MERCURY LEVELS IN FLORIDA SHARKS: INTERIM REPORT

BIODIVERSITY RESEARCH INSTITUTE

SFSSP

BioDiversity Research Institute (BRI) is a nonprofit organization located in Gorham, Maine. Founded in 1998, BRI is dedicated to progressive environmental research and education that furthers local, regional and global sustainability and conservation policies. BRI's research efforts emphasize conservation biology issues in New England and across North and Central America.

The South Florida Student Shark Program (SFSSP) is a collaborative, multi-disciplinary research and education program supporting the career development for graduate, undergraduate as well as high school students. Founded in 2006, the SFSSP is a partnership among the University of Miami Rosenstiel School, The Explorers Club & the Herbert W. Hoover Foundation. Focusing on the study and conservation of Floridian shark species, mangrove fish habitat and the Florida watershed, the program encourages students to take an active role in modern scientific education & research. The SFSSP's full-immersion approach allows students to actively grow as future scientists, while supporting the important ongoing research crucial to shark conservation.

To obtain copies of this report contact:

BioDiversity Research Institute
19 Flaggy Meadow Road
Gorham, ME 04038
(207) 839-7600

david.evers@briloon.org
www.BRIloon.org

Photo Caption: *Tiger shark (Galeocerdo cuvier) by Neil Hammerschlag).*

Suggested Citation: *Evers, D.C., N. Hammerschlag & D. Die. 2008. Mercury levels in Florida sharks: Interim Report. Report BRI 2008-02, BioDiversity Research Institute, Gorham, Maine.*

MERCURY LEVELS IN FLORIDA SHARKS

(BRI Report no. 2008-02)

Submitted by:

David Evers
BioDiversity Research Institute
19 Flaggy Meadow Road
Gorham, Maine 04038
(207-839-7600)
david.evers@briloon.org

Neil Hammerschlag
South Florida Student Shark Program
Rosenstiel School of Marine & Atmospheric Science
Unviersity of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
nhammerschlag@rsmas.miami.edu

David Die
South Florida Student Shark Program
Rosenstiel School of Marine & Atmospheric Science
Unviersity of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
ddie@rsmas.miami.edu

Submitted on:

April 7, 2008

Please Note: This interim report is the results of a pilot study, the contents of which have not yet been peer reviewed. Please do not distribute nor use to generate press releases. Research is currently underway to increase sample sizes and generate robust peer-reviewed publications for distribution.

MERCURY LEVELS IN FLORIDA SHARKS

Background

The anthropogenic release of mercury through air emissions and water effluents is a broad concern by local, regional, American (USEPA 2005) and international decision-makers (UNEP 2006). Atmospheric deposition of mercury has links to many sources in the United States, including municipal incinerators, chlor-alkali plants, various mining activites, and coal-fired utilities. These and other sources can cause biological mercury hotspots to form (Evers et al. 2007), especially within landscapes that have an ability to effectively methylate the environmental inorganic mercury loads (Driscoll et al. 2007). Marine systems are sensitive to environmental mercury inputs, particularly in shallow, in-shore waters near large local sources (Fitzpatrick et al. 2007).

In the southeastern United States, Hg is prevalent and the U.S. Fish and Wildlife Service considers it as "being the most serious environmental threat to the well being of fish and wildlife resources" for that region (Facemire et al. 1995). In particular, Florida has a well-documented problem of methylmercury bio-amplification in its freshwater ecosystems. Apex predators such as wading birds have exhibited high mercury exposure and at levels that are considered detrimental to them (Heath and Frederick 2005). Recently, reductions of air pollutants, including mercury, have resulted in the lowering of mercury in freshwater fish and bird tissues, which has even been linked to the reversal of poor reproductive success in wading birds (Frederick et al. 2004). How these spatial and temporal trends manifest in Florida's near-shore marine environment is relatively unknown.

As long-lived, apex predators, various shark species are good indicators for measuring spatial and temporal trends in methylmercury availability for Florida's near-shore marine waters. Sharks are well known for their ability to biomagnify methylmercury and harbor levels that are unsafe for human consumption. Mercury levels in shark muscle tissue regularly exceed the U.S. Environmental Protection Agency (USEPA) action level for human consumption of 0.30 ug/g, (wet weight [ww]) for many areas of the world, such as the northeast Atlantic (Branco et al. 2004), southwest Atlantic (Pinho et al. 2002), Mediterranean Sea (Storelli et al. 2002), Gulf of California (Garcia-Hernandez et al. 2007), and Australian waters (Lyle 1984). Mercury levels in Florida sharks were measured in near-shore and off-shore waters of east-central Florida from

1992-1995 and the majority exceeded the threshold level currently used by Florida for human consumption of 0.50 ug/g (ww) (Adams and McMichael 1999).

Further information on how methylmercury is distributed in the marine system that sharks use is needed because (1) human consumption of shark muscle continues, (2) generic Hg action levels used for sharks need greater resolution that uses species and are ultimately spatially explicit and (3) many shark populations are declining and the impacts of environmental stressors such as mercury pollution are undescribed.

In 2006-2007, we conducted a pilot study to opportunistically capture and non-lethally and relatively non-invasively sample sharks from Biscayne Bay and Florida Bay in southeastern Florida. Results from this effort are comparable to a similar set of species and size classes from an area on the Florida coastline approximately 100 miles north of our pilot study by Adams and McMichael (1999).

Study Area and Methods

All sharks were captured and sampled along Florida's southeastern coast in Biscayne Bay and among islands near the Everglades National Park (Figure 1).

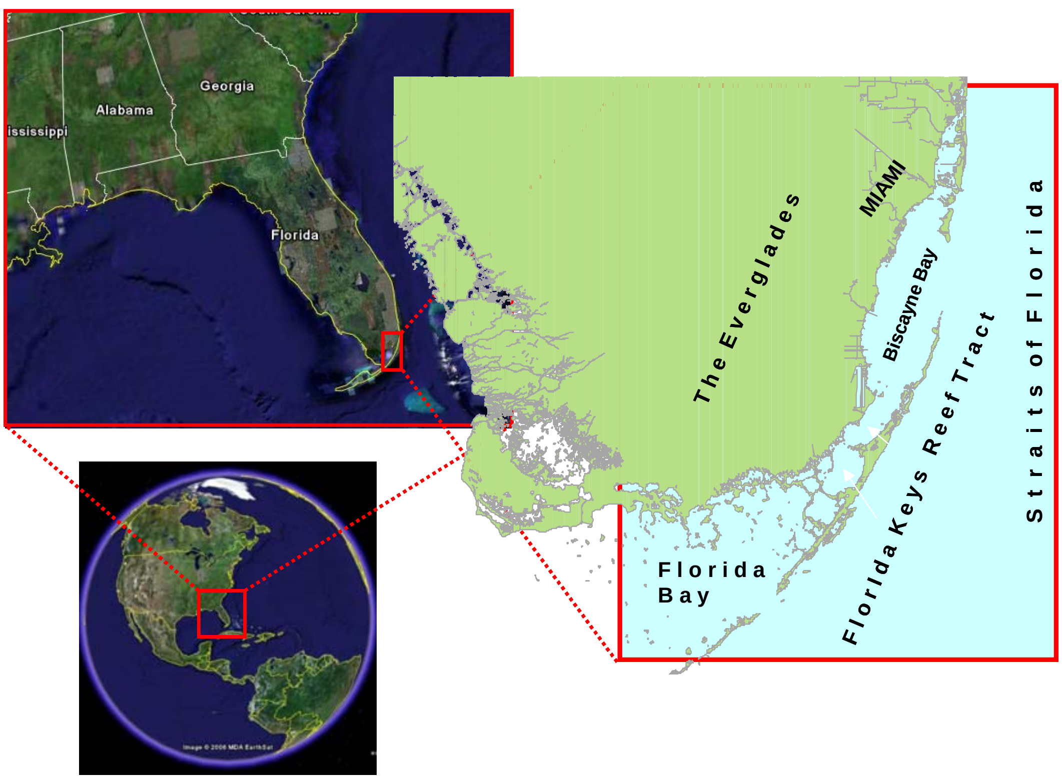

Figure 1. Florida study area.

Sharks were live-captured and sampled using well-established methods. Once captured, a small hepaxial muscle biopsy was taken from below the dorsal fin using a 4 mm (Figure 2). This muscle tissue was then placed in a sealed microtainer, labeled, and frozen. Laboratory analysis of the muscle tissue used cold vapor atomic absorption to determine total Hg levels using well-established methods. Percent moisture was determined to enable confident wet weight (ww) values.

Figure 2. 4-mm muscle biopsy being taken

Results and Discussion

Absolute mercury levels in sharks

In our study, 101 sharks representing five species were sampled and analyzed for mercury exposure in 2006 and 2007, primarily in Florida Bay and Biscayne Bay (Figure 3). The nurse shark had the lowest mean mercury level (0.05 +/- 0.05 ug/g, ww) and is likely feeding relatively low in the foodchain (Figure 4). The Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) had the next highest mean mercury level of 0.56 +/- 0.52 ug/g (ww) and was approximately half of the levels found in the 1992 to 1995 study. The mean Hg level in seven lemon sharks (*Negaprion brevirostris*) is 0.60 +/- 0.35 ug/g (ww) and is compared with the bull shark (*Carcharhinus leucas*) as both species tend to feed on pelagic organisms. The bonnethead shark (*Sphyrna tiburo*) had a mean mercury level of 0.89 +/- 0.62 ug/g (ww). It was nearly double the levels found in the 1992 to 1995 study. Four blacktip sharks (*Carcharhinus limbatus*) were sampled and their mean mercury level was 3.31 +/- 0.57 ug/g (ww) and was well above other species from our 2006-2007 pilot study as well as blacktip sharks from Adams and McMichael (1999).

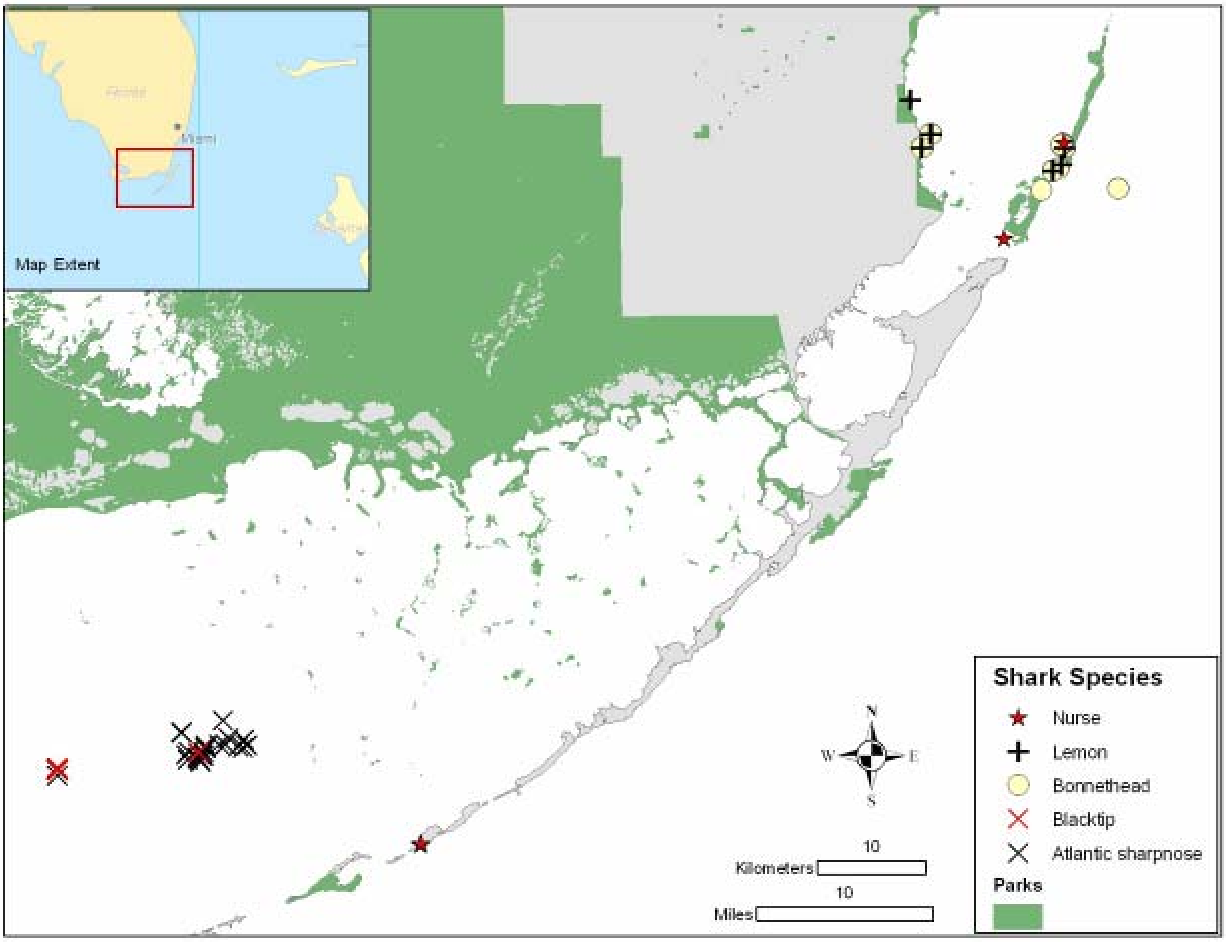

Figure 3. Distribution of sharks sampled in Florida Bay and Biscayne Bay.

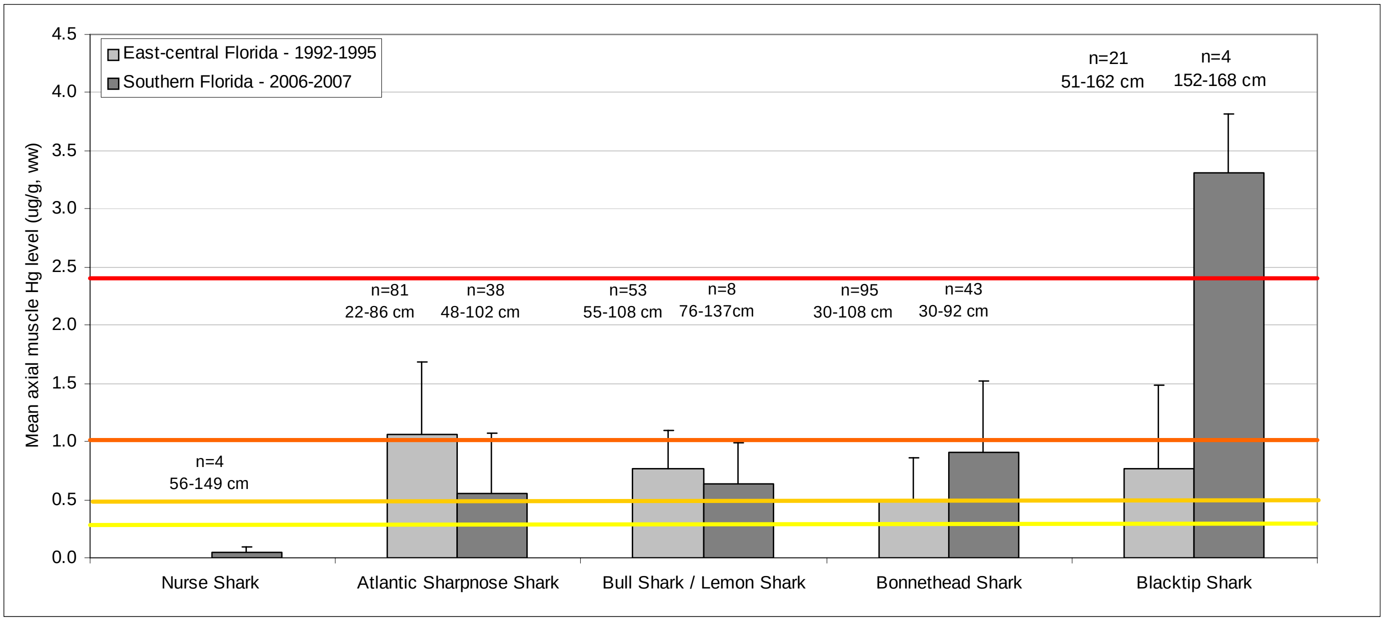

Figure 4. Arithmetic mean (+/- sd) of Hg levels in six shark species[1]. Our pilot study represents southern Florida in 2006 and 2007. A comparison is made with a nearby study by Adams and McMichael (1999) of sharks sampled in east-central Florida from 1992-1995.

Shark Hg levels correlate with length

Fish length is positively correlated with Hg (Fitzgerald et al. 2007), including sharks (Hueter et al. 1995; Lacerda et al. 2000; Pinho et al. 2002). This relationship is not necessarily highly correlated in all species (Evers and Graham 2007). In our Florida study, we compared the length and muscle Hg levels of the bonnethead (Figure 5) and Atlantic sharpnose (Figure 6) sharks and found a significant and positive correlation, although there was high variation. As with studies in Belize with the Caribbean sharpnose shark (*Rhizoprionodon porosus*) by Evers and Graham (2007), the relationship in length and muscle Hg levels for the Atlantic sharpnose shark were weak.

[1] The yellow line is the USEPA action level for human health concerns (0.30 ug/g, ww). The orange-yellow line is the Florida Department of Environmental Protection (FLDEP) human health advisory (0.50 ug/g, ww). The orange line is the Federal Drug Administration (FDA) action level for human health concerns (1.0 ug/g, ww). The red line is the adverse effects level to freshwater fish (2.37 ug/g, ww).

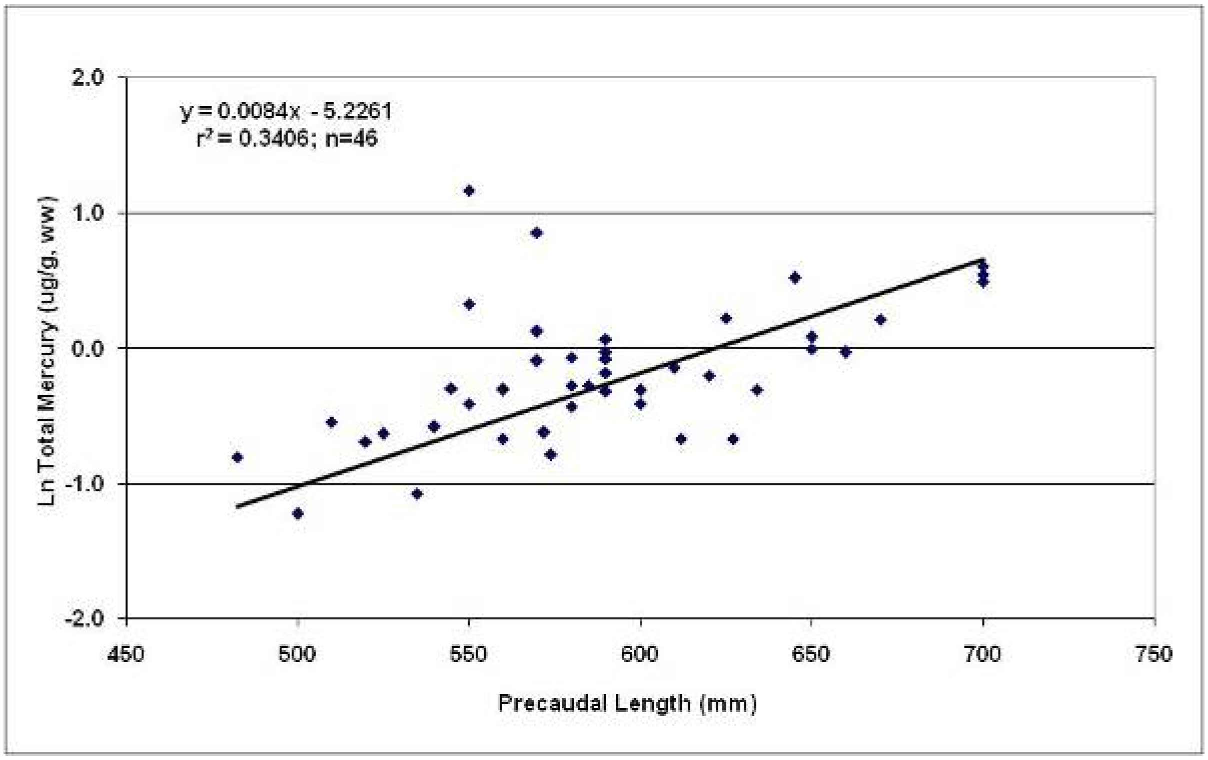

Figure 5. Relation between Hg levels and precaudal length for bonnethead shark.

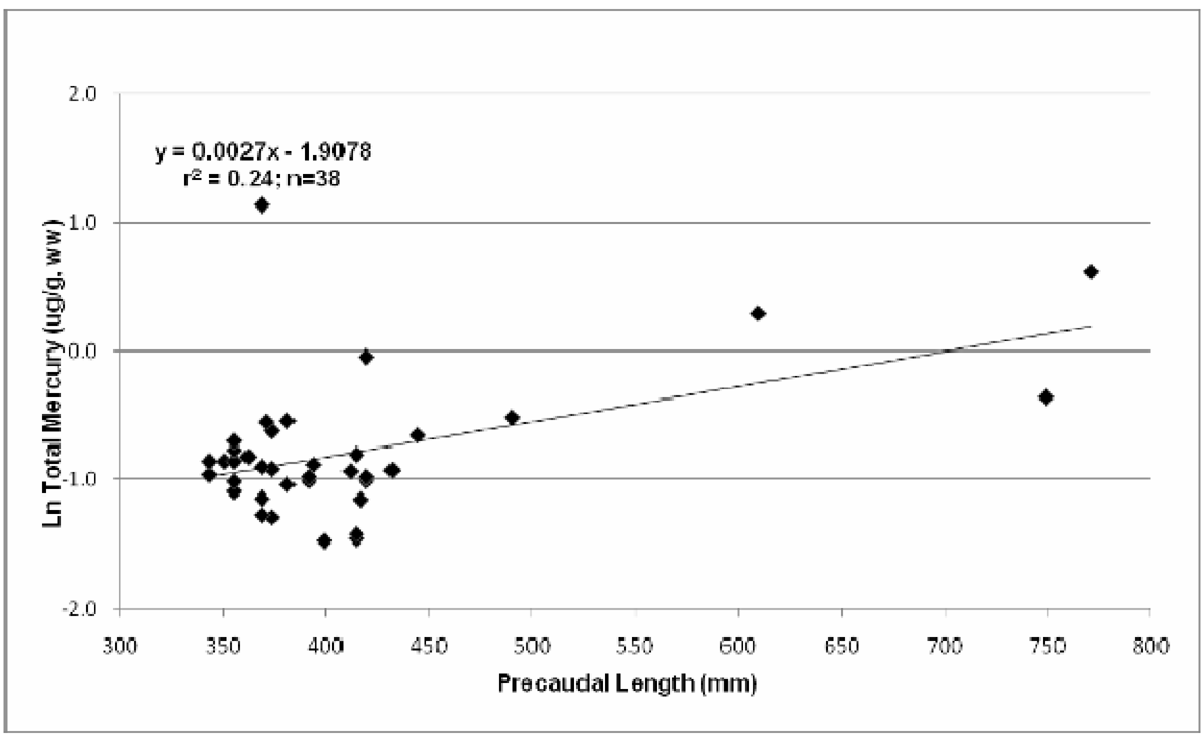

Figure 6. Relation between Hg level and precaudal length for Atlantic sharpnose shark.

Normalized mercury levels in sharks

Because Hg levels correlate with overall length, they are therefore normalized to better compare across species. Shark Hg levels normalized by total length indicate a ranking pattern similar to the absolute shark Hg levels (Figure 7, 8). Nurse sharks have the lowest exposure to Hg and blacktip sharks have the highest, however, the disparity between bonnethead sharks and blacktips sharks is not as distinct. Mercury levels in Atlantic sharpnose sharks, normalized for size, appear to be higher than lemon sharks.

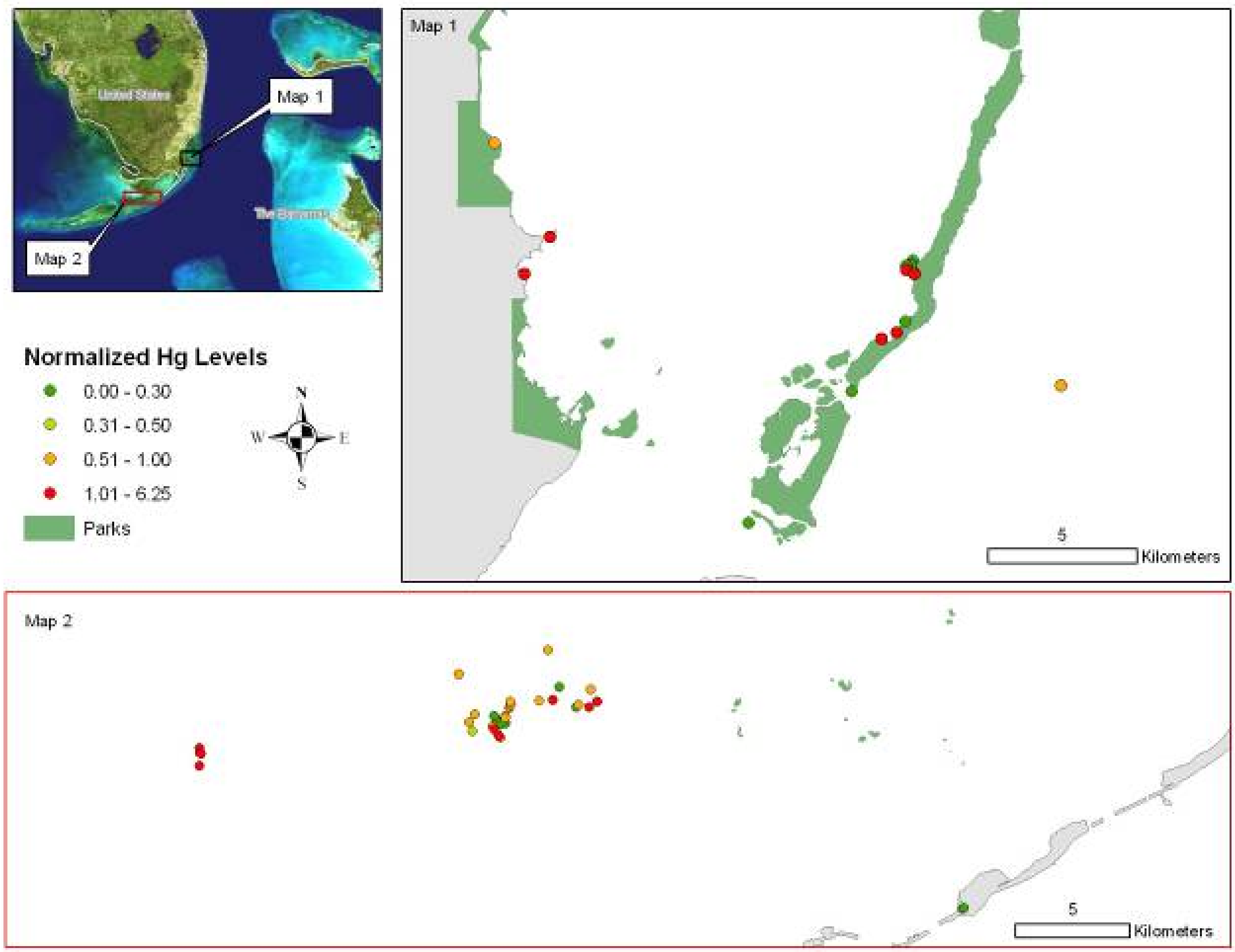

Figure 7. Geographic pattern of normalized Hg levels.

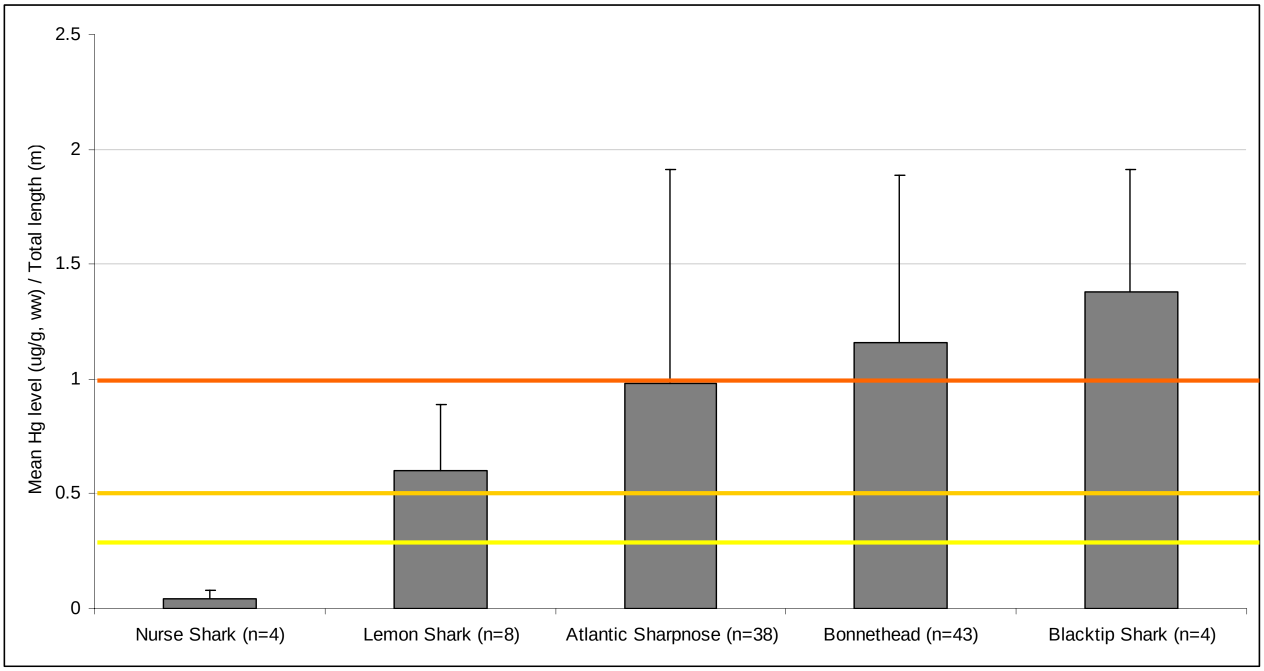

Figure 8. Normalized Hg levels in sharks sampled in 2006 and 2007[2].

Ecological concerns

Well-described effect levels for Hg on sharks or other elasmobranches are not available. Effect levels for teleost fish are also poorly described. Friedmann et al. (1996) demonstrated through a dosing study that young walleye with a mean muscle Hg level of 2.37 ug/g, ww (the high dose) had significant growth and reproductive impacts. Two species of sharks from the Florida study area had muscle Hg levels above the effects level; each of the four blacktip sharks were above the effect level. The potential impacts of Hg poisoning to sharks needs to be better understood for purposes of shark conservation.

Human health concerns

The majority of shark muscle Hg levels in our southeastern Florida dataset were greater than levels safe for consumption by sensitive groups of people, such as young children and

[2] The yellow line is the USEPA action level for human health concerns (0.30 ug/g, ww). The orange-yellow line is the Florida Department of Environmental Protection (FLDEP) human health advisory (0.50 ug/g, ww). The orange line is the Federal Drug Administration (FDA) action level for human health concerns (1.0 ug/g, ww).

pregnant women (Table 1). While the level of an unsafe dietary uptake of methylmercury for humans is debatable, there is broad scientific agreement that the exposure and effects of methylmercury is a worldwide concern and "all efforts need to be made to reduce and eliminate sources of exposure" (Mergler et al. 2007). While commercial fish consumption is the usual source of dietary uptake of methylmercury of concern for the general U.S. population (Hightower and Moore 2003), sportfish consumption (Knobeloch et al. 2007) and subsistence fisheries (Jewet and Duffy 2007) can also be of concern.

The risk of dietary uptake of methylmercury for humans is well-established as being high. Mean muscle Hg levels for the U.S. Federal Drug Administration (FDA) dataset on sharks (n=351) is 0.99 ug/g (CI = ND to 4.54 ug/g, ww) and is second only to tilefish (multiple species in the family Malacanthidae) mean Hg levels (Fitzgerald et al. 2007). Increased effort is needed to distinguish shark species for Hg advisories general human consumption; the Florida dataset demonstrates that some species are well below the mean of the U.S. FDA dataset (i.e., nurse shark, Atlantic sharpnose shark, and lemon shark), near it (i.e., bonnethead shark), and well above it (i.e., blacktip shark).

Table 1. Percent of individual sharks sampled exceeding various human health advisory levels.

	Sample Size	USEPA	FLDEP	FDA
Nurse Shark	4	0%	0%	0%
Atlantic Sharpnose Shark	38	87%	29%	8%
Lemon Shark	8	78%	67%	22%
Bonnethead Shark	43	93%	87%	26%
Blacktip Shark	4	100%`	100%	100%

Future Sample Sizes:

Our sample sizes for species such as nurse, lemon and blacktip sharks are low, preventing appropriate analysis and interpretation of results. However, we plan to increase our sample size of these and other species in 2008. We have already collected samples from seven more blacktips which have yet to be analyzed and expect to obtain at least another 10 in 2008, bringing our total sample size to over 20 individuals before the end of the year. Similarly, we already have samples yet to be analyzed from seven nurse sharks and expect another 10 before the end of the year, brining our sample size to over 20 individuals. Similar sample sizes are expected for lemon sharks. In addition to these species, we expect to obtain samples for shark previously not examined due to the addition of new sampling methods in shark surveys. In 2008 we expect to obtain samples from species including bull (*Carcharhinus leucas*), tiger (*Galeocerdo cuvier*), blacknose (*Charcharhinus acronotos*) and sandbar sharks (*Charcharhinus plumbeus*). We already have samples yet to be analyzed from four bull shark, one blacknose and one sandbar. We do not expect sample sizes for these species to exceed 10 individuals in 2008.

Recommendations

We recommend further sampling efforts to better understand (1) potential habitats and geographic locations where biological Hg hotspots exist, (2) shark species and populations that are at greatest risk to elevated Hg levels (e.g., blacktip sharks and other higher trophic level species) and (3) the levels of Hg body burdens that can cause physiological, behavioral, and reproductive harm.

A sampling design that further describes Hg profiles by species (including methylmercury ratios and comparisons of muscle tissue and biopsies), size, age and sex, and foodchain length (determined by stable isotope carbon-nitrogen signatures) will provide interpretive strength. Pilot studies that include measures of fitness and reproductive performance will be invaluable for determining lowest observed adverse effect levels.

Both atmospheric deposition and waterborne point sources of mercury can be locally and regionally changed through regulations with evidence of rapid recovery in biota (at least in freshwater systems). Certain water and land management practices can further assist in reducing environmental mercury loads available to near-shore marine organisms. By defining biological Hg hotspots and sharks at greatest risk, ecosystem functions and biotic community structure can be more closely examined for potential negative impacts from Hg on the overall health of shark populations.

Acknowledgments

Special thanks to Richard Curry, Howard Max Tritt, and Elsa Alvear from Biscayne National Park for supervising and supporting field logistics and boat operations. Thanks to PJ Walker from Everglades National Park for project support. Field sampling was conducted by the University of Miami's South Florida Student Shark Program; special thanks to Dan Ovando, Leann Winn, Anthony DiSilvestro, Liz Dacko, Annie Morgan, Sabrina Garcia, Adam Matulik and Daniell Washington. Chris Perkins of the University of Connecticut supervised all laboratory analysis. Funding and in-kind support for this project was provided by the BioDiversity Research Institute, The Southern Florida Chapter of the Explorers Club, the NOAA LMRCSC, the Herbert W. Hoover Foundation, Mote Marine Laboratory and Biscayne National Park. Research was conducted under permits BISC-2008-SCI-0005, EVER-2008-SCI-0001, FWC-05SR-957 and IACUC-05244.

Neil Hammerschlag with nurse shark

Literature Cited

Adams, D.H. and R.H. McMichael, Jr. 1999. Mercury levels in four species of sharks from the Atlantic Coast. Fisheries Bulletin 97:372-379.

Branco, V., J. Canario, C. Vale, J. Raimundo, and C. Reis. 2004. Total and organic mercury concentrations in muscle tissue of the blue shark (*Prionace glauca* L. 1758) from the Northeast Atlantic. Marine Pollution Bull. 49:854-874.

Driscoll, C.T., Y.J. Han, C.Y. Chen, D.C. Evers, K.F. Lambert, T.M. Holsen, N.C. Kamman, and R. Munson. Mercury contamination in remote forest and aquatic ecosystems in the northeastern U.S.: Sources, transformations and management options. Bioscience 57:17-28.

Evers, D.C. and R. T. Graham. 2007. Assessing the global threat of mercury: A case study of the Mesoamerican Reef –with preliminary findings for sharks and groupers. BRI Report submitted to the Henry Foundation. BioDiversity Research Institute, Gorham, Maine.

Evers, D.C., Y.J. Han, C.T. Driscoll, N.C. Kamman, M.W. Goodale, K.F. Lambert, T.M. Holsen, C.Y. Chen, T.A. Clair, and T. Butler. Identification and Evaluation of Biological Hotspots of Mercury in the Northeastern U.S. and Eastern Canada. Bioscience 57:29-43.

Facemire, C; Augspurger, T; Bateman, D; Brim, M; Conzelmann, P; Delchamps, S; Douglas, E; Inmon, L; Looney, K; Lopez, F; Masson, G; Morrison, D; Morse, N; Robison, A. 1995. Impacts of mercury contamination in the southeastern United States.Water, Air, & Soil Pollution 80:923-926.

Frederick PC, Hylton B, Heath JA, Spalding MG. 2004. A historical record of mercury contamination in southern Florida (USA) as inferred from avian feather tissue. 2004. Environmental Toxicology and Chemistry 23:1474-1478.

Friedmann, A.S., M.C. Watzin, T. Brinck-Johnson, and J.C. Leiter. 1996. Low levels of dietary methylmercury inhibit growth and gonadal development in juvenile walleye (*Stizostedion vitreum*). Aquatic Toxicology 35: 265-278.

Garcia-Hernandez, J., L. Cadena-Cardenas, m. Betancourt-Lozano, L.M. Garcia-del-la-Parra, l. Garcia-Rico, and F. Marquez-Farias. 2007. Total mercury content found in edible tissues of top predator fish from the Gulf of Calfornia, Mexico. Toxicol. Environ. Chem. 89:507-522.

Heath, J.A. and P.C. Frederick. 2005. Relationships among mercury concentrations, hormones, and nesting effort of white ibises (*Eudocimus albus*) in the Florida Everglades. Auk 122:255-267.

Hightower, J.M.and D. Moore. 2003. Mercury levels in high-end consumers of fish Environ. Health Perspectives 111:604-608.

Hueter, R.E., W. G. Fong, G. Henderson, M. F. French, and C. A. Manire. 1995. Methylmercury concentration in shark muscle by species, size and distribution of sharks in Florida coastal waters. Water, Air, Soil Pollut. 80: 893-899

Jewett, S.C. and L.K. Duffy. 2007. Mercury in fishes of Alaska, with emphasis on subsistence species. Science Total Environ. *In Press*.

Knobeloch, L., G. Gliori, and H. Anderson. 2007. Assessment of methylmercury exposure in Wisconsin. Environ. Research 103:205-210.

Lacerda, L.D., H.H. Paraquetti, R.V. Marins, C.E. Rezend, I.R. Zalmon, M.P. Gomes, and V. Farias. 2000. Mercury content in shark species from the South-Eastern Brazilian coast. Braz. J. Biol. 60:571-576.

Lyle, J.M. 1984. Mercury concentrations in four Carcharhinid and three hammerhead sharks from coastal waters of the Northern Territory. Australian Journal of Marine and Freshwater Research 35:441-451.

Mergler, D., H.A. Anderson, L. Hing Man Chan, K.R. Mahaffey, M. Murray, M. Sakamoto, and A.H. Stern. 2007. Methylmercury exposure and health effects in humans: A worldwide concern. Ambio 36:3-11.

Pinho, A.P., J.R.D. Guimaraes, A.S. Martins, P.A.S. Costa, G. Olavo and J. Valentin. 2002. Total mercury in muscle tissue of five shark species from Brazilian offshore waters: Effects of feeding habit, sex, and length. Environmental Research Section A 89:250-258.

Storelli, M.M., R. Giacominelli-Stuffler, and G. Marcotrigiano. 2002. Mercury accumulation and speciation in muscle tissue of different species of sharks from Mediterranean Sea, Italy. Bulletin of Environmental Contamination and Toxicology 68:201-210.

[UNEP]. United Nations Environment Program. 2002. Global mercury assessment. United Nations, NY.

[USEPA]. United States Environmental Protection Agency. 2005. Technical Support Document for the Final Clean Air Mercury Rule. Office of Air Quality Planning and Standards, Washington, DC.