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Total Mercury Levels in Muscle Tissue of Swordfish (*Xiphias gladius*) and Bluefin Tuna (*Thunnus thynnus*) from the Mediterranean Sea (Italy)

M. M. STORELLI AND G. O. MARCOTRIGIANO*

Pharmacological-Biologic Department, Medicine Veterinary Faculty, University of Bari, Strada Prov. le per Casamassima km 3, 70010 Valenzano (BA), Italy

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ABSTRACT

This study was carried out to determine the current levels of total mercury in the muscle tissue of swordfish (*Xiphias gladius*) and bluefin tuna (*Thunnus thynnus*) caught in the Mediterranean Sea with the purpose of ascertaining whether the concentrations exceeded the maximum level fixed by the European Commission Decision. In addition, specimens of each species were divided into different ranges of weight to investigate the influence of size on mercury accumulation in order to provide data upon which commercial fishing strategies and marketing of swordfish and bluefin tuna may be based. Higher mean levels of total mercury were found in bluefin tuna (1.02 μg g^{-1} wet wt) than in swordfish (0.49 μg g^{-1} wet wt). In 4.3% of swordfish and in 44.3% of bluefin tuna analyzed, total mercury concentrations exceeded the maximum level fixed by the European Commission Decision (Hg = 1 μg g^{-1} wet wt). Besides, for bluefin tuna the total mercury level variability observed, due to size, suggests that there should be greater regulatory control by the authorities.

Presently, the role of heavy metals as pollutants is widely recognized. In particular, mercury has received much attention due to the well-known toxic effects of this metal. Given its capacity for biomagnification along food webs, mercury is often present at high levels in marine species. Within the marine fauna, large predators, such as swordfish, tuna fish, and sharks, show the maximum capacities for bioaccumulation of mercury and might be used as species to monitor levels of contaminants in the marine environment *(16, 21)*. Several authors *(3, 11, 17)* reported high levels of mercury in swordfish and tuna fish from different oceanic waters. The Mediterranean is a semienclosed sea, connected with the Atlantic ocean through the straits of Gibraltar. Water exchange at the straits of Gibraltar is estimated at 5×10^{13} m^3 $year^{-1}$ for the inflowing flux and 4% less for the outflowing flux *(12)*. In addition to the little water exchange with the Atlantic ocean, the Mediterranean Sea is located on a mercury bed containing some of the richest natural reserves of this metal *(2)*. In recent decades, several studies on pelagic species often reported higher levels of mercury in Mediterranean specimens than in similar fish collected in other areas, in particularly in the Northen Atlantic *(7, 26)*. In Mediterranean tuna, a mercury accumulation rate four to five times higher than in Atlantic tuna was reported *(5)*. Similar figures were also found for *Sardina pilchardus* and *Engraulis encrasicolus (27)*. It was suggested that the difference in mercury levels found in Mediterranean and Atlantic fish is due to ecological factors such as differences in food availability, fish growth rate (i.e., fish from the Mediterranean could be older than fish of the same species and weight caught in the Atlantic), and also difference in food type or quality, with mercury contents higher in the Mediterranean than the Atlantic or other oceans *(2)*. In light of the above concern, this study was carried out to determine the current levels of total mercury in muscle tissue of swordfish (*Xiphias gladius*) and bluefin tuna (*Thunnus thynnus*), species of great commercial importance, caught in the Mediterranean Sea, for the purpose of ascertaining whether the concentrations exceeded the maximum level fixed by the European Commission Decision *(18)*. In addition, specimens of each species were divided into different ranges of weight to investigate the influence of size on mercury accumulation in order to provide data upon which commercial fishing strategies and marketing of swordfish and tuna fish may be based.

MATERIAL AND METHODS

In June to August 1998 during several trawl surveys, 162 specimens of swordfish (*X. gladius*) from Ionian Sea and 169 specimens of bluefin tuna (*T. thynnus*) from the Thyrrenian Sea were caught. From each specimen, approximately 0.1 to 0.3 kg of muscle tissue was removed from the anterior portion of the carcass by a transverse dissection near the dorsal fin. Table 1 shows the weight range and the number of specimens of swordfish and bluefin tuna for each size. Total mercury content was determined on homogenates of muscle tissue using a wet digestion method. A quantity of 2 to 3 g of sample was weighed into a conical flask, and 10 ml of sulfuric acid and nitric acid mixture (1:1) was added. The flask was heated to 60 to 70°C under reflux for about 5 h. After addition of deionized water to 100 ml the solution was ready for analysis *(13)*. The quantitative analysis of mercury was carried out by cold vapor atomic absorption spec-

* Author for correspondence. Tel: +39 080 5446066; Fax: +39 080 5446063; E-mail: g.o.marcotrigiano@veterinaria.uniba.it.

TABLE 1. *Number of specimens, weight ranges (kg), and total mercury concentrations (μg g^{-1} wet wt) in swordfish (*X. gladius*) and bluefin tuna (*T. thynnus*)*

Species	No. of specimens	Weight range (kg)	Total Hg concentrations
Totals for swordfish	162	6.0–125.0	0.15–1.05
		47.2 ± 36.2	0.49 ± 0.26
Swordfish	21	6–10	0.17 ± 0.03
	25	11–20	0.23 ± 0.03
	19	21–30	0.34 ± 0.04
	12	31–40	0.47 ± 0.04
	17	41–50	0.53 ± 0.07
	15	51–60	0.53 ± 0.12
	19	61–70	0.60 ± 0.04
	11	71–80	0.61 ± 0.04
	9	81–90	0.67 ± 0.06
	7	91–100	0.89 ± 0.03
	7	>100	1.02 ± 0.07
Totals for bluefin tuna	169	0.33–158.0	0.07–4.26
		39.5 ± 43.8	1.02 ± 0.99
Bluefin tuna	32	<5	0.12 ± 0.06
	27	5–10	0.41 ± 0.05
	19	11–20	0.73 ± 0.07
	16	31–40	0.82 ± 0.07
	10	41–50	1.21 ± 0.30
	12	51–60	1.50 ± 0.20
	15	61–70	1.40 ± 0.05
	11	71–80	1.69 ± 0.01
	12	81–90	1.57 ± 0.38
	9	91–100	2.32 ± 0.74
	6	>100	3.23 ± 1.10

trophotometry (Perkin-Elmer 5000, Norwalk, Conn.) after reduction by $SnCl_2$ (A.V.A. Thermo Jarrel Ash Corp., Franklin, Mass.) *(13).* To obtain the calibration curve (slope: 0.00249; correlation coefficient: 0.98399), aliquots of 0.2, 0.4, 0.8, and 1 ml (concentration range: 5 to 50 μg/liter) were taken from a mercury solution standard at a concentration of 5 mg/liter, prepared by dilution from a solution standard (1,000 mg/liter; Perkin-Elmer Pure). The detection limit for mercury was 0.050 mg/kg. Three replicate samples for each individual fish were assayed and the results averaged; the error did not exceed 7%. All data were computed on a mg/kg fresh weight basis. Recoveries of Hg from spiked samples (0.1 to 10 μg/g), yielded on average 98 ± 3% (n = 20).

The analytical methodologies were validated using the certified reference material, DORM-1, a dogfish muscle, from the National Research Council, Canada. About 300 mg of the material was weighed, and five replicates were measured for mercury. The values found (0.715 ± 0.055 mg/kg dry wt) were in reasonable agreement but slightly lower than the certified values (0.798 ± 0.074 mg/kg dry wt).

RESULTS AND DISCUSSION

The total mercury residue concentrations in the muscle tissue of swordfish and bluefin tuna are shown in Table 1. Total mercury levels ranged from 0.15 to 1.05 μg g^{-1} wet wt (average = 0.49 μg g^{-1} wet wt) in swordfish and from 0.07 to 4.26 μg g^{-1} wet wt (average = 1.02 μg g^{-1} wet wt) in bluefin tuna. The comparison of the present total mercury levels for swordfish with those from other seas showed values comparable with those reported from the Azores coast *(16)* and Spanish Mediterranean coast *(21).* High mercury concentrations in muscle tissue of swordfish were observed by Monteiro and Lopes *(16)* in specimens weighing 120 to 250 kg with maximum values of 4.31 μg g^{-1} wet wt in females and 4.91 μg g^{-1} wet wt in males. Low values were reported by Chalasi et al. *(9)* in muscle tissue of swordfish weighting between 15 and 70 kg caught off the Algerian coast. The comparison of our results with published data for bluefin tuna showed higher levels than those detected by Pastor et al. *(21)* in specimens from the Spanish Mediterranean coast and were remarkably lower than those reported in specimens from Japan with values of 0.36 to 5.25 μg g^{-1} wet wt *(17).*

Comparing the two different species studied, higher mean levels of total mercury were found in bluefin tuna (1.02 μg g^{-1} wet wt) than in swordfish (0.49 μg g^{-1} wet wt). The mean mercury concentrations were about two to four times higher in bluefin tuna than in swordfish when the weight ranges of fish were the same (Fig. 1). A combination of several factors may be responsible for the observed differences. First of all the feeding behavior seems to be a determining cause of the different mercury concentration between the two species. The importance of the dietary input to body mercury load in fish is widely recognized *(22, 23).* Studies carried out on the stomach contents of swordfish and bluefin tuna from Mediterranean Sea show that the swordfish is mainly a mollusc and cephalopod feeder *(4),* while bluefin tuna is primarily piscivorous *(20).* Animals feeding mainly on cephalopods, opposite to those that are piscivorous, tend to concentrate more cadmium than mercury, because it is known that cephalopods have high levels of cadmium *(8, 24).* Therefore, it is quite reasonable to find higher mercury levels in bluefin tuna than in swordfish. In addition, the different rates of physiological processes, particularly the growth and the metabolic capacity of fish, could also play an important role in determining differences in the contaminant burden between the two species. Estimated age in Mediterranean bluefin tuna specimens of length 56 to 82 cm was 1 to 2 years *(19),* while in Mediterranean swordfish, with a similar length range, the estimated age was under 1 year *(14).* Therefore, considering the length range of both species, bluefin tuna exhibit more growth. Moreover, tunas have rates of digestion two to five times higher than those of other piscivorous species when comparisons are made to other fishes of equal body size held at equivalent water temperatures *(6).* It is apparent from the above discussion that differential growth rate is a governing parameter in pollutant uptake, but also in dietary intake; hence, the kind and the amount of fish eaten influences the body burden.

Specimens of each species were divided into different size groups to investigate the influence of size on mercury accumulation. The total mercury contents in the muscle tissue versus the body weight of swordfish and bluefin tuna are shown in Figure 2a and 2b, respectively. For swordfish and bluefin tuna the correlation coefficients between total mercury versus body weight were 0.95 and 0.92, respectively, and the values were significantly correlated (P <

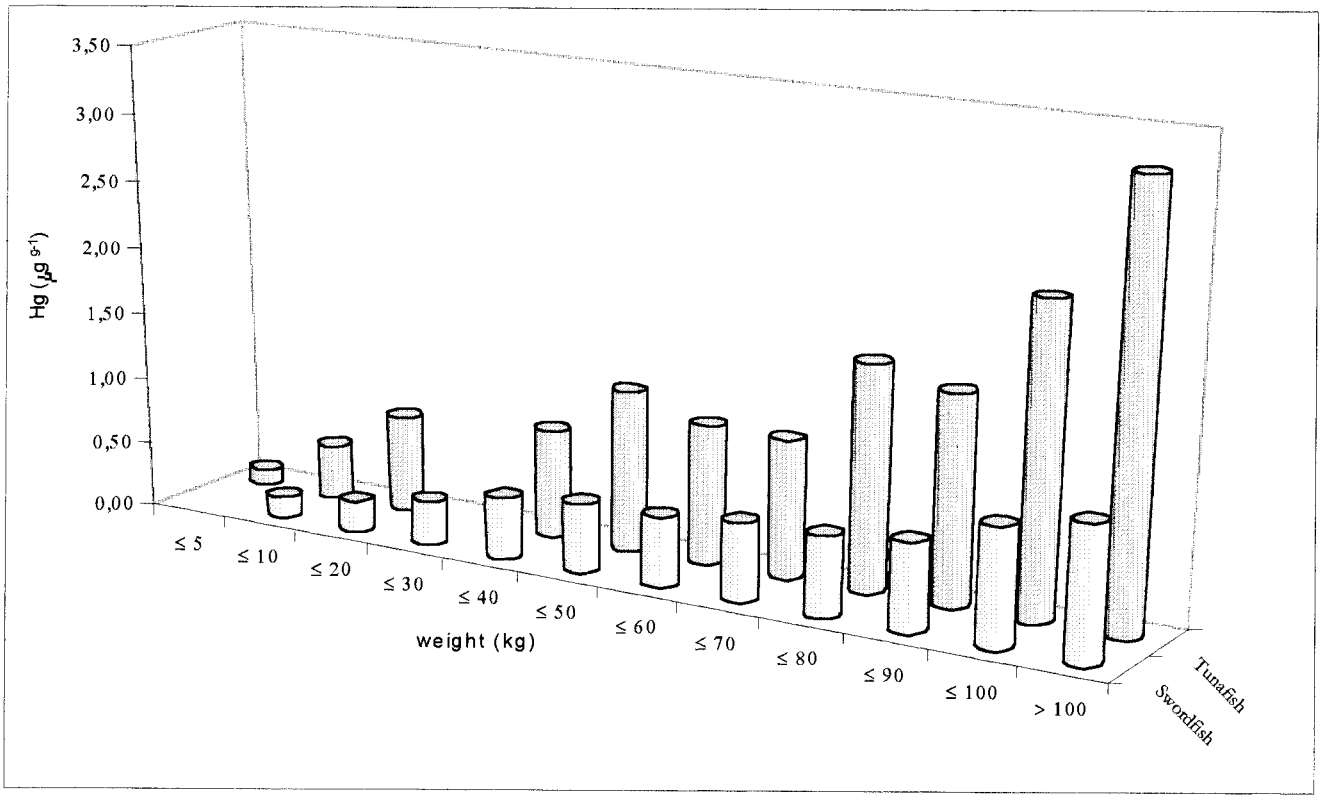

FIGURE 1. *Total mercury concentrations (μg g^{-1} wet wt) in function of weight ranges in muscle tissue of swordfish (*Xiphias gladius*) and bluefin tuna (*Thunnus thynnus*).*

0.0001). This linear correlation was already observed either in swordfish and tunas or in other organisms of the marine ichthyofauna *(1, 10, 15, 16, 23, 25).* The relation between mercury concentrations and fish size was undertaken for the purpose of ascertaining whether there might be a strong enough correlation to establish fish size limits with safe heavy metal concentrations. A detailed examination of data (Table 1 and Fig. 2) clearly indicates that in swordfish of weight between 30 and 90 kg, the total mercury concentrations showed a very moderate increase (0.47 to 0.67 μg g^{-1} wet wt). Above this size, the concentrations were augmented, reaching values greater than 1 μg g^{-1} wet wt in individuals that weigh more than 100 kg. By contrast, in bluefin tuna that weigh 30 to 90 kg, total mercury concentrations showed a noticeable increase (0.82 to 1.57 μg g^{-1} wet wt) with very high levels in specimens weighing more than 90 kg.

Total mercury contamination in fish products destined for food consumption is regulated by the European Commission Decision (ECD) 93/351 of 19 May 1993 *(18).* The ECD asserts that the mean content of total mercury in edible parts of fish products should not exceed 0.5 μg g^{-1} wet wt. Nevertheless, for specific fishing species listed in Annex A of the same ECD, the tolerable mean content of mercury is fixed at 1 μg g^{-1} wet wt. Swordfish and bluefin tuna are among the species listed in Annex A. Thus, according to the regulation in force *(18),* total mercury levels in swordfish specimens weighing less than 100 kg were below the prescribed limit (Hg = 1 μg g^{-1} wet wt) while specimens above 100 kg reached this limit. Whereas, for bluefin tuna the maximum level fixed by the ECD was already exceeded in specimens weighing above 40 kg. In percentages, total mercury levels exceeded the prescribed limit in 4.3% of swordfish and in 44.3% of bluefin tuna analyzed.

These results emphasize the importance of biological parameters in studies on bioaccumulation of mercury, mainly in large predators that show high levels of this metal, due to mercury biomagnification via the marine food web. Moreover, the mercury level variability due to size must be taken into account for the commercial fishing strat-

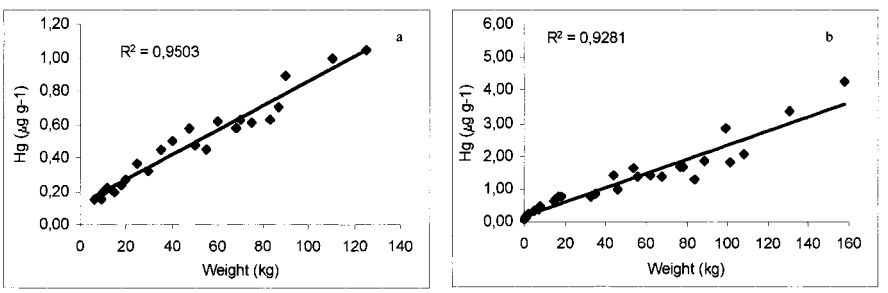

FIGURE 2. *Relationship between weight of swordfish (*Xiphias gladius*) (a) and bluefin tuna (*Thunnus thynnus*) (b) and total mercury concentrations (μg g^{-1} wet wt) in muscle tissue.*

egies and marketing of swordfish, but mainly for bluefin tuna for which there should be more frequent control by the authorities or the specimens marketed weigh less than 40 kg.

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