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Baseline

Accumulation of heavy metals to assess the health status of swordfish in a comparative analysis of Mediterranean and Atlantic areas

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A B S T R A C T

During the last few decades, the combined effects of natural and human activities acting on the Mediterranean Sea basin have caused a reduction in the swordfish (Xiphias gladius, L. 1758) population. In this project, we investigated the accumulation of lead (Pb), cadmium (Cd) and mercury (Hg) levels in the Atlantic and Mediterranean populations of swordfish during a five-year survey. In the marine environment, top predators such as swordfish accumulate high concentrations of toxic metals, and thus, potentially incur a high toxicological risk. Furthermore, heavy metals, such as chemical pollutants, have strong long-term effects on fish, and thus, constitute a high risk for the resource and humans that consume it. The aim of this work is to contribute to the assessment of the state of European swordfish population health. We analyzed muscle tissue from 56 specimens captured in Mediterranean and Atlantic areas for trace elements. Mean concentrations of Hg, Cd, and Pb were in the following ranges: 0.66–2.41, 0.04–0.16, and 0.97–1.36 mg/kg ww, respectively. These data suggest a need for continuous monitoring to avoid reductions in the population of this fish species of high commercial and ecological interest.

1. Introduction

Recent studies examined during the latest International Commission for the Conservation of Atlantic Tunas (ICCAT) meetings have shown that the Mediterranean and Atlantic swordfish populations are two separate fish stocks, even though no definite boundary information is available. Furthermore, the Mediterranean swordfish features unique biological characteristics, such as growing rate and sexual maturity age, that differ from those of the Atlantic specimens (ICCAT, 2008). Two different approaches – based on either a long-term or short-term model – that surfaced from the last ICCAT report have pointed to a highly negative outlook for the sustainability of the Mediterranean swordfish population. This pauperization of the stock is due to a number of reasons, including overfishing and pollution.

Considering the innumerable toxic substances found in the marine environment, exceptional research and control efforts have been devoted to heavy metals. Pd, Hg, and Cd are non-essential trace elements that provide valuable eco-toxicological data. It is now generally accepted that amounts of contaminants discharged into the environment and into the Mediterranean Sea in particular – have continued to increase and have reached alarming levels, which has prompted calls for in-depth studies (WHO, 2007) and major regulatory measures. Species that are at the top of the trophic chain in the sea environment, such as Xiphias *gladius* in the Mediterranean Sea, tend to accumulate considerable amounts of heavy metals in their tissues. Furthermore, because these species are top predators, they carry out very intense metabolic activities that require a continuous supply of energy. As a result, their rate of predation and food consumption is extremely high, which significantly contributes to accumulation of pollutants in their tissues. After all, the net accumulation of metals in an organism is given by the difference between their absorption and excretion (Canli and Atli, 2003). As recently pointed out, high concentrations of these elements are found in the Mediterranean Sea in many types of commercially important fish (Langston, 1990; Kalay et al., 1999; Demirak et al., 2006; Papetti and Rossi, 2009). The Mediterranean Sea is a nearly closed basin that is surrounded by highly industrialized areas, and thus, is a region at risk of contaminant accumulation. From a geochemical point of view, there are large areas of the Mediterranean Sea characterized by mercury anomalies (Bernhard and Brondi, 1986), meaning zones with an extremely high mercury concentrations. Anomalously high mercury concentrations with respect to the underlying conditions are the most conspicuous manifestation of a concentration of mining operations in a region. Erosion and leaching phenomena transport pollutants directly to the oceanic environment through the river system. Moreover, the Mediterranean Sea is an almost completely

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closed basin that has been surrounded by some of the most populated and industrialized countries in the world since time immemorial, which has caused a temporally and spatially constant rate of pollution by toxic compounds. These are the reasons that large Mediterranean deep-sea fishes, such as tuna and swordfish, tend to exhibit high levels of heavy metal accumulation (Fossi et al., 2001; Storelli et al., 2005), higher than those of populations inhabiting other areas. It has been a number of years since the European Community, through European Food Safety Authority (EFSA), has investigated the distribution and accumulation of key heavy metals in fish, paying special attention to the species with high commercial value. In addition to persistent organic compounds such as PCBs, dioxins, etc. (Severino and Anastasio, 2006), presence of a few metals such as lead, cadmium and, in particular, mercury may give rise to concerns for consumers because of their tendency to bioaccumulate and biomagnify up the food chain. At present, even though studies assessing the levels of chemical contaminants in the *X. gladius* of the Mediterranean have been carried out (Papetti and Rossi, 2009; Storelli et al., 2005; Stefanelli et al., 2004; Storelli and Marcotrigiano, 2001), there are no comparative studies to other areas. Furthermore, a few authors (Fossi et al., 2004) have discovered toxicological effects of endocrine disrupters on the Mediterranean population of *X. gladius*. According to the "Red Queen" hypothesis (Van Valen, 1973), populations that experience a loss of heterozygosity, as is case with the Mediterranean swordfish (Chow et al., 1997), are more likely to lose their capacity to resist outside agents. In addition to affecting the nucleotide structure of the DNA, a few heavy metals, such as mercury, may alter swordfish reproductive capacities, which will lead to a reduction in both their adaptive capacity and state of health.

2. Materials and methods

Fifty-six individuals were analyzed for cadmium, lead, and mercury: 11 were from the North-western Atlantic, 11 from the Center-north Atlantic and 34 from the Mediterranean area (Table 1, Fig. 1).

Professional (drifting longline) fishing boats conducted the majority of the sampling. The date, catch site (coordinates) and lower-jaw-fork-length (LJFL) of each specimen were recorded at the time of the catch. Pieces of tissue (approximately 10 g muscle) were collected from the tail or caudal fin of each fish for heavy metal analysis. The tissues were kept at −80° C until analysis.

After being homogenized and oven dried at 105° Celsius for 5 h, the tissue (muscle) was mineralized according to Papetti and Rossi (2009), whereby samples of dry tissue (0.2–0.3 g) were reduced in 3 ml of HNO_3 (65%) and 0.5 ml of H_2O_2 for 6–8 h in compliance with the FAO method (Ylmaz, 2003). After cooling, the resulting product was brought to 10 ml and analyzed with a graphite-furnace atomic absorption spectrometer (HGA 500) for Pb and Cd, and with a hydride-generation atomic absorption spectrometer (FIAS3) for Hg. The heavy metal concentrations were expressed in milligrams per kilo of wet weight (mg/kg ww). The calibration was made using appropriate dilutions of stock solutions of Pb, Cd, and Hg (1000 ppm). The relative standard deviation (SD) and percent standard deviation (%RSD) calculations were based upon five replicate samples. To ensure the accuracy of the method, the same analyses were conducted on certified control samples (IEAE-407) with a recovery value for the analyzed metal of 95% (Table 2).

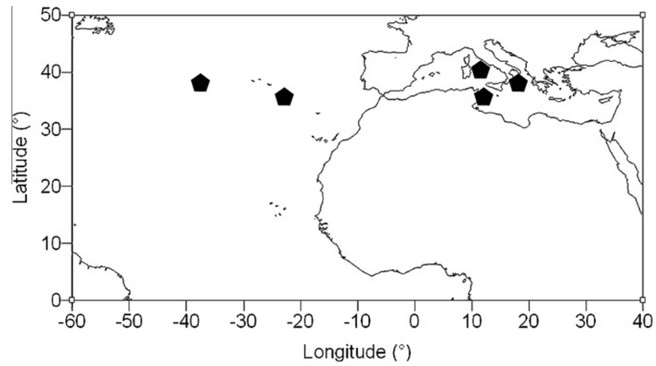

Fig. 1. Sampling localities for Xiphias gladius. Sampling codes, and catching methods are reported in Table 1.

Table 1
Sampling area.

Sampling area	Code	N	Catch landing location	Catching method
Ionian sea	IOS	12	San Cesareo	Drifting longline
Southern Tyrrhenian sea	STS	10	Marina di Camerota Messina	Drifting longline Harpoon fishing
Central Tyrrhenian sea	CTS	12	Civitavecchia Ponza Island	Sporting equipment Drifting longline
North-western Atlantic	NWA	11	Azores Islands	Drifting longline Bottom-set longline
North-central Atlantic	NCA	11	Azores Islands	Drifting longline

3. Results and discussion

Muscle fragments were used to monitor the levels of the heavy metal accumulation in swordfish. Even though liver tissue is usually associated with higher concentrations of chemical contaminants, the decision to analyze muscle tissue was warranted because of the need to relate the data to the risk associated with human consumption of fish, and because liver is not an edible fish part, it poses no risk for human health. Furthermore, muscle is one of the main reservoirs sectors for the "accumulation" of contaminants, unlike the liver and hepatopancreas, which may be viewed as sectors for the "disposal" of these elements, and, therefore, provide information about the instantaneous environmental availability of metals (Renzoni et al., 1993), while preserving no historical memory of it.

Even though the results point to high variability in heavy metal concentrations, significant differences were found among the different elements taken into consideration. Table 3 shows the data relative to the Cd, Pb, and Hg concentrations in tissues from *X. gladius* from the various sampling locations.

There were considerable differences in both lead and cadmium concentrations between the two study areas, with significantly lower mean concentration values in the North-west Atlantic (NWA: Cd = 0.045 $\mu g\ g^{-1}$ ww; Pb = 1.078 $\mu g\ g^{-1}$ ww) and the North-central Atlantic samples (NCA: Cd = 0.042 $\mu g\ g^{-1}$ ww; Pb = 0.968 $\mu g\ g^{-1}$ ww) than in the three Mediterranean samples

Table 2
Determination of Hg, Cd and Pb in tissue Certified Reference Material (IAEA-407).

Metal	IAEA 407 Measured Mean ± Ds	Fish tissue Certified Mean ± Ds
Hg	0.226 ± 0.008	0.222 ± 0.024
Cd	0.174 ± 0.006	0.189 ± 0.019
Pb	0.129 ± 0.010	0.120 ± 0.060

All concentration are expressed in mg kg^{-1}. The composition of the tissue powder (IAEA-407): Fe 146, Ni 0.6, Cu 3.28, Pb 0.12, Hg 0.222, Zn 67.1, Cd 0.189, Cr 0.73, Co 0.10, and Mn 3.52 (mg/kg). Mean of five determinations at 95% confidence level.