High concentrations of Mercury in yellowfin tuna (*Thunnus albacares*) from the Galápagos Marine Reserve and continental Waters, Ecuador

Muñoz, Laia[1,2], Valle, Carlos A[2], Emslie, Steven[3], Alava, Juan José[4]

[1-2]Universidad San Francisco de Quito, Ecuador.

[3]University of North Carolina Wilmington, North Carolina, United States.

[4]Institute for the Oceans and Fisheries, University of British Columbia, Vancouver; Brittish Columbia Canada.

[1]laiajulianamu@gmail.com

ABSTRACT

Among the most traded tuna species is yellowfin tuna (*Thunnus albacares).* Ecuador is the eighth ranked country in the world with the most metric tons of tuna caught. Fish meat is consumed by a large part of the world's population and it is considered a source of nutrition that brings health benefits. However, this meat can also bring risks to people because is substantial bioaccumulation of heavy metals, including mercury, in fish and sea food in general. The objective of this study was to evaluate the concentrations of total mercury present in the red muscle of yellowfin tuna caught by artisanal fisheries in the Marine Reserve of the Galápagos Islands and the mainland coast of Ecuador. It was found that 8% of the tuna analyzed in this study were above the tolerable levels of mercury established by Food and Agricultural Association (FAO). The maximum value found was 6.81 µg/g (ppm) wet weight, one of the highest values of mercury reported for yellowfin tuna in the Pacific.

INTRODUCTION

Fisheries play an important role in the world since about 3 billion people use fish as their main protein source (FAO 2014). The demand for fish is very high and is mainly assumed by developing countries that export their fish (Pauly and Zeller 2016). One of the most exploited families of commercial species in the world is the Scombridae (family of tunas; Juan-Jordá et al. 2013). Tunas are top, opportunistic, epipelagic predators, distributed in tropical and subtropical waters in the world's oceans (Block et al. 2001). The yellowfin tuna, *Thunnus albacares*, is among the most traded tuna species. This species is close to being cataloged as a threatened species according to IUCN (2011). One of the developing countries that practices fishing for both sustenance and export is Ecuador (Galland et al. 2016), recurring to both industrial and artisanal practices. The artisanal fishery is currently extremely important in the Ecuadorian economy because it represents the largest number of food production jobs (Martínez-Ortiz et al. 2015). Fish meat is considered a source of nutrition and health advantages (Gribble et al. 2016). However, it can also pose risks to humans, since large accumulations of heavy metals, including mercury, can be found in fish and sea food in general (Bosch et al. 2015). The presence of metals in marine ecosystems causes problems both for the organisms that are there and for the humans that consume them (Araújo and Cedeño-Macias 2016). Fish can show adverse effects in their growth and survival when exposed to high levels of mercury. Effects on people include neurological problems and developmental failures in the case of fetuses. Therefore the objective of this study was to assess the concentrations of total mercury (THg) in the red muscle of yellowfin tuna caught by artisanal fisheries in the Galápagos Marine Reserve and Ecuador's mainland coast.

Figure 1.Sampling of red muscle from specimens of yellowfin tuna at Galápagos fishing port (left) and Santa Rosa fishing port (right)

METHODS

The collection of samples was conducted in the Galápagos Marine Reserve (GMR) and along the Ecuadorian coast. The GMR samples were obtained at two sites, the ports of San Cristóbal Island and Santa Cruz Island. On the Ecuadorian coast, the samples were taken in the port of Santa Rosa in the province of Santa Elena (Figure 1). The collection of samples was completed during the cold period of 2015 (July and August) and the hot season of 2016 (January and February). A total of 104 samples from the Galápagos and 46 samples from the continental coast were collected during the cold season (2015) and 139 from Galápagos and 58 from the coast during the hot season (2016). The sample were stored on ice at -20°C. Each sampled individual was measured for the fork length. Only the individuals from whom a certain location of capture was known were measured and sampled (Figure 2). The samples were lyophilized for the mercury analyses. Measurements of total mercury in tissues were performed on a Milestone DMA-80 mercury analyzer. Values were obtained in parts per million (ppm) of dry weight, these values were converted to wet weight (ww) using a moisture percentage of 70% as reported by Teffer et al. (2014) for yellowfin tuna. All the mercury found in these tunas was assumed to be methylmercury, as it has been shown that between 90% and 100% of the total mercury found in fish tissues, especially top predators, is in the form (Bosch et al. 2016).

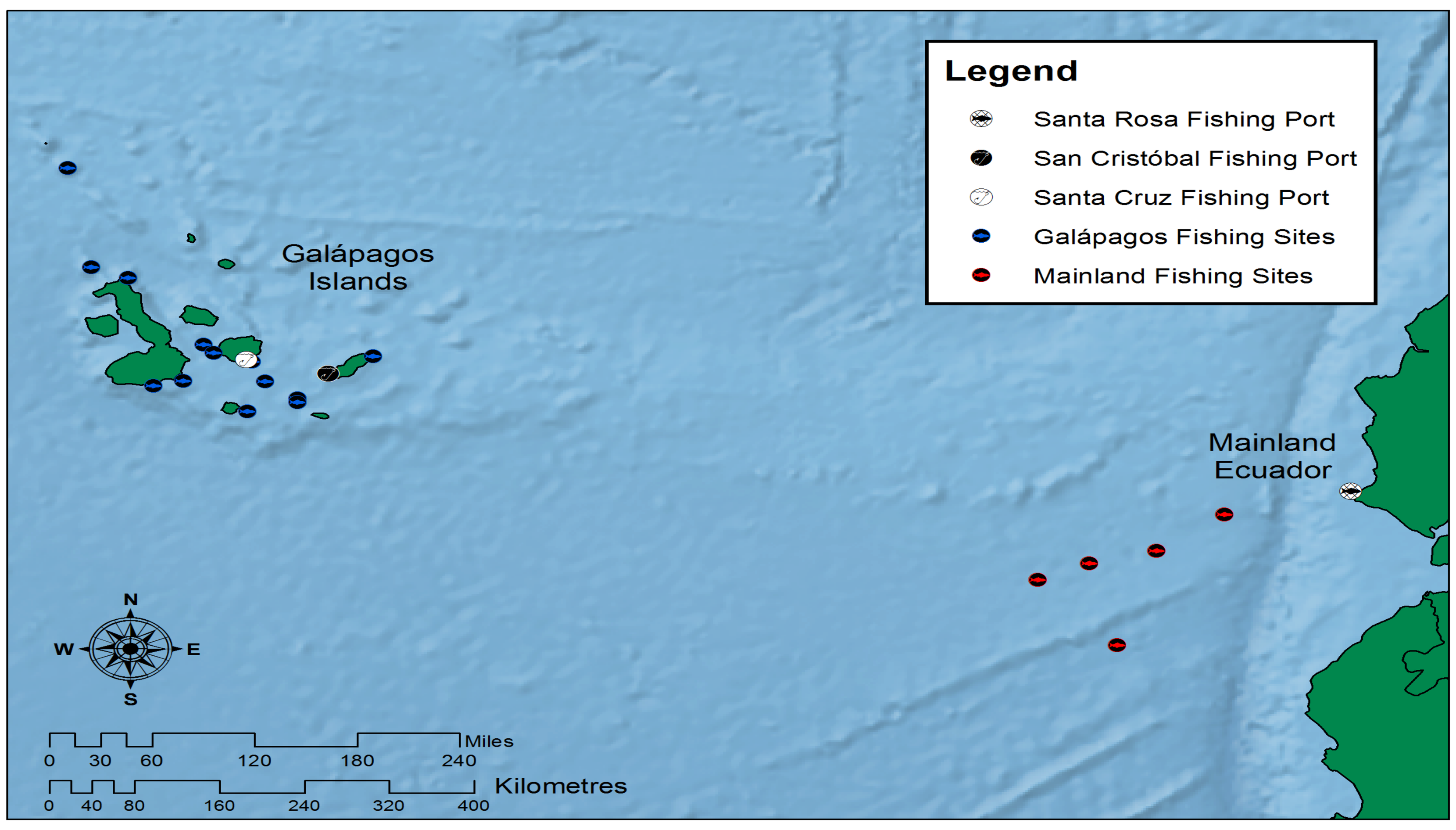

Figure 2. Map of fishing zones showing the sampling sites in marine Waters around the Galápagos Marine Reserve and off Ecuador´s mainland coast. The Galápagos Island are located at 1000km from the Ecuadorian coast.

RESULTS

A total of 347 individuals were collected. The size of the tunas sampled ranged from 34 to 200 centimetres of fork length. The sizes of the individuals from Galápagos were significantly larger from those of continental coast (u = 2815.5, p = 0.000). Larger tunas were more abundant in the Galápagos, especially in the northern part of the islands. Tuna size was also different between the hot and cold seasons (u = 17602, p = 0.000; Figure 3). In both Galápagos and mainland larger tunas were observed during the hot season. Of the tunas that were possibly sexually mature, only 4.81% were caught in the coastal mainland while 95.18% were caught in Galápagos.

Concentrations of mercury had significant differences between Galápagos and the mainland (u = 3928, p = 0.000). The tunas collected in Galápagos had a higher mercury concentration than those from the continental coast (Figure 3), and individuals from the north of Galápagos showed the highest mercury concentrations of all individuals collected. Mercury concentration were not significantly different between the hot and cool seasons (u = 14923, p = 0.873). Mercury values were related to tuna size (r = 0.579, p = 0.000). The tunas with the larger sizes showed higher concentrations of mercury. The mercury in individuals caught in the GMR ranged from 0.0917 to 6.8197 ppm while the range of individuals captured in the continental region ranged from 0.0703 to 3.1385 ppm, with the former being the highest concentrations of mercury for yellowfin tuna ever reported. The mean was 0.53 ppm (±0.55). The maximum allowable limits established by FAO / WHO (2016) are 1 ppm mercury in yellowfin tuna. 8% of the tunas in the present study were above the established limits.

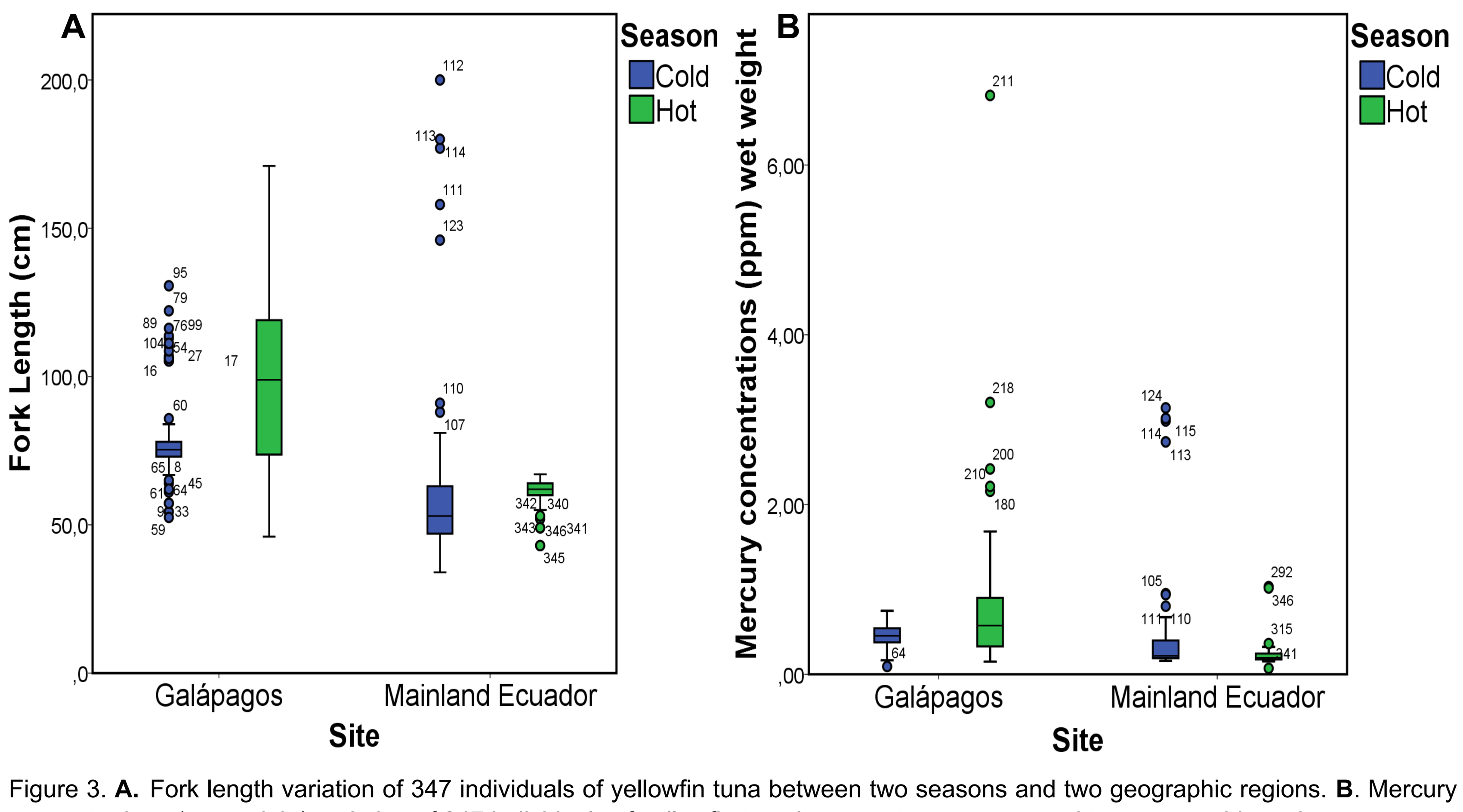

Figure 3. **A.** Fork length variation of 347 individuals of yellowfin tuna between two seasons and two geographic regions. **B.** Mercury concentrations (wet weight) variation of 347 individuals of yellowfin tuna between two seasons and two geographic regions.

DISCUSSION AND CONCLUSIONS

The difference in sizes that are captured with the different fishing gears was observed in the present study: Individuals captured on the continental coast had smaller sizes compared to individuals from Galápagos. The fishing gear closest to the surface typically captures juvenile and shorter individuals, as opposed to deep-sea fishing gear that captures adult and longer individuals (CIAT 2015). Overfishing of juvenile individuals (growth) has major effects in the abundance of individuals in a population (Siskey et al., 2016).

Contamination in tuna is an indicator of ocean pollution (Chen et al., 2014). Our study for the first time provides mercury concentrations in yellowfin tuna in the GMR and the mainland coast of Ecuador. The results allow us to infer that there are differences in the concentrations of mercury present in the tissues of the individuals from Galápagos and those from the continental coast. Individuals captured on the coast had lower concentrations of mercury in their tissues. These results can be explained by the size differences of the individuals of the two locations, and within Galápagos as the larger individuals that were captured in the north of the archipelago had the highest concentrations of mercury. This relationship suggests that there is long-term bioaccumulation of mercury in larger tuna and mercury contamination in the GMR ecosystem. On the other hand, no differences were found in mercury concentrations between seasons, suggesting that mercury contamination in this region is being distributed in the same way. The present study was compared with other studies in the same species. The mercury concentrations reported by this study are the highest yet reported in yellowfin tuna. An increase in mercury concentrations over time was observed. This is congruent with what was found by Drevnick et al. (2015) who reports that the concentration of mercury in yellowfin increased 3.8% per year from 1998 to 2008 to the north of the Pacific Ocean. Fish can have adverse effects in their growth and survival when exposed to high levels of mercury. Piscivorous fish are at high risk for being exposed to high toxicity. Mercury concentrations found in this study may be affecting populations of yellowfin tuna.

Effects on people include neurological problems and developmental failures in the case of fetuses. According to FAO/WHO (2016) for an average person with 70 kg of body mass, the permitted intake index is 1.6 ppm. Using the mean of the data found in this study (0.53) it was estimated that an Ecuadorian with 70 kg of weight should consume approximately 222 grams of yellowfin tuna per week at a risk of contamination from mercury intake.

REFERENCES

FAO. 2014. The state of world fisheries and aquaculture. Food and agriculture organization of the united nations, Roma.

Pauly, D., and D. Zeller. 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. Nature Communications **7**:9.

Juan Jorda, M., I. Mosqueira, J. Freire, and K. Dulvy. 2013. The Conservation and Management of Tunas and Their Relatives: Setting Life History Research Priorities. Plos One **8**:1-18.

Block, B., and D. Stevens. 2001. Tuna Physiology, Ecology and Evolution. Academic Press, San Diego, California.

Galland, G., A. Rogers, and A. Nickson. 2016. Netting Billions: A Global Valuation of Tuna. The PEW Charitable Trusts, Philadelphia.

Martínez- Ortiz, J., A. Aires- da Silva, C. Lennert-Cody, and M. Maunder. 2015. The Ecuadorian Artisanal Fishery for Large Pelagics: Species Composition and Spatio-Temporal Dynamics. Plos One **10**:1-29.

Gribbble, M., R. Karimi, B. Feingold, J. Nyland, T. O´hara, M. Glaydyshev, and C. Chen. 2016. Mercury, selenium and fish oils in marine food webs and implications for human health. Journal of the Marine Biological Association of the United Kingdom **96**:43-59.

Bosch, A., B. O´Neill, G. Sigge, S. Kerwath, and L. Hoffman. 2015. Heavy metals in marine fish meat and consumer health: a review. Science Food Agriculture **96**:32-48.

Araújo, C., and L. Cedeño-Macias. 2016. Heavy metals in yellowfin tuna (Thunnus albacares) and common dolphinfish (Coryphaena hippurus) landed on the Ecuadorian coast. Science of the Total Environment **541**:149-154.

Juan-Jordá, M., I. Mosqueira, J. Freire, and K. Dulvy. 2015. Population declines of tuna and relatives depend on their speed of life. The Royal Society Publishing **282**:1.

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