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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641035, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: Common Silverline *Spindasis vulcanus vulcanus* in poster colours adapted from photograph by Kalpesh Tayade. © Pooja R. Patil.

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SHORT COMMUNICATION

Mercury in tuna from the western equatorial Atlantic Ocean and health risk assessment

Ana Paula Madeira Di Beneditto [1]*, Inácio Abreu Pestana [2]*, Igor David da Costa [3], Marcelo Gomes de Almeida [4], Braulio Cherene Vaz de Oliveira [5] & Carlos Eduardo de Rezende [6]

[1,2,4,5,6] Universidade Estadual do Norte Fluminense Darcy Ribeiro, CBB, Laboratório de Ciências Ambientais, Av. Alberto Lamego 2000, Campos dos Goytacazes, RJ, 28013-602, Brazil.
[3] Universidade Federal Fluminense, Instituto do Noroeste Fluminense de Educação Superior, Av. João Jasbick, s/nº, Santo Antônio de Pádua, RJ, 28470-000, Brazil.
* These authors contributed equally to this work.
[1] anadibeneditto@gmail.com (corresponding author), [2] inacio@uenf.br, [3] igorbiologia@yahoo.com.br, [4] marcelogaa@yahoo.com.br, [5] brauliocherene@gmail.com, [6] crezende@uenf.br

Abstract: This study analyses the mercury (Hg) concentration in the meat of *Thunnus albacares* and *Thunnus obesus* caught from the western equatorial Atlantic Ocean. The objective was to estimate the Hg intake via tuna ingestion and presents the possible health risk assessment. For *T. albacares* and *T. obesus*, the median concentration was 212 ng·g^{-1} and 475.1 ng·g^{-1} wet weight, respectively. The Hg concentrations were below the maximum tolerable limit established by international and Brazilian regulations for fishery products. The consumption would pose a risk for human populations that ingest more than 80 g·day^{-1}. Regular monitoring of both human consumption rates and Hg levels in fish are recommended.

Keywords: Hg, human health, *Thunnus albacares*, *Thunnus obesus*.

Portuguese: Este estudo analisa a concentração de mercúrio (Hg) na carne de *Thunnus albacares* e *T. obesus* capturados em pescarias no Oceano Atlântico equatorial ocidental, estima a ingestão de Hg via ingestão de atum e apresenta a avaliação de risco à saúde. Para *T. albacares* e *T. obesus*, a mediana das concentrações foi 212 ng·g^{-1} e 475,1 ng·g^{-1} peso úmido, respectivamente. As concentrações de Hg ficaram abaixo do limite máximo tolerável estabelecido pelas regulamentações internacionais e brasileiras. O consumo representaria um risco para as populações humanas que ingerem mais de 80 g·dia-1.

In Brazil, the tuna fishery targeted mainly the yellowfin tuna *T. albacares* Bonnaterre, 1788) and the bigeye tuna *T. obesus* (Lowe, 1839), which are among the main tuna species caught worldwide (Guillotreau et al. 2017; Rodrigues et al. 2020). Tuna species are large and long-lived predatory fishes with wide distribution, becoming good bio monitors of contaminants, such as mercury (Hg) (Ferriss & Essington 2011; Jinadasa et al. 2019; Tseng et al. 2021). In the marine environment, >95% of the Hg in the meat of predatory fish is methylmercury, a potent neurotoxin (Lescord et al. 2018). This study analyzes the Hg concentration in tuna meat from western equatorial Atlantic Ocean, and estimates the Hg intake via tuna ingestion.

Tuna sampling was conducted in 2019 and 2020 at the fish market named *Mercado Municipal Central Leste*, located in São Paulo State, southeastern Brazil. The fish

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Table 1. Sample size, fork length, weight and Hg concentration (wet and dry basis) in the muscle of *Thunnus albacares* and *Thunnus obesus* from the western equatorial Atlantic Ocean. The values are shown as the median ± interquartile range (minimum and maximum). Lowercase letters compare the variables between sampling years for the same species. Uppercase letters compare the variables between species and consider the data from both samplings.

Species	*T. albacares*		*T. obesus*	
Year	2019 (n = 32)	2020 (n = 18)	2019 (n = 26)	2020(n = 6)
Fork length (cm)	123.5 ± 22.3^a (97–167)	139.5 ± 9.3^b (129–176)	104 ± 38^a (91–181)	104.5 ± 5.3^a (101–111)
Weight (kg)	25.5 ± 19.6^a (12.6–65.2)	39.5 ± 9.5^b (29.3–76.1)	18.2 ± 20.7^a (11.9–72.3)	18.5 ± 1.5^a (16.9–20.4)
Hg (ng·g^{-1} wet weight)	168.3 ± 80.2^a (82.1–455.1)	309.5 ± 98.8^b (103.2–570.3)	499 ± 195.9^a (204.1–1347.5)	457.7 ± 51.9^a (387.7–475.1)
Hg (ng·g^{-1} dry weight)	636.6 ± 303.4^a (310.6–1722)	1170.9 ± 373.9^b (390.5–2157.6)	1840.5 ± 722.5^a (752.8–4970.4)	1688.5 ± 191.4^a (1430–1752.5)
Log [Hg (ng·g^{-1} wet weight)]·kg^{-1}	6.7 ± 2.5^a (3.4–11.9)	7.2 ± 2.7^b (3.5–19.1)	26.7 ± 8.4^a (4.9–49.7)	23.4 ± 2.8^a (20.2–28.1)
All samples	*T. albacares*		*T. obesus*	
Fork length (cm)	132.5 ± 23.5^A		104 ± 20^B	
Weight (kg)	32.4 ± 20^A		18.2 ± 9.1^B	
Hg (ng·g^{-1} wet weight)	212 ± 149.6^B		475.1 ± 107.8^A	
Hg (ng·g^{-1} dry weight)	802 ± 565.9^B		1752.5 ± 397.7^A	

sampled at the market were caught from commercial fishery done by the fishing fleet of *Areia Branca* Harbor. This fishing fleet operates in the western equatorial Atlantic Ocean (off northern Brazil), in the vicinity of one of the oceanic buoys of PIRATA Program ("Pilot Moored Array in the Tropical Atlantic"). The fishing area is located in waters that are 4,000 m deep, at 0°, 35 °W, and 600 km offshore (international waters). The sample size for *T. albacares* was 32 individuals in 2019, and 18 individuals in 2020; and for *T. obesus* it was 26 and six individuals in 2019 and 2020, respectively. Sample of meat from the fish belly (5 g of wet weight) was removed from each individual at the fish market. The samples were brought to the laboratory and kept frozen (-20 °C) in dry sterile vials, freeze-dried and homogenized with a mortar and pestle (Table 1). Mercury determinations followed Bastos et al. (1998) and were conducted with an ICP-OES (Varian, Liberty II Model 720 ES, Australia) with a cold vapor accessory (VGA-77). The recovery values for the certified reference material (DORM-4) ranged 85–95 %. The coefficients of variation of the triplicate analyses were <10%. The results were calculated as ng·g^{-1} dry weight and converted to a wet weight basis. For *T. albacares*, the water loss after freeze-drying was 74±1%, and for *T. obesus,* it was 73±1%.

The maximum permissible limit for Hg in predatory fishes established by the World Health Organization —WHO (FAO/WHO 1991) and Brazilian Government (ANVISA 2021), is 1 mg·kg^{-1} (or 1,000 ng·g^{-1}) wet weight. The estimated daily intake proposed in Caldas et al. (2016) was used for the intake analysis: EDI = C·IR/BW, where EDI is the estimated dietary intake of Hg (µg·day^{-1}·kg^{-1}), C is the Hg concentration in the fish meat (µg·g^{-1} wet weight), IR is the intake rate in Brazil (27 g·day^{-1}; Barone et al. 2017), and BW is the body weight (70 kg for a Brazilian adult). The provisional upper tolerable weekly intakes - PTWI limit for Hg is 1.6 µg·week^{-1}·kg^{-1} or 0.57 µg·day^{-1}·kg^{-1} (FAO/WHO 2003). We calculated the IR of tuna meat that would be necessary to reach the intake limit for Hg. We considered the median Hg concentration as a fixed variable and applied the EDI formula to estimate the IR needed to reach the intake limits established by the FAO/WHO (2003).

ANOVAs (aov function, base package; R Core Team 2022) were used to test the differences in Hg concentrations among the species and sampling years. Estimations of Hg intake due to tuna consumption by humans were conducted by Monte Carlo Method (Khitalishvili 2016) to incorporate the variability of each variable (Hg concentration in fish, human intake rate and body weight) in the final results.

Total Hg concentration varied between sampling years for *T. albacares*, and between the two tuna species (higher Hg concentrations in *T. obesus*) (Table 1). *T. albacares* sampled in 2020 was larger and heavier than in 2019, and the size difference was consistent with the Hg concentrations, reflecting Hg bioaccumulation during the fish growth (Lacerda et al. 2017). The enrichment of more bioavailable organic Hg complexes in deep waters, such as methylmercury, and the tuna foraging depths explain the interspecific differences in Hg concentrations (Choy et al. 2009; Ferriss & Essington

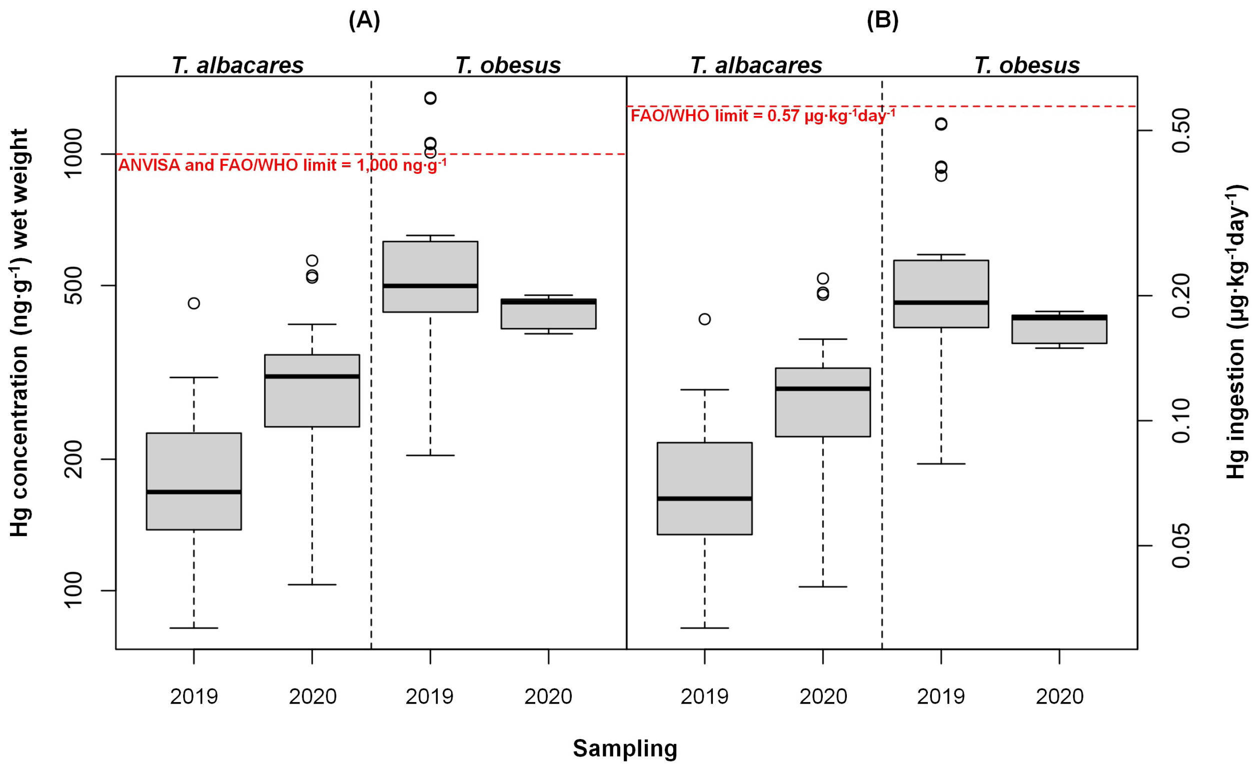

Figure 1. Medians, interquartile ranges, minimum and maximum values of Hg concentrations in *Thunnus albacares* and *Thunnus obesus* from the western equatorial Atlantic Ocean: A—Hg concentrations in muscle and the tolerable maximum limit established by ANVISA and FAO/WHO (dotted red line and value inside) | B—Hg intake estimates by adults and the tolerable intake limit (dotted red line and value inside). Open circles are outliers.

2011; Lacerda et al. 2017).

The Hg concentrations were below the maximum tolerable limits established by ANVISA (2021) and FAO/WHO (1991) for fishery products, except for five *T. obesus* whose concentrations were higher than the limit (1,000 ng g^{-1}) (Figure 1A). The estimates for Hg intake due to tuna consumption were below the tolerable intake limit established by the FAO/WHO (Figure 1B). This result was expected since the Brazilian *per capita* intake of fishery products is half of the world intake (9.75 kg·$year^{-1}$ x 20.5 kg·$year^{-1}$) (Barone et al. 2017; FAO 2020).

Currently, Brazil exports whole large tuna to Indonesia, Vietnam and the United States (https://www.volza.com/exports-brazil/brazil-export-data-of-whole+tuna). Considering that whole large tuna are exported to other countries, it is important to conduct case-by-case health risk assessments. In this sense, tuna consumption from the western equatorial Atlantic Ocean would pose a risk for human populations that ingest more than 80 g·day^{-1} tuna meat (IR based on our most contaminated fish: *T. obesus* individuals caught in 2019). Both tuna species are safe for intake as seafood, at least in the present, but we recommend regular monitoring of both consumption rates and Hg levels, since the encouragement of seafood consumption has increased worldwide, as well the anthropic pollution that reaches the ocean basins.

References

ANVISA - Agência Nacional de Vigilância Sanitária (2021). Estabelece os limites máximos tolerados (LMT) de contaminantes em alimentos. Diário Oficial [da] República Federativa do Brasil. https://www.in.gov.br/en/web/dou/-/instrucao-normativa-in-n-88-de-26-de-marco-de-2021-311655598

Barone, R.S.C., E.K. Lorenz, D.Y. Sonoda & J.E.P. Cyrino (2017). Fish and fishery products trade in Brazil, 2005 to 2015: a review of available data and trends. *Scientia Agricola* 74: 417–424. https://doi.org/10.1590/1678-992X-2016-0300

Bastos, W.R., O. Malm, W.C. Pfeiffer & D. Cleary (1998). Establishment and analytical quality control of laboratories for Hg determination in biological and geological samples in the Amazon, Brazil. *Ciência e Cultura* 50: 255–260.

Caldas, D., I.A. Pestana, F.C. Henry, M.S.M.B. Salomão & C.M.M. Souza (2016). Risk of ingesting As, Cd, and Pb in animal products in north Rio de Janeiro state, Brazil. *Chemosphere* 164: 508–515. https://doi.org/10.1016/j.chemosphere.2016.08.130

Choy, C.A., B.N. Popp, J.J. Kanekoc & J.C. Drazena (2009). The influence of depth on mercury levels in pelagic fishes and their prey. *Proceedings of the National Academy of Sciences* 106: 13865–13869. https://doi.org/10.1073/pnas.0900711106

FAO (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in Action. Food and Aquaculture Organization of the United Nations, Rome. https://doi.org/10.4060/ca9229en

FAO/WHO (1991). Report of the Nineteenth Session of the Joint FAO/WHO Codex Alimentarius Commission. Food and Agriculture Organization of the United Nations/World Health Organization. https://www.fao.org/3/t0490e/T0490E01.htm

FAO/WHO (2003). Summary of Evaluations Performed by the Joint FAO/WHO Expert Committee on Food Additives. Food and Agriculture Organization of the United Nations/World Health Organization. https://inchem.org/documents/jecfa/jeceval/jec_1509.htm

Ferriss, B.E. & T.E. Essington (2011). Regional patterns in mercury and selenium concentrations of Yellowfin Tuna (*Thunnus albacares*) and Bigeye Tuna (*Thunnus obesus*) in the Pacific Ocean. *Canadian Journal of Fishery and Aquatic Science* 68: 2046–2056. https://doi.org/10.1139/f2011-120

Jinadasa, B.K.K.K., G.S. Chathurika, G.D.T.M. Jayasinghe & C.D. Jayaweera (2019). Mercury and cadmium distribution in Yellowfin Tuna (*Thunnus albacares*) from two fishing grounds in the Indian Ocean near Sri Lanka. *Heliyon* 5: e01875. https://doi.org/10.1016/j.heliyon.2019.e01875

Guillotreau, P., D. Squires, J. Sun & G.A. Compeán (2017). Local, regional and global markets: what drives the tuna fisheries? *Reviews in Fish Biology and Fisheries* 27: 909–929. https://doi.org/10.1007/s11160-016-9456-8.

Khitalishvili, K. (2016). Monte Carlo simulation in R: basic example. Available at: https://rpubs.com/Koba/Monte-Carlo-Basic-Example

Lacerda, L.D., F. Goyanna, M.F. Bezerra & G.B. Silva (2017). Mercury concentrations in Tuna (*Thunnus albacares* and *Thunnus obesus*) from the Brazilian Equatorial Atlantic Ocean. *Bulletin of Environmental Contamination and Toxicology* 98: 149–155. https://doi.org/10.1007/s00128-016-2007-0

Lescord, G.L., T.A. Johnston, B.A. Branfireun & J.M. Gunn (2018). Percentage of methylmercury in the muscle tissue of freshwater fish varies with body size and age and among species. *Environmental Toxicology and Chemistry* 37: 2682–2691. https://doi.org/10.1002/etc.4233

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: https://www.r-project.org/

Rodrigues, S.L., V.G.O. Carneiro, A.J.R. Freitas & H.A. Andrade (2020). Spatiotemporal variability of target-species in tuna and tuna-like fishing in Brazil. *Boletim do Instituto de Pesca* 46: e587. https://doi.org/10.20950/1678-2305.2020.46.2.587

Tseng, C.M., S.J. Ang, Y.S. Chen, J.C. Shiao, C.H. Lamborg, X. He & J.R. Reinfeld (2021). Bluefin tuna reveal global patterns of mercury pollution and bioavailability in the world's oceans. *The Proceedings of the National Academy of Sciences* 118: e2111205118. https://doi.org/10.1073/pnas.2111205118

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