often found deceased fish, including porcupinefish, along the shore as the tide receded in the morning. Fish have likely not been documented in ringtail diets elsewhere because most ringtails occur in desert, oak woodland, and forest regions without water bodies nearby. On the Espíritu Santo archipelago, porcupinefish regularly wash up along the shoreline and ringtails are opportunistic scavengers.

It was surprising to observe a ringtail eating this particular fish species because porcupinefish contain tetrodotoxin (TTX), a powerful neurotoxin, in their skin and some internal organs (Bane et al., 2014). Although ringtails were observed at the same camera trap the next night (Fig. 2f) and for several more weeks, we were unable to identify them individually, so we could not determine whether the ringtail subsequently survived or died from TTX poisoning. If the ringtail survived after consuming porcupinefish, there are three possible scenarios: 1) the porcupinefish did not contain a substantial TTX concentration, 2) the ringtail was able to avoid porcupinefish organs that contain TTX, or 3) island ringtails have evolved TTX resistance. Porcupinefish accumulate TTX by consuming toxic gastropods and echinoderms (Noguchi et al., 2006), and thus their toxicity likely varies with diet. Furthermore, porcupinefish muscle fibers are more sensitive to TTX than those of other TTX-sequestering species (Kidokoro et al., 1974), which suggests that their capacity to accumulate TTX is limited. Still, even a low concentration of TTX would kill most consumers (Lago et al., 2015).

Perhaps ringtails have evolved the ability to avoid consuming parts of porcupinefish that contain TTX. In our

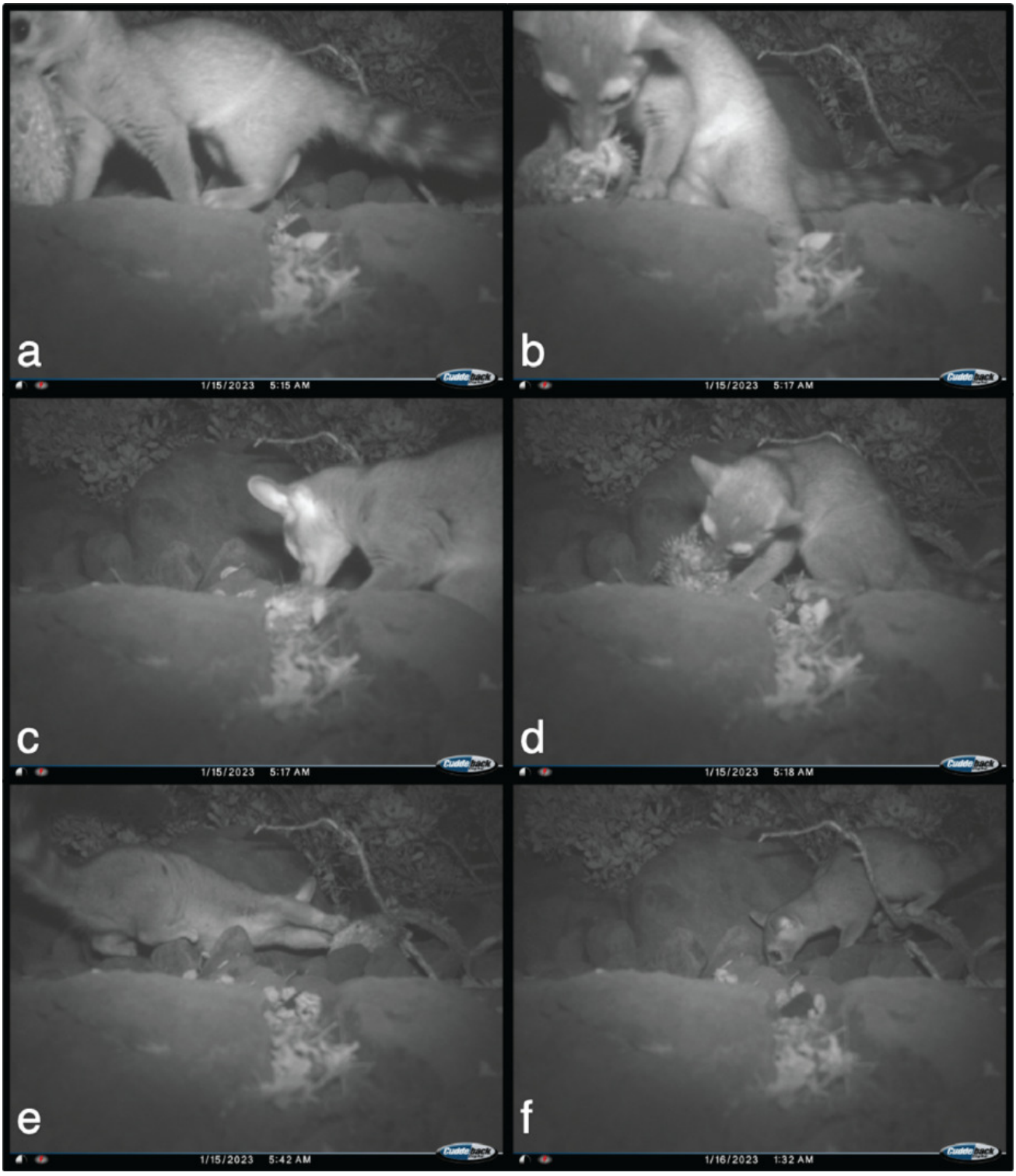

FIG. 2. Five camera trap photos show a ringtail (*Bassariscus astutus saxicola*) consuming a recently deceased porcupinefish (likely *Diodon holocanthus*) near a beach on Isla Espíritu Santo in the Gulf of California (a-e) and one photo shows a ringtail visit the same location twenty hours later (f). A compilation of camera trap videos is available as supplementary material (Supplementary Video 1).

footage, the ringtail appeared to rip into the fish via its tail, avoiding the spines (Supplementary Video 1). Porcupinefish spines, in addition to the liver and ovaries, maintain the high TTX concentrations while muscle tissues contain negligible TTX (Bane et al., 2014; Chen & Chou, 1998; Noguchi et al., 2006). This method of consuming the fish while avoiding its spines could be an adaptive behavior that allows the ringtail to exploit a predictable, high-protein food source on islands. Similarly, several human cultures have developed porcupinefish cooking techniques to safely consume the fish without risking toxin exposure (Hajeb et al., 2012).

Alternatively, island ringtails may have evolved TTX resistance. Resistance to TTX has evolved multiple times in

various predator species, most notably garter snakes (Brodie & Brodie, 1990), but has never been confirmed in mammals (van Thiel et al., 2022). Other carnivorans have evolved resistance to numerous other toxins prevalent in snakes and scorpions, including neurotoxins (van Thiel et al., 2022). It is believed that *Bassariscus astutus* diverged from its sister species *Bassariscus sumichrasti* approximately 10 million years ago (Koepfli et al., 2007), though it is unknown how long the island ringtails have been genetically isolated from mainland ringtails. If island ringtails have been isolated from mainland ringtails since the formation of the Gulf of California, approximately 5-10 million years ago, they may have evolved TTX resistance to take advantage of a more prevalent resource. However, it is also possible that humans introduced ringtails to the islands or enabled their migration, thereby facilitating gene flow between island and mainland ringtails. It is possible that mainland ringtails possess toxin resistance because they are known to consume venomous and chemically defended arthropods such as scorpions and wasps (Harrison, 2012). In various parts of their range, mainland ringtails may also consume prey that contain TTX (e.g., newts). From our single observation, we have no data on the consumption rates of ringtails on porcupinefish, and we have only qualitative data on the availability of porcupinefish on the shoreline. While conclusive evidence is presently lacking, the evolution of TTX resistance is one of several possibilities that may explain our observation. Further investigation into whether island ringtails have TTX resistance and, if so, how recently it evolved may be of great interest from ecological, evolutionary, and biomedical perspectives.

Consuming fish could have implications for ringtail health or other aspects of their feeding ecology; for example, ringtails may be more active on the coastlines when tides recede, thus altering their spatiotemporal activity patterns. Evidence suggests that fish are not a significant component of ringtail diets during most of the year, but could be an important supplementary food source during seasons when other prey may be less available (Calderón Vega, 2002; Sansores Sánchez, 2016). We conclude that species with broad ranges and omnivorous diets require location-specific dietary studies that account for seasonal variation in resource availability to more wholly understand their ecosystem roles.

We thank R. Medellín and C. Moreno for project feedback and permitting. We thank all Comisión Nacional de Áreas Naturales Protegidas staff and El Duque Adventures staff for their guidance. We thank K. Dial for help with image and video processing. The research that led to this work was supported by the Animal Behavior Society Student Research Grant, the UCLA Latin American Institute Graduate Student Summer Research Grant, the UCLA International Institute Fieldwork Fellowship, the San Diego Zoo Wildlife Alliance, and student research grants from the UCLA Department of Ecology and Evolutionary Biology.

Submitted: April 18, 2025 CDT. Accepted: September 15, 2025 CDT.

References

Ackerson, B. K., & Harveson, L. A. (2006). Characteristics of a ringtail (*Bassariscus astutus*) population in Trans Pecos, Texas. *The Texas Journal of Science*, *58*(2), 169–184.

Alexander, L. F., Verts, B. J., & Farrell, T. P. (1994). Diet of ringtails (*Bassariscus astutus*) in Oregon. *Northwestern Naturalist*, *75*(3), 97–101. https://doi.org/10.2307/3536831

Bane, V., Lehane, M., Dikshit, M., O'Riordan, A., & Furey, A. (2014). Tetrodotoxin: Chemistry, toxicity, source, distribution and detection. *Toxins*, *6*(2), Article 2. https://doi.org/10.3390/toxins6020693

Brodie, E. D., III, & Brodie, E. D., Jr. (1990). Tetrodotoxin resistance in garter snakes: An evolutionary response of predators to dangerous prey. *Evolution*, *44*(3), 651–659. https://doi.org/10.1111/j.1558-5646.1990.tb05945.x

Brody, A. J., & Koch, D. B. (1983). Spring ranges, food habits, and habitat utilization of ringtails in the geysers. *Transactions of the Western Section of the Wildlife Society*, *19*, 67–75.

Calderón Vega, J. I. (2002). *Habitos alimentarios del babisuri* Bassariscus astutus saxicola *(Carnivora: Procyonidae) en la Isla Espíritu Santo, Baja California Sur* [Thesis]. Universidad Nacional Autonóma de México.

Castellanos Morales, G. (2006). *Sobre el ámbito hogareño y los hábitos alimentarios de un carnívoro en un ambiente suburbano: El cacomixtle (*Bassariscus astutus*) en la reserva ecológica "El Pedregal de San Ángel" Ciudiad Universitaria, México, D.F.* [Thesis]. Universidad Nacional Autonóma de México.

Chen, C.-Y., & Chou, H.-N. (1998). Detection of tetrodotoxin by high performance liquid chromatography in lined-moon shell and puffer fish. *Acta Zoologica Taiwanica*, *9*(1), 41–48.

Codron, D., Codron, J., Lee-Thorp, J. A., Sponheimer, M., de Ruiter, D., & Brink, J. S. (2007). Stable isotope characterization of mammalian predator–prey relationships in a South African savanna. *European Journal of Wildlife Research*, *53*(3), 161–170. https://doi.org/10.1007/s10344-006-0075-x

Cove, M. V., Maurer, A. S., & O'Connell, A. F. (2017). Camera traps reveal an apparent mutualism between a common mesocarnivore and an endangered ungulate. *Mammalian Biology*, *87*, 143–145. https://doi.org/10.1016/j.mambio.2017.08.007

Hajeb, P., Mei, H. C., Noordin, W. N., & Mahyudin, N. A. (2012). Make the deadly yellow puffer fish a safe food to eat. *Journal of Food Agriculture and Environment*, *10*(3–4), 72–77.

Harrison, R. L. (2012). Ringtail (*Bassariscus astutus*) ecology and behavior in central New Mexico, USA. *Western North American Naturalist*, *72*(4), 495–506. https://doi.org/10.3398/064.072.0407

Kidokoro, Y., Grinnell, A. D., & Eaton, D. C. (1974). Tetrodotoxin sensitivity of muscle action potentials in pufferfishes and related fishes. *Journal of Comparative Physiology*, *89*(1), 59–72. https://doi.org/10.1007/BF00696163

Klare, U., Kamler, J. F., & Macdonald, D. W. (2011). A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review*, *41*(4), 294–312. https://doi.org/10.1111/j.1365-2907.2011.00183.x

Koepfli, K.-P., Gompper, M. E., Eizirik, E., Ho, C.-C., Linden, L., Maldonado, J. E., & Wayne, R. K. (2007). Phylogeny of the *Procyonidae* (Mammalia: Carnivora): Molecules, morphology and the Great American Interchange. *Molecular Phylogenetics and Evolution*, *43*, 1076–1095. https://doi.org/10.1016/j.ympev.2006.10.003

Lago, J., Rodríguez, L. P., Blanco, L., Vieites, J. M., & Cabado, A. G. (2015). Tetrodotoxin, an extremely potent marine neurotoxin: Distribution, toxicity, origin and therapeutical Uses. *Marine Drugs*, *13*(10), Article 10. https://doi.org/10.3390/md13106384

Middleton, O., Svensson, H., Scharlemann, J. P. W., Faurby, S., & Sandom, C. (2021). CarniDIET 1.0: A database of terrestrial carnivorous mammal diets. *Global Ecology and Biogeography*, *30*(6), 1175–1182. https://doi.org/10.1111/geb.13296

Monterroso, P., Godinho, R., Oliveira, T., Ferreras, P., Kelly, M. J., Morin, D. J., Waits, L. P., Alves, P. C., & Mills, L. S. (2019). Feeding ecological knowledge: The underutilised power of faecal DNA approaches for carnivore diet analysis. *Mammal Review*, *49*(2), 97–112. https://doi.org/10.1111/mam.12144

Mowat, G., Heard, D. C., & Curtis, P. J. (2023). Combining stable isotope ratios with elemental concentrations to improve the estimation of terrestrial carnivore diets. *Global Ecology and Conservation*, *45*, e02507. https://doi.org/10.1016/j.gecco.2023.e02507

Noguchi, T., Arakawa, O., & Takatani, T. (2006). Toxicity of pufferfish *Takifugu rubripes* cultured in netcages at sea or aquaria on land. *Comparative Biochemistry and Physiology Part D: Genomics and Proteomics*, *1*(1), 153–157. https://doi.org/10.1016/j.cbd.2005.11.003

Poglayen-Neuwall, I., & Toweill, D. E. (1988). *Bassariscus astutus*. *Mammalian Species*, *327*, 1–8. https://doi.org/10.2307/3504321

Rodríguez-Estrella, R., Moreno, A. R., & Tam, K. G. (2000). Spring diet of the endemic ring-tailed cat (*Bassariscus astutus insulicola*) population on an island in the Gulf of California, Mexico. *Journal of Arid Environments*, *44*(2), 241–246. https://doi.org/10.1006/jare.1999.0579

Rulison, E. L., Luiselli, L., & Burke, R. L. (2012). Relative impacts of habitat and geography on raccoon diets. *The American Midland Naturalist*, *168*(2), 231–246. https://doi.org/10.1674/0003-0031-168.2.231

Sansores Sánchez, R. E. (2016). *Influencia de los recursos antropogénicos en la abundancia y dieta del babisuri (*Bassariscus astutus saxicola *Merriam, 1897) en el complejo insular Espíritu Santo, B.C.S., México* [Thesis]. Centro de Investigaciones Biológicas del Noroeste S. C.

Taylor, W. P. (1954). Food Habits and Notes on Life History of the Ring-Tailed Cat in Texas. *Journal of Mammalogy*, *35*(1), 55–63. https://doi.org/10.2307/1376073

van Thiel, J., Khan, M. A., Wouters, R. M., Harris, R. J., Casewell, N. R., Fry, B. G., Kini, R. M., Mackessy, S. P., Vonk, F. J., Wüster, W., & Richardson, M. K. (2022). Convergent evolution of toxin resistance in animals. *Biological Reviews*, *97*(5), 1823–1843. https://doi.org/10.1111/brv.12865

Wagnon, C. J., & Serfass, T. L. (2017). Use of camera traps provides insight into the feeding ecology of red foxes (*Vulpes vulpes*). *The Canadian Field-Naturalist*, *131*(1), Article 1. https://doi.org/10.22621/cfn.v131i1.1950

SUPPLEMENTARY MATERIALS

Supplementary Video 1. Compilation of five camera trap videos showing a ringtail (*Bassariscus astutus saxicola*) consuming a porcupinefish (likely *Diodon holocanthus*) on Isla Espíritu Santo in the Gulf of California.

Download: https://swn.scholasticahq.com/article/144855-camera-trap-footage-of-island-endemic-ringtail-consuming-neurotoxic-porcupinefish/attachment/303720.mp4?auth_token=bepeumjHmTpDO11KHVXl