Total mercury levels in tunas from offshore waters of the Florida Atlantic coast

Douglas H. Adams *

1. Introduction

Yellowfin tuna (Thunnus albacares), blackfin tuna (T. atlanticus), and little tunny (Euthynnus alletteratus), support significant recreational and commercial fisheries in Florida and throughout their respective ranges. Greater than 2.7 million pounds of these three tuna species were landed in Florida during 2002 (National Marine Fisheries Service, Fisheries Statistics and Economic Division, personal communication). The majority of recreational landings of blackfin tuna and little tunny in the southeastern United States are typically from Florida waters (National Marine Fisheries Service, Fisheries Statistics and Economic Division, personal communication). Although mercury and other contaminants in tunas and other pelagic species are of widespread interest and concern, data regarding mercury levels in tunas from the southeastern United States are very limited. Due to the current lack of information, increased monitoring of mercury in these species has been recommended by both state and federal fishery agencies. Fish-consumption advisories issued by the Florida Department of Health (DOH) for mercury in fish from Florida waters currently include blackfin tuna and little tunny (DOH, 2003). This advisory urges limited consumption of blackfin tuna from waters off the central Atlantic coast of Florida and limited consumption of little tunny from all Florida coastal waters (DOH, 2003).

The objectives of this study were to analyze and interpret the total mercury content in dorsal muscle tissue of yellowfin tuna, blackfin tuna, and little tunny collected from coastal and offshore waters Florida's Atlantic coast from 1999 to 2002. This study will also provide critical data to public health agencies within the State of Florida and elsewhere in the region to assess potential public health issues related to mercury concentrations in tunas from Florida and adjacent states in the southeastern United States.

2. Methods and materials

Tuna samples were collected from the recreational fishery operating in coastal and offshore waters of Florida's Atlantic coast from the Daytona Beach area south to the Florida Keys (Fig. 1). The majority of yellowfin tuna and blackfin tuna were collected in offshore waters from the Daytona Beach-Cape Canaveral area south to Vero Beach. Little tunny were collected principally from coastal and offshore waters of Daytona Beach south to the Florida Keys. Fish sizes of all three tuna species were representative of those typically landed by the recreational fishery in this region. Samples were collected from 1999 to 2002.

Fishes were placed directly on ice and returned to the laboratory or were processed in the field; species, fork

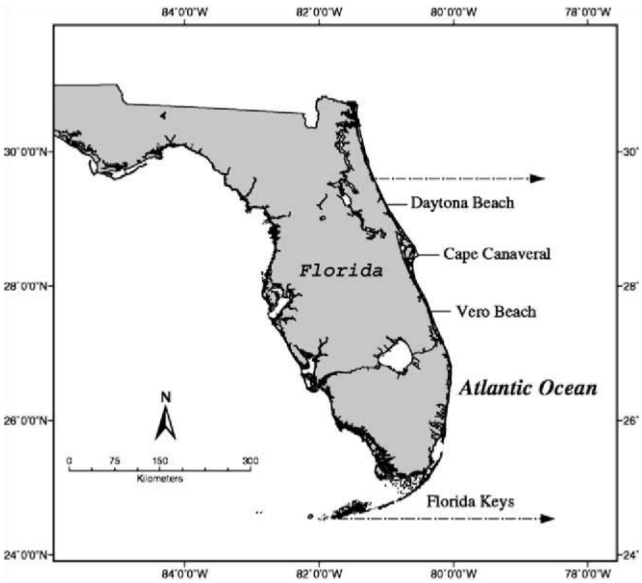

Fig. 1. Map of Florida study area where tunas were collected for use in mercury analysis. The offshore area delineated between the horizontal dashed lines indicates the area where tuna were collected during the study period.

length (FL), and sex were recorded. Total fish weights were recorded or were generated using length–weight regression equations (Wild, 1986; FWC-FMRI, unpublished data). A clean stainless-steel knife was used to remove samples of axial muscle from the left dorsal area above the lateral line and anterior to the origin of the
first dorsal fin. White muscle tissue taken from this region is representative of the portion of fish consumed by humans (Adams et al., 2003). Care was taken to assure that the sample made no contact with epidermal or dermal layers, scales, or other surrounding surfaces during the extraction process. Tissue samples were immediately placed in sterile polyethylene vials and frozen at)20 C until analyzed. Before analysis, tissue samples were digested using standard procedures in accord with US Environmental Protection Agency (EPA) Method 245.1 to convert all mercury in the sample to Hg(II) (EPA, 1991; Frick, 1996). The mercury in each
digested sample was reduced to elemental mercury by reaction with excess stannous chloride ($SnCl_2$). This

Table 1

elemental mercury [Hg(0)] was purged from solution in a gas–liquid separator and swept into an atomic absorption spectrometer for detection and quantification by cold vapor atomic absorption spectrometry following standardized procedures (EPA, 1991; Booeshahgi et al., 1995). Quality control measures included analysis of laboratory method blanks, duplicate or triplicate tissue samples, duplicate matrix spikes, and standard fish-tissue reference material (DOLT-2, obtained from the National Research Council of Canada) for each group of 20 or fewer fish samples analyzed (EPA, 1991; Frick, 1996). Total mercury levels are reported as parts per million (ppm) wet weight.

Linear and nonlinear regressions were used to describe relationships between fish size and total mercury concentration. When appropriate, mercury data used in regressions were log transformed to meet homoscedasticity requirements. A t-test or Mann–Whitney Rank Sum test, as appropriate, was used to test for significant differences in total mercury levels in males and females of each tuna species, and for significant differences in the sizes of males and females of each tuna species.

3. Results

3.1. Yellowfin tuna

A total of 56 yellowfin tuna ranging from 602 to 1340

mm FL (X ¼ 847 mm FL) were analyzed for total mercury (Table 1). Seventy-seven percent of the yellowfin tuna examined were of legal size (P690 mm FL in US Atlantic waters). Of 56 examined, 31 were male, 22 female, and 3 could not be sexed. Total mercury levels ranged from 0.068 to 0.65 ppm with a mean of 0.25 and a median of 0.22 ppm. Total mercury levels were positively related to fish length (P < 0:0001) (Fig. 2) and to fish total weight (P < 0:0001) (Fig. 3).

Females examined in this study (X ¼ 904 mm FL) were significantly larger than males (X ¼ 790 mm FL) (Mann–Whitney rank sum test, P < 0:05). Mercury

levels for females (X ¼ 0:30 ppm, median 0.29 ppm) were significantly higher than for males (X ¼ 0:21 ppm, median 0.17 ppm) (t-test, P < 0:05), due likely in part to these size differences.

Only two individuals (approximately 3.6% of all yellowfin tuna and 4.6% of all legal-sized yellowfin tuna examined) contained levels greater than or equal to the 0.5 ppm threshold level set by DOH. Both fish (1115 and 1131 mm FL) were of legal size.

3.2. Blackfin tuna

Thirty-seven blackfin tuna, 452–860 mm FL (X ¼ 732 mm FL), were analyzed for total mercury (Table 1). There is currently no minimum size limit on this species in US Atlantic waters. The majority (75.7%; n¼ 28) of blackfin tuna examined in this study were male. Total mercury levels ranged from 0.16 to 2.0 ppm with a mean of 1.07 and a median of 1.10 ppm. Total mercury levels were positively related to fish length (P < 0:0001) (Fig. 4) and to fish total weight (P < 0:0001).

Total mercury levels in tuna species from coastal and offshore waters of the Atlantic coast of Florida

Species	Number	Fork length (mm)			Total mercury (ppm wet weight)				
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	Median	Standard deviation
Yellowfin tuna, Thunnus albacares	56	847	602	1340	0.25	0.068	0.65	0.22	0.12
Blackfin tuna, Thunnus atlanticus	37	732	452	860	1.07	0.16	2.0	1.10	0.54
Little tunny, Euthynnus alletteratus	114	594	320	803	0.94	0.11	3.4	0.86	0.60

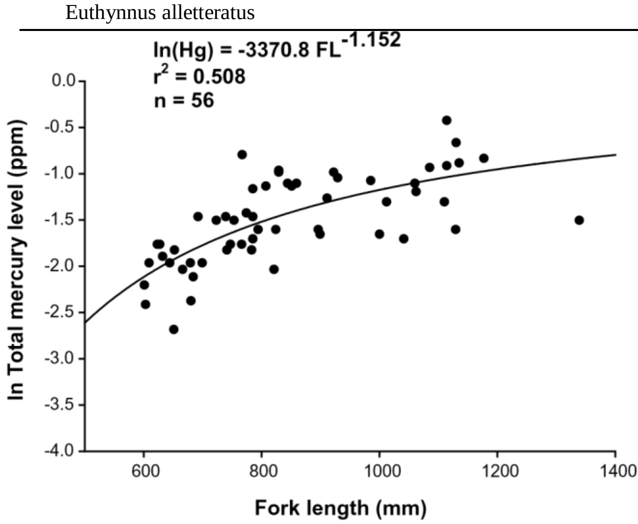

Fig. 2. Relationship between total mercury levels (ppm) and fork lengths (mm) of yellowfin tuna, Thunnus albacares, from offshore waters of the Atlantic coast of Florida.

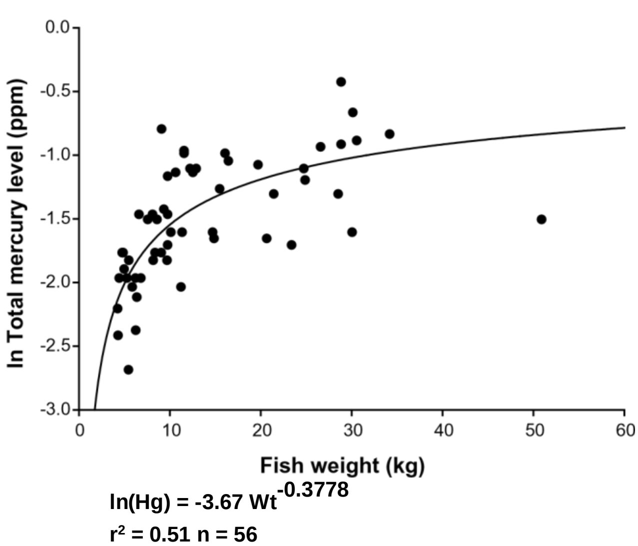

Fig. 3. Relationship between total mercury levels (ppm) and total fish weights (kg) of yellowfin tuna, Thunnus albacares, from offshore waters of the Atlantic coast of Florida.

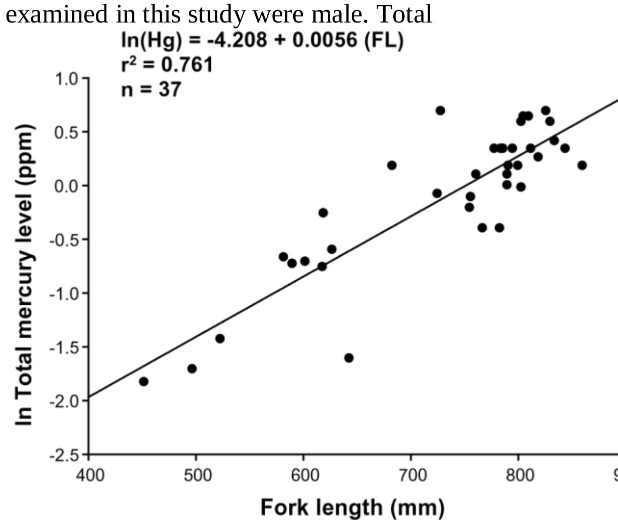

Fig. 4. Relationship between total mercury levels (ppm) and fork lengths (mm) of blackfin tuna, Thunnus atlanticus, from offshore waters of the Atlantic coast of Florida.

Male blackfin tuna examined in this study (X ¼ 747 mm FL) were significantly larger than females (X ¼ 683 mm FL) (Mann–Whitney rank sum test, P < 0:05); however, mercury levels were not significantly different between the sexes (t-test, P < 0:05).

Approximately 81% of all blackfin tuna analyzed contained total mercury levels greater than or equal to the 0.5 ppm threshold level set by DOH. Approximately 19% of all blackfin tuna contained total mercury levels greater than or equal to the DOH's 1.5 ppm no-consumption level.

3.3. Little tunny

A total of 114 little tunny, 320–803 mm FL (X ¼ 594 mm FL) were analyzed for total mercury (Table 1). Sizes of fish examined were representative of those often encountered by recreational fishermen off the Atlantic coast of Florida; there is currently no minimum size limit on this species in US Atlantic waters. Of the 82 little tunny for which sex was determined, 52 were male, 30 female. Total mercury levels ranged from 0.11 to 3.4 ppm with a mean of 0.94 and a median of 0.86 ppm. Total mercury levels were positively related to fish length (P < 0:0001) (Fig. 5) and to fish total weight (P < 0:0001) (Fig. 6).

Although male little tunny examined in this study (X ¼ 637 mm FL) were significantly larger than females (X ¼ 607 mm FL) (Mann–Whitney rank sum test, P < 0:05), mercury levels were not significantly different between the sexes (t-test, P < 0:05).

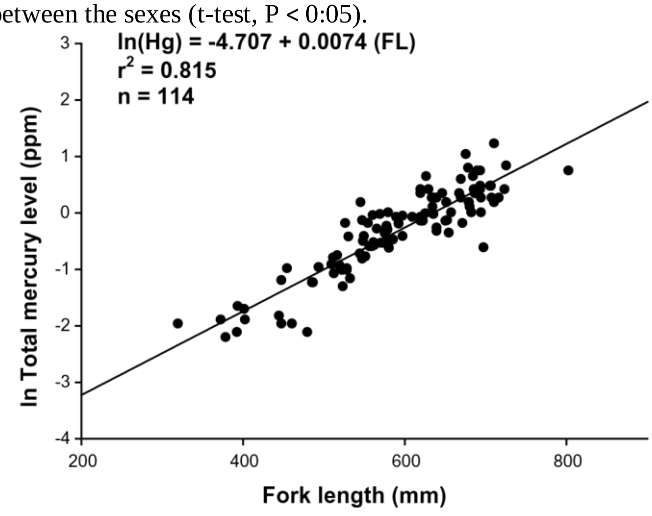

Fig. 5. Relationship between total mercury levels (ppm) and fork lengths (mm) of little tunny, Euthynnus alletteratus, from coastal and offshore waters of the Atlantic coast of Florida.

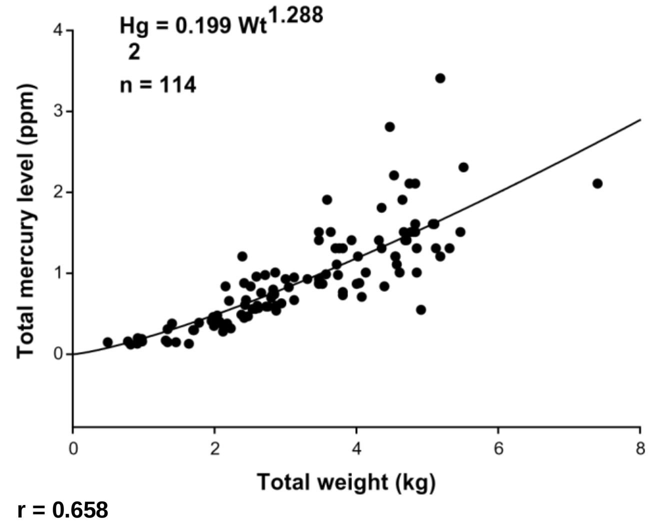

Fig. 6. Relationship between total mercury levels (ppm) and total fish weight (kg) of little tunny, Euthynnus alletteratus, from coastal and offshore waters of the Atlantic coast of Florida.

Approximately 75% of all little tunny examined contained total mercury levels greater than or equal to the 0.5 ppm threshold level set by DOH. Approximately 18% of all little tunny contained total mercury levels greater than or equal to the DOH's 1.5 ppm no-consumption level.

4. Discussion

Limited information exists regarding mercury in tunas from U.S. Atlantic waters. In an earlier study by the National Marine Fisheries Service (NMFS), 50 muscle samples from little tunny collected from the northern Gulf of Mexico were analyzed (Hall et al., 1978). It is not clear if total length, standard length, or fork length were measured in the NMFS study; fish examined ranged from 560 to 750 mm (X ¼ 647 mm). Total mercury for these fish ranged from 0.31 to 1.75 ppm (X ¼ 0:806 ppm) (Hall et al., 1978). The mean and maximum total mercury levels recorded by Hall et al. (1978) were lower than those observed in this study, but sampling procedures and analytical methods used in the two studies may not be directly comparable.

Total mercury levels in the three tuna species examined were clearly different. Yellowfin tuna mercury levels were relatively low for all size-classes examined, and very few individuals had levels greater than or equal to the DOH's 0.5 ppm threshold level. A high percentage of blackfin tuna and little tunny samples contained levels greater than or equal to 0.5 ppm. Several factors are likely responsible for the observed differences in mercury levels in the three species. For marine fishes, dietary exposure is an important source of total mercury (Wang, 2002), and differences in the feeding ecology of these species likely influence observed mercury burdens. All three species principally consume a variety of fish, crustaceans, and mollusks (Dragovich, 1969, 1970; Dragovich and Potthoff, 1972; Manooch and Mason, 1983; Manooch et al., 1985). In waters off the southeastern United States, small fishes are the dominant prey for both blackfin and little tunny based on percent volume and an index of relative importance (Manooch and Mason, 1983; Manooch et al., 1985). Although fish are well represented in the diet of yellowfin tuna from this region, cephalopods (principally squid) are a very important prey for this species. Cephalopods are a smaller component in the diets of either blackfin or little tunny than they are in the diet of yellowfin tuna (Manooch and Mason, 1983; Manooch et al., 1985). Total mercury levels in several squid species from the Atlantic Ocean are typically low (<0.1 ppm) (Hall et al., 1978; Law et al., 1997) and may be lower than the levels in many of the fish species typically consumed by tunas in Florida offshore waters.

Yellowfin tuna, blackfin tuna, and little tunny are classified as highly migratory species capable of traveling great distances (FAO, 1997), and determination of spatial trends in mercury levels within and between these species may be difficult. Blackfin tuna and little tunny are neritic in distribution, whereas yellowfin tuna are truly oceanic, typically found farther offshore in Florida waters. Differences may exist between the mercury concentrations in prey available in neritic and oceanic habitats off the southeastern US, but at present, this aspect is poorly understood.

Information regarding age and growth of these species in waters of the southeast US is limited, and specific ages of individuals examined in this study have not yet been determined. Differences in age, growth rates, and related physiological aspects likely influence mercury concentrations in the muscle tissue of these species. Of the age and growth of the three species, we know most about yellowfin tuna, principally from populations in the eastern Atlantic, Indian and Pacific oceans. Preliminary estimates of ages of yellowfin tuna from this study, based on length-at-age data for tuna from other regions (Wild, 1986; Stequert et al., 1996), indicate that the majority of fish sampled are between 1.5 and 2.5 years old.

No reliable age and growth information is available for blackfin tuna and little tunny in the region. Age and growth differences may exist between these species and yellowfin tuna which could help further explain the disparity in mercury levels observed in this study. Significant positive relationships between total mercury levels and fish length and fish weight for all three tuna species suggest that mercury levels increase as these fish grow.

Our results indicate that most yellowfin tuna examined to date from Florida's Atlantic waters contain low mercury levels, relative to current regulatory levels and other tuna species analyzed. Mercury levels in the majority of blackfin tuna and little tunny examined were greater than 0.5 ppm, supporting the current DOH fish consumption advisory that urges limited consumption of these species. Analysis of additional samples from Florida and adjacent waters of the southeastern United States will help to better understand mercury levels in tuna species from this region.

Acknowledgements

We thank the staff of the FDEP Division of Technical Services for the laboratory analysis that made this study possible. The efforts of staff from FWC-FMRI Fisheries Assessment who assisted in collecting tuna and processing samples were greatly appreciated. Also, many thanks to the recreational anglers from Florida who allowed us access to their tuna. J. Leiby, G. Onorato, R. Paperno, J. Quinn, and R. Ruiz-Carus offered helpful suggestions for improving the manuscript. This study was supported in part by funding from the Department of the Interior, US Fish and Wildlife Service, and Federal Aid in Sport Fish Restoration, Project F-43, as well as by State of Florida Saltwater Fishing License monies.

doi:10.1016/j.marpolbul.2004.06.005

References

Adams, D.H., McMichael, R.H. Jr., Henderson, G.E., 2003. Mercury levels in marine and estuarine fishes of Florida: 1989–2001. Florida Marine Research Institute Technical Report TR-9. second ed. Rev. pp. 57.

Booeshahgi, F., Witt, M., Cano, K., 1995. Analysis of total mercury in tissue by cold vapor atomic absorption. Florida Department of Environmental Protection, Division of Technical Services, Tallahassee, MT-010-1.

DOH (Florida Department Of Health). 2003. Florida Fish Consumption Advisories. Tallahassee, Florida. pp. 7.

Dragovich, A., 1969. Review of studies of tuna food in the Atlantic Ocean. US Fish Wildlife Service, Special Science Report—Fisheries. No. 593. pp. 21.

Dragovich, A., 1970. The food of skipjack and yellowfin tunas in the Atlantic Ocean. Fishery Bulletin 68 (3), 445–460.

Dragovich, A., Potthoff, T., 1972. Comparative study of food of skipjack and yellowfin tunas off the coast of West Africa. Fishery Bulletin 70 (4), 1087–1110.

EPA (US Environmental Protection Agency). 1991. Determination of mercury in tissues by cold vapor atomic absorption spectrometry: method 245.6 (revision 2.3). US Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Cincinnati, Ohio. pp. 13.

FAO (Food and Agriculture Organization of the United Nations). 1997. Review of the state of world fishery resources: marine fisheries (English). Special topics. Global resources of tuna and tuna-like

species. In: FAO Fisheries Circular (FAO), no. 920 / FAO, Rome (Italy). Fishery Resources Division, pp. 177.
Frick, T., 1996. Digestion of fish tissue samples for total mercury analysis. Florida Department of Environmental Protection, Division of Technical Services, Tallahassee. MT-015-1.
Hall, R.A., Zook, E.G., Meaburn, G.M., 1978. National marine fisheries service survey of trace elements in the fishery resource. NOAA Technical Report NMFS SSRF-721. pp. 313.
Law, R.J., Morris, R.J., Allchin, C.R., Jones, B.R., 1997. Metals and chlorobiphenyls in tissues of sperm whales (Physeter macrocephalus) and other cetacean species exploiting similar diets. Bulletin De L'Institut Royal Des Sciences Naturelles de Belgique. BelgiqueBiologie 67 (Suppl.), 79–90.
Manooch III, C.S., Mason, D.L., 1983. Comparative food studies of yellowfin tuna, Thunnus albacares, and blackfin tuna, Thunnus atlanticus (Pisces: Scombridae) from the southeastern and gulf coasts of the United States. Brimleyana 9, 33–52.
Manooch III, C.S., Mason, D.L., Nelson, R.S., 1985. Foods of the little tunny, Euthynnus alletteratus, collected along the southeastern and gulf coast of the United States. Bulletin of the Japanese Society of Scientific Fisheries 51 (8), 1207–1218.
Stequert, B., Panfili, J., Dean, J.M., 1996. Age and growth of yellowfin tuna, Thunnus albacares, from the western Indian Ocean, based on otolith microstructure. Fishery Bulletin 94, 124–134.
Wang, W., 2002. Interactions of trace metals and different marine food chains. Marine Ecology Progress Series 243, 295–309.
Wild, A., 1986. Growth of yellowfin tuna, Thunnus albacares, in the eastern Pacific Ocean based on otolith increments. Inter-American Tropical Tuna Commission, Bulletin 18, 421–482.