Time to Sound the Alarm on the Silent Threat of Inorganic Pollutants

By Adriana Cortés-Gómez, Camila Miguel, and Marc Girondot

Pollution is considered to be one of the top global threats to sea turtles and has been the focus of growing concern in recent years. Although much attention has been given to ocean plastic pollution and other forms of visible waste, invisible forms of pollution have been growing in scale and can now be found in virtually all of Earth's waters, where they affect the well-being of marine creatures great and small.

One particularly insidious type of contamination is that of heavy metals, such as lead and cadmium; such contamination typically originates from industrial activities. When unnaturally high amounts of such metals enter an environment, they can accumulate in animal tissues and biomagnify as they are passed up the food chain. In many animals as well as in people, even slightly elevated levels of some heavy metals are known to cause cancers, developmental malformations, and numerous pathologies—including reproductive problems and kidney failure. In one well-studied population of killer whales (orcas) in Scotland, researchers observed over many years that the accumulation of such pollutants led to the deaths of several individuals and is now causing many animals to become infertile.

Cadmium in Ridley Turtles from the Mexican Pacific

Heavy metal pollution is specifically implicated as a threat to the health of olive ridley turtles at La Escobilla in Oaxaca, Mexico. This 15-kilometer (9.3-mile) stretch of beach is the site of one of the most remarkable success stories in global sea turtle conservation, and it now sees in excess of one million nesting ridleys annually—more than anywhere else in the world (see *SWOT Report*, vol. XVI, pp. 24–33). On some nights during mass nesting arribadas, miles of shoreline are covered in an unbroken vista of flying sand and heaving shells as turtles lay their eggs. It wasn't always like this at La Escobilla. Nesting had declined significantly following decades of egg and turtle harvest and rebounded only after harvesting was outlawed in the 1990s. Today, with tens of millions of hatchlings emerging each year, La Escobilla is key to the future of this once declining species.

However, research underway since 2012 has revealed shockingly high levels of accumulated cadmium in turtle tissues, a contaminant that may drastically impact both current and future generations of turtles. Samples collected from 46 animals in 2012 showed mean cadmium levels of 150 ppm/wet weight, the highest levels ever reported for a large marine animal. Researchers had hoped this finding was caused by a one-time pollution event, but further sampling showed that by 2019, cadmium had grown to 243 ppm in turtles' kidneys. To put this observation in perspective, levels above 15 ppm in humans can cause chronic problems that, if not treated, can lead to death.

Although there are no such established thresholds in turtles, biomarkers such as oxidative stress, stress proteins, and asymmetry, as well as histopathological studies, indicate that the sampled animals experienced significant health effects. In some cases, cadmium can be implicated as the direct cause of death. Other species sampled near La Escobilla have also been affected; record cadmium levels were found in tissue samples from an adult leatherback, an immature dolphin, and a baby sea lion, urging researchers to sound the alarm and call for immediate actions to reverse this threat.

It has been difficult to identify a source for this contaminant in Pacific Mexico. Cadmium, mercury, and other heavy metals can occur naturally in the environment from erosion, weathering, movement of dust, and volcanic activities. But rapid urban development, increases in fertilizer and pesticide use, mining and smelting, fossil fuel residues, and industrial discharge have drastically raised the amounts of such elements in ecosystems worldwide.

Mining Disaster Continues to Impact Green Turtles in Brazil

In November 2015, a dam collapsed in Minas Gerais, Brazil, releasing an estimated 43 million cubic meters of iron ore tailings into the Doce River in what is considered one of the global mining industry's biggest environmental disasters (see *SWOT Report*, vol. XII, pp. 36–37). The resulting mudflow spread 668 kilometers (415 miles) downstream, killing dozens of people and sweeping away everything in its path before reaching the Atlantic Ocean, where it contaminated coastal areas important for sea turtle nesting and feeding.

Since the disaster, researchers from the Chelonia Mydas Project at the Marcos Daniel Institute have been monitoring the impacted areas and focusing on the health of juvenile green turtles that inhabit the Santa Cruz district in the state of Espírito Santo. That area was most directly affected by the tailing plume. During the two-year period from 2018 to 2020, the health of the turtles there was compared with that of green turtles residing at Coroa Vermelha Island in the state of Bahia, the nearest green turtle feeding area that was not directly impacted by the contaminant plume.

Results showed that the Santa Cruz green turtles suffered from notably worse nutritional conditions, as well as a higher incidence of anemia, immunosuppression, fibropapillomatosis tumors, and ectoparasite load, in addition to possible hepato-renal pathologies. There is strong evidence to show that the pollution caused by the chemical tailings is responsible for the observed health differences, and a high priority is to continue monitoring in order to observe the contamination's longer-term impacts on the animals and to better understand the health impacts they experience.

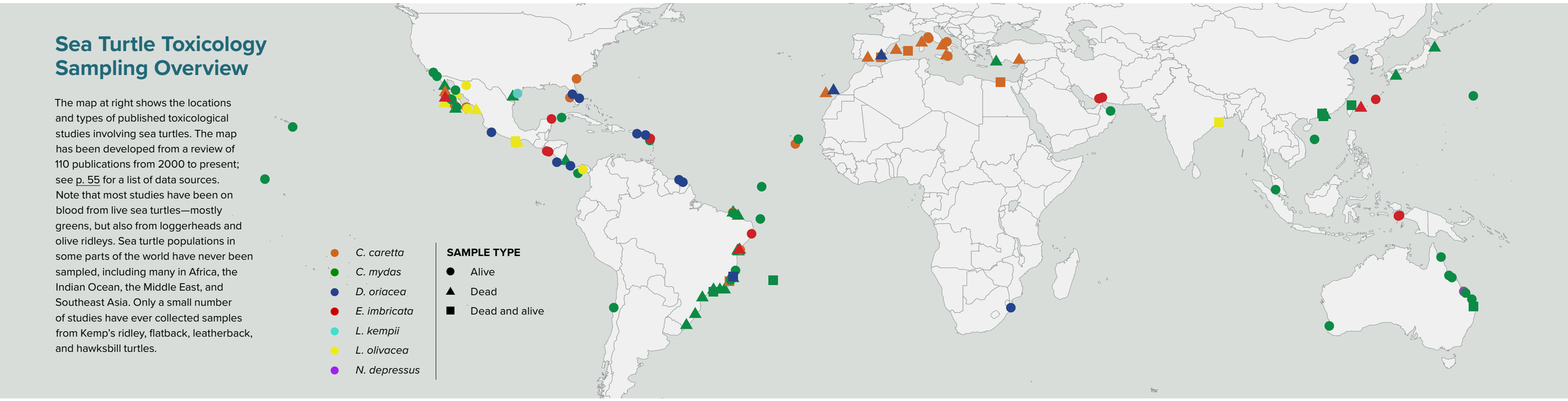
A Desperate Need for More Data

Sea turtles are surprisingly susceptible to ocean-borne pollutants in a variety of natural forms (such as red tides) and manmade forms. Extended exposure to contaminants can compromise turtles' physiology, cause abnormalities in their embryos, impair their reproductive success and immune function, disrupt their endocrine systems, cause them chronic stress, and increase their susceptibility to diseases. Although the impacts of heavy metal exposure on sea turtles are just beginning to be understood, findings from the sea turtle case studies outlined here as well as elsewhere (see *SWOT Report*, vol. XIII, pp. 8–9) suggest that there is much reason for alarm. Because sea turtles are long-lived and slow to mature, it may take years of continuous study before researchers are able to understand the full impacts of such exposure. More and longer-term research is critically needed to comprehend the scale of this problem and to implement solutions. Sea turtles are an excellent flagship species to draw attention to this important issue, which has drastic impacts on countless other species—including humans. It is imperative that researchers worldwide begin at once to conduct more and broader sampling of the tissues of sea turtles and other species and that they pay greater attention to the sources of heavy metal and other contaminants in order to find ways to stop this invisible threat. •

PREVIOUS SPREAD: The Día de los Muertos 2021 arribada at Playa Escobilla, Oaxaca, Mexico (see Editor's Note), photographed as part of a global project led by photographer Tui De Roy for a coffee table book about sea turtles to be published by Princeton University Press in 2024. © Tui De Roy / Roving Tortoise Photos

Sea Turtle Toxicology Sampling Overview

The map at right shows the locations and types of published toxicological studies involving sea turtles. The map has been developed from a review of 110 publications from 2000 to present; see p. 55 for a list of data sources. Note that most studies have been on blood from live sea turtles—mostly greens, but also from loggerheads and olive ridleys. Sea turtle populations in some parts of the world have never been sampled, including many in Africa, the Indian Ocean, the Middle East, and Southeast Asia. Only a small number of studies have ever collected samples from Kemp's ridley, flatback, leatherback, and hawksbill turtles.



Sea Turtle Toxicology Sampling Overview Data Citations

The dataset for the toxins map on pp. 12–13 was created using the data from Cortés-Gómez, Romero, and Girondot (2017). In addition, data from the following publications were added to the original dataset for this map.

Abdallah, M. A. M. 2011. Bioaccumulation of toxic metals in loggerhead turtles from Mediterranean Sea coast, Egypt. In: E. Özhan (ed.), *Proceedings of the 10th International Conference on the Mediterranean Coastal Environment, Rhodes, Greece*.

Aguirre, A. A., G. H. Balazs, B. Zimmerman, and F. D. Galey. 1994. Organic contaminants and trace metals in the tissues of green turtles (*Chelonia mydas*) afflicted with fibropapillomas in the Hawaiian Islands. *Marine Pollution Bulletin* 28 (2):109–114.

Anan, Y., T. Kunito, H. Sakai, and S. Tanabe. 2002. Subcellular distribution of trace elements in the liver of sea turtles. *Marine Pollution Bulletin* 45: 224–229.

Anan, Y., T. Kunito, I. Watanabe, H. Sakai, and S. Tanabe. 2001. Trace element accumulation in hawksbill turtles (*Eretmochelys imbricata*) and green turtles (*Chelonia mydas*) from Yaeyama Islands, Japan. *Environmental Toxicology and Chemistry* 20 (12): 2802–2814.

Andreani, G., M. Santoro, S. Cottignoli, M. Fabbri, et al. 2008. Metal distribution and metallothionein in loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles. *Science of the Total Environment* 390 (1): 287–294.

Aymak, C., A. H. Uçar, and S. Ergene. 2021. Distribution of heavy metals in tissues of stranded loggerhead turtles (*Caretta caretta*) on Kazanlı Beach, Turkey. *North-Western Journal of Zoology* 17 (1): 82–91.

Barbieri, E. 2009. Concentration of heavy metals in tissues of green turtles (*Chelonia mydas*) sampled in the Cananéia Estuary, Brazil. *Brazilian Journal of Oceanography* 57 (3): 243–248.

Bardales, F. A. L., and M. G. Q. Benavides. 2016. Determinación de concentraciones de metales pesados en sangre de hembras anidantes de tortugas carey (*Eretmocheys imbricata*) en la Bahía de Jiquilisco, Departamento de Usulután, El Salvador. Bachelor's thesis, Universidad de El Salvador.

Bezerra, M. F., L. D. Lacerda, B. G. D. Costa, and E. H. S. M. Lima. 2012. Mercury in the sea turtle *Chelonia mydas* (Linnaeus, 1958) from Ceará coast, NE Brazil. *Anais de Academia Brasileira de Ciências* 84 (1): 123–128.

Bezerra, M. F., L. D. Lacerda, E. H. S. M. Lima, and M. T. D. Melo. 2013. Monitoring mercury in green sea turtles using keratinized carapace fragments (scutes). *Marine Pollution Bulletin* 77 (1–2): 424–427.

Bezerra, M. F., L. D. Lacerda, C. E. Rezende, M. A. L. Franco, et al. 2015. Food preferences and Hg distribution in *Chelonia mydas* assessed by stable isotopes. *Environmental Pollution* 206: 236–246.

Camacho, M., J. Orós, and L. D. Boada. 2013. Potential adverse effects of inorganic pollutants on clinical parameters of loggerhead sea turtles (*Caretta caretta*): Results from a nesting colony from Cape Verde, West Africa. *Marine Environmental Research* 92: 15–22.

Cortés-Gómez, A. A., G. Fuentes-Mascorro, and D. Romero. 2014. Metals and metalloids in whole blood and tissues of olive ridley turtles (*Lepidochelys olivacea*) from La Escobilla Beach (Oaxaca, Mexico). *Marine Pollution Bulletin* 89 (1–2): 367–375.

Cortés-Gómez, A. A., P. Morcillo, F. A. Guardiola, C. Espinosa, et al. 2018. Molecular oxidative stress markers in olive ridley turtles (*Lepidochelys olivacea*) and their relation to metal concentrations in wild populations. *Environmental Pollution* 233: 156–167.

Cortés-Gómez, A. A., D. Romero, and M. Girondot. 2017. The current situation of inorganic elements in marine turtles: A general review and meta-analysis. *Environmental Pollution* 229: 567–585.

Cortés-Gómez, A. A., D. Romero, and M. Girondot. 2018. Carapace asymmetry: A possible biomarker for metal accumulation in adult olive ridleys marine turtles? *Marine Pollution Bulletin* 129 (1): 92–101.

Cortés-Gómez, A. A., A. Tvarijonaviciute, M. Girondot, F. Tecles, and D. Romero. 2018. Relationship between plasma biochemistry values and metal concentrations in nesting olive ridley sea turtles. *Environmental Science and Pollution Research* 25: 36671–36679.

Cortés-Gómez, A. A., A. Tvarijonaviciute, M. Teles, R. Cuenca, et al. 2017. p-Nitrophenyl acetate esterase activity and cortisol as biomarkers of metal pollution in blood of olive ridley turtles (*Lepidochelys olivacea*). *Archives of Environmental Contamination and Toxicology* 75(1): 25–36.

Day, R. D., S. J. Christopher, P. R. Becker, and D. W. Whitaker. 2005. Monitoring mercury in the loggerhead sea turtle, *Caretta caretta. Environmental Science and Technology* 39(2): 437–446.

du Preez, M. 2018. Metallic elements in South African sea turtle and crocodile eggs and eggshells. Master's dissertation, North-West University.

Dyc, C., A. Covaci, C. Debier, C. Leroy, et al. 2015. Pollutant exposure in green and hawksbill marine turtles from the Caribbean region. *Regional Studies in Marine Science* 2: 158–170.

Frías-Espericueta, M. G., J. I. Osuna-López, A. Ruiz-Telles, J. M. Quintero-Alvarez, et al. 2006. Heavy metals in the tissues of the sea turtle *Lepidochelys olivacea* from a nesting site of the Northwest Coast of Mexico. *Bulletin of Environmental Contamination and Toxicology* 77: 179–185.

García-Fernández, A. J., P. Gómez-Ramírez, E. Martínez-López, A. Hernández-García, et al. 2009. Heavy metals in tissues from loggerhead turtles (*Caretta caretta*) from the southwestern Mediterranean (Spain). *Ecotoxicology and Environmental Safety* 72 (2): 557–563.

Gardner, S. C., S. L. Fitzgerald, B. A. Vargas, and L. M. Rodríguez. 2006. Heavy metal accumulation in four species of sea turtles from the Baja California Peninsula, Mexico. *Biometals* 19: 91–99.

Guirlet, E., K. Dasb, and M. Girondot. 2008. Maternal transfer of trace elements in leatherback turtles (*Dermochelys coriacea*) of French Guiana. *Aquatic Toxicology* 88: 267–276.

Kampalath, R., S. C. Gardner, L. Méndez-Rodríguez, and J. A. Jay. 2006. Total and methylmercury in three species of sea turtles of Baja California Sur. *Marine Pollution Bulletin* 52 (12): 1784–1832.

Labrada-Martagón, V., P.A.T. Rodríguez, L.C. Méndez-Rodríguez, and T. Zenteno-Savín. 2011. Oxidative stress indicators and chemical contaminants in East Pacific green turtles (*Chelonia mydas*) inhabiting two foraging coastal lagoons in the Baja California Peninsula. *Comparative Biochemistry and Physiology Part C: Toxicology and Pharmacology* 154 (2): 65–75.

Lam, J. C. W., S. Tanabe, S. K. Chan, E. K. W. Yuen, et al. 2004. Trace element residues in tissues of green turtles (*Chelonia mydas*) from South China waters. *Marine Pollution Bulletin* 48(1–2): 174–182.

Ley-Quiñónez, C. P., N. A. Rossi-Lafferriere, T. L. Espinoza-Carreón, C. E. Hart, et al. 2017. Associations between trace elements and clinical health parameters in the North Pacific loggerhead sea turtle (*Caretta caretta*) from Baja California Sur, Mexico. *Environmental Science and Pollution Research* 24 (10): 9530–9537.

Ley-Quiñónez, C. P, A. A. Zavala-Norzagaray, T. L. Espinosa-Carreón, H. Peckham, et al. 2011. Baseline heavy metals and metalloid values in blood of loggerhead turtles (*Caretta caretta*) from Baja California Sur, Mexico. *Marine Pollution Bulletin* 62 (9): 1979–1983.

Ley-Quiñónez, C. P., A. A. Zavala-Norzagaray, J. G. Rendón-Maldonado, T. L. Espinosa-Carreón, et al. 2013. Selected heavy metals and selenium in the blood of black sea turtle (*Chelonia mydas agasiizzi*) from Sonora, Mexico. *Bulletin of Environmental Contamination and Toxicology* 91 (6): 645–651.

Macêdo, G. R., T. B. Tarantino, I. S. Barbosa, T. T. Pires, et al. 2015. Trace elements distribution in hawksbill turtle (*Eretmochelys imbricata*) and green turtle (*Chelonia mydas*) tissues on the northern coast of Bahía, Brazil. *Marine Pollution Bulletin* 94 (1–2): 284–289.

Páez-Osuna, F., M. F. Calderón-Campuzano, M. F. Soto-Jiménez, and J. Ruelas-Inzunza. 2010. Lead in blood and eggs of the sea turtle, *Lepidochelys olivacea*, from the eastern Pacific: concentration, isotopic composition and maternal transfer. *Marine Pollution Bulletin* 60 (3): 433–439.

Páez-Osuna, F., M. F. Calderón-Campuzano, M. F. Soto-Jiménez, and J. Ruelas-Inzunza. 2010. Trace metals (Cd, Cu, Ni, and Zn) in blood and eggs of the sea turtle *Lepidochelys olivacea* from a nesting colony of Oaxaca, Mexico. *Archives of Environmental Contamination and Toxicology* 59 (4): 632–641.

Páez-Osuna, F., M. F. Calderón-Campuzano, M. F. Soto-Jiménez, and J. Ruelas-Inzunza. 2011. Mercury in blood and eggs of the sea turtle *Lepidochelys olivacea* from a nesting colony in Oaxaca, Mexico. *Marine Pollution Bulletin* 62 (6): 1320–1323.

Pena, F. L. 2018. Quantifying pre-industrial to mid–late 20th century anthropogenic lead, mercury and cadmium pollution in Caribbean marine environments using skeletonized sea turtle remains. Master's thesis, Missippi State University.

Prioste, F. E. S. 2016. Detection and quantification of selected inorganic chemical elements in blood and tissue samples from green turtles—*Chelonia mydas* (Linnaeus, 1758)—from the Brazilian coast: Possible correlation with fibropapillomatosis. Doctoral thesis, Universidade de São Paulo.

Prioste, F. E. S., V. C. O. Souza, M. R. Queiroz, R. G. Chiacchio, et al. 2015. Chemical element concentrations in the blood of green turtles (*Chelonia mydas*) captured at Fernando de Noronha Marine National Park, Brazil. *Journal of Environmental and Analytical Toxicology* 5: 1–5.

Rodríguez, C. A. B. 2017. Mercúrio e metil mercúrio em carapaça da tartaruga marinha *Caretta caretta* (Linnaeus, 1758), no nordeste do Brasil, e seu uso potencial em monitoramento ambiental. Dissertation, Universidade Federal do Ceará.

Rodríguez, C. A. B., M. F. Bezerra, and L. D. Lacerda. 2018. Use of carapace for monitoring mercury in two species of sea turtles in northeast of Brazil. *Arquivos de Ciências do Mar* 51 (1): 93–100.

Roe, J. H., N. S. Sill, M. R. Columbia, et al. 2011. Trace metals in eggs and hatchlings of pacific leatherback turtles (*Dermochelys coriacea*) nesting at Playa Grande, Costa Rica. *Chelonian Conservation and Biology* 10 (1): 3–9.

Ross, D. A., H. M. Guzmán, C. Potvin, and V. J. van Hinsberg. 2017. A review of toxic metal contamination in marine turtle tissues and its implications for human health. *Regional Studies in Marine Science* 15: 1–9.

Ross, D. A., H. M. Guzmán, V. J. van Hinsberg, and C. Potvin. 2016. Metal contents of marine turtle eggs (*Chelonia mydas*; *Lepidochelys olivacea*) from the tropical eastern Pacific and the implications for human health. *Journal of Environmental Science and Health*, Part B 51 (10): 1–13.

Sakai, H., K. Saeki, H. Ichihashi, H. Suganuma, et al. 2000. Species-specific distribution of heavy metals in tissues and organs of loggerhead turtle (*Caretta caretta*) and green turtle (*Chelonia mydas*) from Japanese Coastal Waters. *Marine Pollution Bulletin* 40 (8): 701–709.

Silva, C. C., R. D. Klein, I. F. Barcarolli, and A. Bianchini. 2016. Metal contamination as a possible etiology of fibropapillomatosis in juvenile female green sea turtles *Chelonia mydas* from the southern Atlantic Ocean. *Aquatic Toxicology* 170: 42–51.

Silva, C. C., A. S. Varela, I. B. Barcarolli, and A. Bianchini. 2014. Concentrations and distributions of metals in tissues of stranded green sea turtles (*Chelonia mydas*) from the southern Atlantic coast of Brazil. *Science of the Total Environment* 466–467: 109–118.

Silva, L. M. 2011. Metais pesados em tecidos de *Chelonia mydas* encalhadas no litoral do Rio Grande do Sul, Brasil. Bachelor's thesis, Universidade Federal do Rio Grande do Sul.

Simões, T. N. 2016. Metais pesados em sedimento, cascas de ovos e sangue de tartarugas marinhas da espécie *Eretmochelys imbricata* (Linnaeus, 1766). Dissertation, Universidade Federal de Pernambuco.

Storelli, M. M., A. Storelli, R. D'Addabbo, C. Marano, et al. 2005. Trace elements in loggerhead turtles (*Caretta caretta*) from the eastern Mediterranean Sea: Overview and evaluation. *Environmental Pollution* 135 (1): 163–70.

Talavera-Saenz, A., S. C. Gardner, R. R. Rodríguez, and B. A. Vargas. 2007. Metal profiles used as environmental markers of green turtle (*Chelonia mydas*) foraging resources. *Science of the Total Environment* 373: 94–102.

Tauer, A. M., M. J. Liles, S. Chavarría, M. Valle, et al. 2017. Hematology, biochemistry, and toxicology of wild hawksbill turtles (*Eretmochelys imbricata*) nesting in mangrove estuaries in the eastern Pacific Ocean. BioRxiv: 238956.

Vazquez, G. F., M. C. Reyes, G. Fernández, J. E. C. Aguayo, and V. K. Sharma. 1997. Contamination in marine turtle (*Dermochelys coriacea*) egg shells of Playón de Mexiquillo, Michoacán, Mexico. *Bulletin of Environmental Contamination and Toxicology* 58: 326–333.

Zavala-Norzagaray, A. A., C. P. Ley-Quiñónez, T. L. Espinosa-Carreón, A. Canizalez, et al. 2014. Trace elements in blood of sea turtles *Lepidochelys olivacea* in the Gulf of California, Mexico. *Bulletin of Environmental Contamination and Toxicology* 93: 536–541.