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MERCURY CONCENTRATIONS IN SOUTH TEXAS GAME FISHES

BY

E. ANTHONY REISINGER, JR.

THESIS

Presented to the Faculty of the Graduate School of

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In Partial Fulfillment

Of the Requirements

For the Degree

MASTER OF SCIENCE INTERDISCIPLINARY STUDIES BIOLOGY

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MERCURY CONCENTRATIONS IN SOUTH TEXAS GAME FISHES

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DEDICATION

This thesis is dedicated to my parents, Corinne Donahue Reisinger and Edward Anthony Reisinger, Sr. who through their love of the sea and its bounties inspired me to pursue an exhilarating career in marine fisheries even though I wanted to be an artist.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the support and cooperation of numerous entities: Texas Sea Grant and Bob Stickney for providing funding and support to make this study possible, NOAA Fisheries, National Seafood Inspection Laboratory and Tony Lowery for analyzing all the fish samples gratis, Cameron County Judge Gilberto Hinojosa, his staff and the Cameron County Commissioners for supporting the project, Genaro Lopez and his students for his guidance, assistance and collection and preparation of samples, David Hicks, a statistical wizard, for his expertise and help in statistics, Nancy Sclight and Gene Paull for helping bridge the gap connecting art and science, my son Anthony S. Reisinger for assistance with the graphics, the Port Mansfield Fishing Tournaments Board of Directors for allowing us to collect samples, the Ladies Kingfish Tournament board of directors for allowing us to collect samples, Tim Bonner with Texas State University Department of Biology and his graduate students for collecting samples at the Port Mansfield Tournaments, Kit Doncaster, National Marine Fisheries Service, for collecting samples at the tournaments, Steve Walker for help in collecting snook, Tom Kilgore for collecting blue crabs, Kirk Wiles and Mike Tennant with the Texas Department of State Health Services for generously providing historic mercury data and references for aquatic species in Texas, and Guillermo Aguilar for his GIS expertise in creating the sample area chart, and Daniele Provenzano for reviewing the defense presentation.

This was truly a cooperative project with many players, and the variety of the participants and volunteers shows willingness to investigate this controversial metal and the impact it has on one of our most passionate pursuits.

ABSTRACT

Mercury (Hg) is one of the most ubiquitous and controversial metals in the world primarily due to the toxicity of the organic form of the metal, methylmercury (MeHg). MeHg is a neurotoxin at high levels, known to manifest its effects on humans primarily through consumption of certain fish and marine mammals, which tend to bioaccumulate MeHg in their tissues over time. Increased fish consumption and, thus, mercury intake in residents of coastal areas necessitates a better awareness of MeHg content in game fish species, thus the subject of this study.

Three hundred thirty-nine tissue samples were taken from 19 south Texas marine species collected primarily at three fishing tournaments in 2004, tested for total Hg concentrations and analyzed with regression analyses and ANOVA. Results of individual species regression analyses all indicate exponential correlations for the comparisons of fish length (curved fork length for pelagic species and total length for the remainder) vs. total Hg. Sampled species were divided into four groups for further analysis: demersal vs. pelagic and inshore vs. offshore. Inshore and demersal fish species were found to exhibit mean concentrations of total Hg of 0.22 and 0.19 ppm. Both offshore and pelagic fish species had higher mean total Hg concentrations of 0.80 ppm. Two species were found to equal or exceed the U.S. Food and Drug Administration's action level of 1.0 ppm for fish. Those were blackfin tuna (*Thunnus atlanticus*) and king mackerel (Scomberomorus cavalla). Tissue samples were analyzed from blue crab (Callinectes sapidus) taken from the Arroyo Colorado, yielding a low unadjusted mean total Hg concentration of 0.15±0.08 ppm for a mean carapace length 14. 5 cm. Consumption limit comparisons are presented for 11 south Texas game fish species using EPA

recommendations based on a reference dose (RfD) of 0.0001 mg/kg of body weight/day (U.S. EPA, 1999). Similar comparisons are offered for different size ranges of nine of those species with significant length to total Hg relationships.

TABLE OF CONTENTS

TITLE PAGE	i
SIGNATURE PAGE	ii
COPYRIGHT	iii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
ABSTRACT	vi
INTRODUCTION	1
Background	1
Study Area	12
Objectives	16
MATERIALS AND METHODS	17
RESULTS	20
CONCLUSIONS AND RECOMMENDATIONS	24
LITERATURE CITED	36
FIGURES	43
TABLES	72
APPENDIX	82
CURRICULUM VITAE	92

INTRODUCTION

BACKGROUND

Health warnings concerning seafood consumption and a number of recent stories touting the benefits of seafood consumption are confusing to the public. Numerous studies document the detrimental effects of ingesting high concentrations of Hg and the subtle effects of long term ingestion of lower doses associated with eating fish. The health benefits of eating fish in relation to omega-3 fatty acids accent the necessity of fish in our diet to a point where it is recommended at least two times a week (U.S. DHHS and U.S. DA, 2005). Confusion tends to lead to avoidance and we need more information pertaining to the fish we eat, especially the ones we catch ourselves.

In March, 2004 the Food and Drug Administration (FDA) and Environmental Protection Agency (U.S. EPA, 2004) issued the following advice for women of child bearing age and children:

"Do not eat Shark, Swordfish, King Mackerel, or Tilefish because they contain high levels of mercury.

- Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.
 - Five of the most commonly eaten fish that are low in mercury are shrimp,
 canned light tuna, salmon, pollock, and catfish.
 - Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

- 2. Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.
- 3. Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions."

This was an historic and unprecedented effort by the FDA and EPA and was met with particular consternation from the tuna industry. The agencies further warned the same group to limit consumption of tuna steaks to one meal or six ounces per week citing higher Hg concentrations in steaks compared to canned light tuna.

Shark, swordfish and king mackerel are considered recreational species in the Gulf of Mexico and Texas. There are also commercial fisheries for these species and tilefish in the Gulf. A plethora of species, including other members of the tuna family, Scombridae, taken in Gulf waters are not subject to warnings and new evidence is emerging concerning game fish and potential mercury (Hg) exposure by anglers and those who consume their catches. Angler consumption varies nationwide from 2 to >200g/day (U.S. EPA, 1997). Recent focus on recreational species and their Hg content (Lowery and Garrett, 2005) is bringing to light an incipient understanding of Hg levels found in our saltwater species.

Mercury is a naturally occurring element that enters the aquatic environment through erosion and weathering of rocks and soil and can be found in most sediments (Foulke, 1994). It is expected to be present in all the sediments found in the Rio Grande Valley of Texas due to the fact the area is a large river delta made up of sediment carried

down from the Rocky Mountains for over two million years (G. Paull, personal communication). The Texas General Land Office (1995) found small amounts of Hg in Rio Grande sediments and suspected sediment Hg may have contributed to poor benthic conditions. They contrarily determined Hg not to be a factor in concurrent sediment toxicity tests. Suspended sediment levels of Hg for the Rio Grande River at Brownsville, Texas and the Arroyo Colorado at Harlingen, Texas were found to average 0.14 ppm and 0.10 ppm in a study by the U.S. Geological Survey conducted from 1996 to 1998 (Horowitz *et. al.*, 2001).

Another natural source of mercury is the degassing from cinnabar (mercuric sulfide) deposits. Deposits common to the Mediterranean basin showed high mercury concentrations measured over the village of Almaden, Spain downwind from the deposits, reflecting atmospheric transport and deposition (Ferrara, R., et. al., 1998). Similar high Hg concentrations (up to 9.06 ppm) were exhibited the edible red swamp crayfish (*Procambarus clarki*), inhabiting streams in the Almaden area (Higueras et. al., 2006). Cinnabar deposits are present in west Texas where historic mining has occurred in the vicinity of the Rio Grande watershed (TX. GLO, 1995). The large multi-state and international drainage area of the Rio Grande may receive Hg deposition from numerous anthropogenic and natural sources.

Hg has significant anthropogenic sources and is found in elevated concentrations associated with human activity. The burning of fossil fuels contributes the heaviest anthropogenic load to the environment with coal burning for electric power the dominant source. A small contribution, ~1% of the total mercury entering the environment comes from domestic wastewater and municipal sewage. Hg is a byproduct of coal combustion

and Texas reservoirs with adjacent coal burning power plants are notorious for high concentrations of MeHg in lake fish populations (Wiles, K., personal communication). Fish methylmercury (MeHg) concentrations frequently increase after the impoundment of reservoirs (Therrialt and Schneider, 1998).

Landfill incineration has been implicated as a major contributor of Hg to the atmosphere; 25% of the total anthropogenic load with coal incineration contributing 65% of the atmospheric load (Slemr and Langer, 1992). Landfill incineration is of particular interest to south Texas since the Matamoros, Mexico landfill, located southeast of Brownsville has frequent fires and the prevailing southeast winds drive the smoke plume toward Cameron County.

Petroleum drilling activities, specifically the drilling mud or barite discarded around offshore drilling rigs, has been found to manifest higher concentrations of Hg than the surrounding area. The correlation was not found for MeHg in the same barite sediments, possibly indicating the Hg was not available for methylation (Neff, 2002).

Some uncertainty exists with respect to estimates of the relative contributions from natural and anthropogenic sources of mercury emissions to the environment reported in the literature. Pirrone et al. (1996) estimated worldwide emissions of mercury at 2,200 tons/year and concluded that natural sources, industrial sources, and the recycling of anthropogenic mercury each contribute about one-third of the current mercury burden in the atmosphere. A major source of the uncertainty is that emissions from terrestrial and marine systems include a "recycled" anthropogenic source component (WHO, 1990). Two major phenomena possibly contributing to recycled MeHg pulses in south Texas are major freeze events and red tide, *Karenia brevis*,

blooms. Both have caused large fish mortalities in past events. Freezes primarily impact the Laguna Madre while red tide affects offshore and inshore areas. Sarica *et. al.* (2004) found two and threefold increases in particulate and total Hg in a Lake Ontario spawning stream after the annual die-off of spawning salmon. They were also able to compare Hg transfer between the aquatic and terrestrial environment due to predation by a bear which may have a comparable situation with anglers removing fish from the laguna.

Carpi (1997) studied the contamination of sludge-amended soil with inorganic Hg and MeHg and the subsequent emission of this mercury contamination into the atmosphere. He reported the routine application of municipal sewage sludge to crop land significantly increased the concentration of both total Hg and MeHg in surface soil from 80 to 6,100 ppb and 0.3 to 8.3 ppb, respectively. A sludge application demonstration was conducted in the Arroyo Colorado watershed on 16 acres of land used for hay production near Harlingen in the 1993. Soil was tested for Hg with no difference shown between control and experimental plots. In spite of treatment, Hg levels in the soil remained at 0.1 ppm immediately following application and eight months later (Lesikar and Lockamy, 1993).

Regardless of the source, Hg eventually settles into the aquatic sediments where it is methylated by bacteria to form MeHg. MeHg in aquatic sediments is a potential source to biota, most notably fish, through transfer in the food chain where its concentration is magnified as it moves up from one trophic level to another. As much as 15% of MeHg in fish tissues can result from gill uptake, but food is the dominant pathway for MeHg accumulation (Hall *et. al.*, 1997). Large predator fishes are thus exposed to higher levels of MeHg from their prey than are smaller predators. The MeHg binds tightly to the

proteins in fish tissue, including muscle. Pelagic fishes are generally considered to be higher in Hg than those lower on the food chain. Schmitt *et. al.* (2005) showed higher mercury levels in piscivores than benthic feeders in the Rio Grande drainage.

Historically the first worldwide attention drawn to MeHg ingestion in humans was Minamata, Japan where fish consumption from the local area of Minamata Bay in the 1950s caused deaths and neurotoxic symptoms in artisanal fishermen, their families and pets – cats in particular. The effects were attributed to a chloride facility, Chisso Chemical Company, which had released massive amounts of Hg that was used in the manufacturing of plastics, into the bay where bacterial action in the sediments converted it to MeHg. The MeHg in turn moved up the food chain where it bioaccumulated in fish species harvested and consumed by local fishermen.

Since then, excessive Hg levels in edible fish have been recognized as a hazard for humans. There is evidence that it may be the cause of subtle neurological impairments when ingested at even low to moderate levels, particularly during the prenatal and early childhood periods (Tollefson and Cordle, 1986; Grandjean et. al., 1997). Present warnings are now targeting women of child bearing age and children, as a result of those findings. Even adult behavior can be changed (decreased manual dexterity) when they are exposed to MeHg from diets that include fish high in MeHg (Lebel, J., et al., 1998). Long-term consumption of Hg may lead to reduced brain weight (Takeuchi, et al., 1996). A major concern for men's health was brought to light by Salomen et. al., (1995) who found Finnish men with the greatest hair mercury content had a two fold coronary heart disease adjusted risk of acute myocardial infarction and a

nearly three fold adjusted risk of cardiovascular death compared with those with lower hair Hg content.

Contrarily, regular fish consumption has been found to be advantageous to human health, presenting a paradox between the potentially harmful effects of mercury and the beneficial effects of eating fish. An overwhelming amount of evidence pointing to the benefits of regular fish consumption has health authorities concerned about consumption warnings associated with Hg. They are afraid consumers will forgo fish in their diet and in turn will be deprived of essential fatty acids such as omega-3s, in particular eicosaheptaenoic acid (EHA) and docosadecaenoic acid (DHA) in order to avoid Hg exposure (Mahaffey, 2004). Consequences of limiting omega-3 fatty acids in the diet can include depression, coronary heart disease, coordination problems, ADHD, dyslexia and colorectal cancer (Hibbeln and Salem, 1995; Latham *et. al.*; 2001; Richardson and Montgomery, 2005).

A defect action level of 1.0 ppm MeHg in commercially sold fish has been set by the FDA to take action to remove a food product from the market (Clarkson, 1997).

Texas has a more strict action level of 0.7 ppm (Wiles, personal communication). Fish with concentrations above the action levels are considered dangerous to human health.

The EPA has established a MeHg reference dose (RfD) for individuals weighing 71.67 kg (158 lb.) of 0.0001mg/kg of body weight/day (U.S. EPA, 1999). An RfD is the highest daily dose the most sensitive member(s) in the population can be exposed to over a lifetime without experiencing any adverse effect(s). The FDA and EPA levels are based on MeHg because it is the toxic form of the metal. However, most reports in the literature for Hg concentrations in fish are based on unadjusted mean total Hg.

Consumption warnings for fish are also primarily based on data with unadjusted total Hg means (Mahaffey, personal communication). It is assumed by the agencies that MeHg makes up a significant portion of the total Hg in most species. Testing for MeHg is more expensive and time consuming than testing for total Hg, which may explain the lack of MeHg concentration data.

In 2000, a Brownsville physician treating a patient with elevated Hg requested the Texas Department of Health to conduct a study of the Brownsville Ship Channel. The physician said the patient's diet had included seafood from the Brownsville Ship Channel and once seafood was eliminated from the diet, mercury levels declined (Ward et. al., 2000). Average total Hg for 23 samples taken in the study, which included two southern flounder (Paralichthys lethostigma), three spotted sea trout (Cynoscion nebulosus), six sheephead (Archosargus probatocephalus), eight black drum (Pogonias cromis), two red drum (Sciaenops ocellata) and three composite blue crab samples (Callinectes sapidus), was 0.116 ppm, and considered safe for consumption. The Texas Department of Health conducted similar sampling in south Texas with records existing back to 1978, but never found high concentrations that might indicate hot spots for Hg contamination (Wiles. 2006). Lopez (personal communication) stated physicians in Brownsville had similar concerns in 1996 with patients showing higher than normal Hg levels in blood tests, supposedly from eating fish caught at the Port of Brownsville. A preliminary study by Lopez (unpublished) showed results from snook (Centropomus undecimalis) and other fish species taken from the port from 1996-1999 with very low levels of mercury, leading the physicians to surmise some item of seafood other than the local fish was responsible for the elevated levels of mercury in the patient's blood.

Fish are not only sources but are also affected by Hg, though they have differing reactions to the metal. Subtoxic doses of MeHg may inappropriately activate fish leucocytes, potentially altering the process that regulates the magnitude and specificity of the fish immune response to environmental pathogens (MacDougal, et. al., 1996). Fish store Hg in differing concentrations in different organs. Ipinmoroti et al., (1997) determined fish in Nigerian lakes had a descending order of metal concentrations in gills, intestine, head and muscle. Some forms of mercury are eliminated at different rates than others. It appears that elemental Hg is excreted faster than MeHg (Trudel and Rasmussen, 1997). Schmitt et. al. (2005) determined fish in the lower reaches of the Rio Grande basin to be in poor condition compared to those in the middle and upper reaches, but found no elevated concentrations of Hg. They attributed the effects to a combination of contaminants. The investigators did surmise that concentrations >0.5 ppm may represent a risk to fish.

The ratio of MeHg to total Hg (wet weight) varies widely among species and between specimens. Typically, MeHg comprises 75 -90% of the total Hg in Gulf of Mexico fishes with some exceptions (K. Mahaffey, personal communication; T. Lowery, personal communication). Total Hg concentration typically increases exponentially with the length of fish (Van Den Broek, 1981; Al-Hashimi *et. al.*, and 1991; Lowery and Garrett, 2005). MeHg remains the most potentially toxic form to humans via ingestion, especially during developmental stages (Inskip and Piotrowski, 1985; Clarkson, 1997; Roegge, 2006).

Recent preliminary analyses conducted for the Hawaiian Department of Health show as little as 25% MeHg vs. total Hg in blue marlin (*Makaira nigricans*) which typically

exhibit high concentrations of total Hg. These findings may eventually ease warnings on consumption of this species in Hawaii, which are presently promulgated due to the lack of knowledge about the effects of the inorganic form (Brooks B., personal communication).

Emerging evidence suggests a need for reexamination of large pelagic fishes with regard to MeHg vs. total Hg concentrations. Lowery (personal communication) said historic information exists indicating king mackerel may have a lower MeHg ratio around 65% of the total Hg. Forsyth *et.al.*(2004) reported ranges of MeHg as a percentage to total Hg in blacktip sharks (46-73%), blue marlin (51-84%), and yellowfin tuna (39-79%).

Gulf of Mexico pelagic fish species are popular fare for anglers and their families. Blue marlin (*M. nigricans*) is commonly consumed in a smoked form. Discarded blue marlin at fishing tournaments in south Texas are often given to charities to feed children and indigent families. More often the large fish are divided among volunteers willing to rid the anglers of the responsibility of discarding the fish after trophy parts such as the bill and tail are removed. Volunteers and their families tend to work tournaments year after year to procure fish for consumption. Other species given to these groups at fishing tournaments are king mackerel (*Scomberomorous cavalla*), sharks (all species), blackfin tuna (*Thunnus atlanticus*), little tunny (*Euthynnus alletteratus*) and wahoo (*Acanthocybium solandri*). King mackerel is well known for high MeHg concentrations, but those who receive donations of that species tend to ignore the warnings. Information on Hg content in other game fish species exists anecdotally but is ignored in favor of the easy availability of large quantities of fresh meat.

King mackerel, a common pelagic species in the Gulf, has the most well documented Hg concentration and is the object of a Texas State Department of State Health Services annual consumption advisory for fish between 37 and 43 inches total length. The advisory, based on a 0.7 ppm action level, includes the entire Texas coast. Adults are advised to limit consumption to one eight ounce meal per week and women of child bearing age and children should limit consumption to one eight ounce meal per month for that length slot. The state advises that king mackerel over 43 inches in total length should not be consumed. Fish of the same species under 37 inches in total length are considered safe for unrestricted consumption (TDHSSD, 2004).

The majority of the population in the study area is Hispanic and a paucity of data exists on fish consumption by Mexican Americans. The best information on Mexican American fish consumption is provided by a California study (Puffer, 1981). He determined median fish consumption for anglers in this group to be 33 g/day, slightly under the 37 g/day for anglers from all ethnic groups in California. Average consumption by the overall U.S. Hispanic population is less than one fish meal per week (Mahaffey et. al., 2004). Seasonal fish consumption in the study area may be higher due to our proximity to the coast and may reach a much higher level, equaling or exceeding one meal per week in the spring. During that time the predominantly Hispanic and Roman Catholic population observes Lent, a 40 day period in preparation for Easter, and more fish is consumed by Catholic Hispanics at that time than any other during the year.

Awareness of mercury advisories was found to be 12% for Hispanic women in a study of women between 18 and 45 years old (Anderson *et. al.*, 2004). Mahaffey *et. al.*

(2004) found Mexican Americans with low blood levels of mercury reflecting an overall low consumption rate.

STUDY AREA

South Texas waters fished by local tournament anglers contributing to this study include the Lower Laguna Madre area and the offshore Gulf of Mexico between Mexico and Corpus Christi, Texas (Figure 1).

No known major sources or hot spots of Hg are found in the study area. The closest hot spot is Upper Lavaca Bay over 225 kilometers north of Brownsville. An area southwest of Point Comfort is closed to the taking of any species of fish and crabs due to mercury contamination of the bay by Alcoa in the past. To the south in Mexico the nearest area of concern is a coal fired electrical generating plant at Tampico, over 400 kilometers south of Brownsville.

Five potential sources of Hg exist in the study area. One source could be the burning of solid waste at the Matamoros landfill. Minor but persistent burning has plagued that site. The prevailing plume would be northwest over Cameron County. Lopez (personal communication) suggested urban runoff into the Brownsville Ship Channel as a source of Hg in the blood of local residents. Subsequent sampling of fishes in the ship channel yielded low Hg concentrations in tested fish (G. Lopez, unpublished data). The third source is offshore drilling rigs in the sampling area and the use of barite for drilling. The recent surge in petroleum prices has seen a concurrent boom in drilling activity in the Gulf of Mexico with a new exploratory gas rig recently locating off South Padre Island. At least three production platforms are offshore of Port Mansfield and are popular

angling sites for red snapper (*Lutjanus campechanus*), Warsaw grouper (*Epinephalus nigritus*), cobia (*Rachycentron canadum*) and African pompano (*Alectis ciliaris*). A fourth source could be runoff from fields along the Arroyo Colorado that had received sludge applications. Finally the Rio Grande plume may be the most likely contributor of Hg due to a combination of untreated sewage releases from Mexico, historic mining of cinnabar in the upper reaches (TX GLO, 1995), and natural deposition from erosion.

The Lower Laguna Madre is an elongated bar built coastal lagoon, part of one of five hypersaline lagoons in the world (Javor, 1989). The Lower Laguna stretches 91 km (57 mi) from South Bay in the south near the Rio Grande delta, north to the southern end of the land cut. The average width is 8 km (5 mi) according to Tunnell and Judd (2002). The Lower Laguna has limited freshwater inflows: the San Martin Lake drain which drains southern Cameron County, the Arroyo Colorado – a Yazoo stream to the Rio Grande (G. Paull, personal communication) and the largest input draining parts of Hidalgo and Cameron Counties, the North Floodway from Hildalgo County, and Seven Mile Creek in Willacy County. The average depth of the Lower Laguna Madre is 1 m.

The Laguna Madre supports a world class recreational fishery for three major bay species. Sight fishing for red drum (*S. ocellata*) over the seagrass flats of the lagoon is a major draw for recreational fishing tournaments and brings anglers worldwide to experience the fishery. Large spotted seatrout over 76 cm (30 in) are not uncommon in the study area. Southern flounder (*Paralichthys lethostigma*) round out the three most popular species in the area. Black drum (*P. cromis*) is a popular commercial food fish that enjoys a recreational following during its spring run in the Brownsville Ship Channel. The channel and South Bay are havens for the tropical common snook (*C.*

undecimalis). This species seeks structure such as rocks, pilings or mangroves as its habitat.

The offshore part of the study area ranges from the southern limit of the U.S. Fishery Conservation Zone with Mexico, out to almost 1,300 m (700 fm) in depth and over 96.5 km (60 mi) to the east (the limit of distance an offshore vessel can travel and fish during time limits set by fishing tournaments). At the southern limit, the continental shelf is approximately 80.5 km (50 mi) wide and is dominated by the silt deposits of the Rio Grande delta made up of mostly mud with some shell in the substrate. Southerly currents prevail in winter and northerly currents in the summer.

The northern limit of the study area is offshore the Padre Island National Seashore. There the bottom exhibits scattered relief from the Seven and One Half Fathom Bank out to a series of banks near the 70 m (40 fm) curve approximately 48 km (30 mi) offshore. These banks support a primarily monospecific fishery for red snapper (*L. campechanus*). The dominant shark species on the snapper banks is the diminutive Atlantic sharpnose (*Rhizoprionodon terraenovae*), a common catch when fishing for red snapper. Dolphin (*Coryphaena hippurus*) are found in association with *Sargassum* weed lines and flotsam in the offshore study area from around the thirty fathom line to the end of the continental slope and even over the abyssal plane.

The prevailing substrate for the entire study area is mud (Britton and Murphy, 1989), and is a prime fishing ground for brown shrimp, Farfantepeneaus aztecus. A small area 10 - 16 km (6 - 10 mi) offshore of the Port Mansfield jetties is more mud, shell and sand substrate which is considered the only pink shrimp (Farfantepenaeus duorarum) ground within the study area. This zone supports a large blacktip shark

(*Carcharhinus limbatus*) population that is responsible for significant net damage to shrimp trawls. Hand lines baited with fish bycatch are used to take blacktips when shrimp vessels are anchored over the grounds. Shallow areas around 18 m (10 fm) with bottom relief are seasonally trolled for king mackerel (*S. cavalla*).

Bycatch, discarded by shrimp boats anchored around the 55 m (30 fm) curve, attracts little tunny (*E. alletteratus*) and blackfin tuna (*T. atlanticus*) in the summer. This phenomenon, in turn, draws anglers to fish around the anchored vessels in the morning when crews are working up the last shrimp catch from the previous night. Larger tuna such as yellowfin (*Thunnus abacares*) are more commonly caught over the continental slope.

The continental slope portion of the study area harbors a benthic dwelling golden tilefish (*Lopholatilus chamaeleonticeps*) population. Tilefish are subject to the FDA consumption warning and rarely taken recreationally due primarily to the extreme depths, >200 m, of their habitat on the continental slope. The pelagic area over the slope offers prime billfishing seasonally. Another FDA object of warning, swordfish (*Xiphias gladius*) is targeted more commercially than by recreational fishermen. Atlantic sailfish (*Istiophorus albicans*), white marlin (*Tetrapterus albicans*), and blue marlin (*M. nigricans*) are the most sought after by trolling offshore anglers who hook an occasional silky shark (*Carcharhinus calciformis*) or shortfin mako (*Isurus oxyrhinchus*).

That is an overview of the study area and species fished recreationally and in tournaments. Some species already have warnings associated with them yet are still pursued by anglers who may or may not know the potential consequences of ingestion or may know and fish only for sport.

OBJECTIVES

The purpose behind this study was to determine the concentrations of Hg in south Texas game fish species and ascertain relationships between length and total Hg for each species, and relevant groups of species. If information on any species was found to be statistically significant, it would be used to formulate consumption limit comparisons based on EPA recommendations using the RfD of 0.001 mg/kg of body weight/d. Any significant information gained will be used to educate anglers, fishing tournaments, consumers of game fish and the general public of our findings with the assistance of Cameron County, Texas Sea Grant and Texas Cooperative Extension.

MATERIALS AND METHODS

Fish collections were primarily conducted in cooperation with three local fishing tournaments and volunteers. The three tournaments were: the Port Mansfield Fishing Tournament, July 29-39, 2004, the Port Mansfield Lady Anglers Tournament, August 28, 2004, both held in Port Mansfield and the Ladies Kingfish Tournament, South Padre Island, August 14, 2004. Forty specimens of each common tournament species were the goal for annual sampling during the summer of 2004. Eighteen species of fish were targeted for study (Table 1). All fish analyzed were taken by hook and line from the study area. Most snook were collected in the Brownsville Ship Channel with hook and line from November 30, 2004 to January 27, 2005 using artificial baits at night, and collection was not associated with tournament fishing.

Fish lengths were measured and recorded in total length to the nearest 0.1 cm for all species except pelagic species for which curved fork length is recorded. A 2.5 cm³ sample was cut with a sharp stainless steel knife from the anterior left dorsal portion of the loin, above the pectoral fin and lateral line of each fish. Each sample was bagged in a plastic bag, labeled with a code for identification. The samples were stored on ice during the fishing tournaments and frozen until analysis. Samples were shipped via overnight delivery, stored on dry ice, to the National Oceanographic and Atmospheric Administration National Seafood Inspection Laboratory in Pascagoula, Mississippi for analysis. Protocols outlined by Lowery and Garrett, 2005 (Appendix 1) were followed for all sampling and analysis procedures.

Analysis of each sample was performed with a Milestone, Inc. DMA-80 Direct Mercury Analyzer according to U.S. EPA Method 7473 (1998) and Cizdziel et. al.(2002). Total mercury based on wet weight was measured to the nearest 0.01 ppm.

Three hundred twenty-nine fish and 10 blue crab samples were collected and analyzed. The blue crab samples were collected with crab traps in the Arroyo Colorado on August 14, 2004 by a volunteer. Carapace length was measured to the nearest 0.1cm and meat samples were taken from the posterior swimming muscle, commonly called lump meat. Table 1 lists the species common and scientific name, mean lengths, and numbers of each species sampled.

Length vs. total Hg data were analyzed by species, three families (Carharhinidae, Sciaenidae, and Scombridae) with more than one representative species in the total aggregate of 329 samples, and four fish species groups: demersal, pelagic, inshore, and offshore (Table 2). Means for total Hg and lengths were calculated and ANOVAs run to determine the relation of total Hg to length for each species, each group, and the three families represented by more than one species. Regressions, scatterplots, exponential formulas were presented to determine the total Hg concentration in relation to length, and adjusted r² values were calculated. All statistics were based on a 95% confidence interval and compared with the FDA action level 0f 1.0 ppm total Hg as a standard. Monthly consumption limits, for fish species with significant length to total Hg relationships, were developed based on predicted total mercury concentration for different length ranges of tournament caught fish. An average of the upper and lower limits of each length range was used to determine a mean for each range or slot. The consumption limits for fish species with significant length to total Hg levels were

developed as an indicator for anglers to understand their Hg ingestion in relation to fish consumption based on EPA recommendations. Comparisons of demersal to pelagic species and inshore to offshore species were analyzed via ANCOVA comparing the predicted length adjusted natural logarithm of total Hg concentration.

Findings will be presented and disseminated locally to participating fishing tournaments, sportsmen organizations, civic clubs and the public via presentations and news releases. Cameron County, Texas Sea Grant and Texas Cooperative Extension will assist in the information dissemination.

RESULTS

Total Hg concentrations varied by species and length (Table 3). Nine of the 19 species examined showed a significant correlation between total Hg concentration and individual size represented by length.

Individual species total Hg concentrations varied from a low of 0.09 ppm for dolphin to a high 3.29 ppm for the one blue marlin (Figure 2). Total Hg concentration (unadjusted mean = 0.90 ± 0.44 ppm) in Atlantic sharpnose was not related to length (F = 0.117, df = 3, p = 0.765; Figure 3). Two shark species, Atlantic sharpnose and the blacktip are members of the family Carcharhinidae and an analysis of that family yielded an unadjusted mean total Hg of 1.09±0.56 ppm with an insignificant length to total Hg relationship (F = 2.208, df = 4, p = 0.234; Figure 4). Common snook had no significant length to Hg concentration correlation either (F = 0.017, df = 31, p = 0.896), and were low in total Hg concentration at an unadjusted mean of 0.16 ±0.06 ppm (Figure 5). Cobia had the highest unadjusted mean total Hg concentration for all species analyzed (1.49) ± 1.04 ppm) and length was not correlated to total Hg (F = 7.730, df = 3, p = 0.109; Figure 6). Dolphin, the lowest in total Hg of all species in this study with an unadjusted mean concentration at 0.09±0.12 ppm total Hg, had a strong correlation of length to total Hg (F = 94.73, df = 29, p < 0.001; Figure 7). The length to total Hg correlation for greater amberiack (F = 170.551, df = 5, p < 0.001) was significant for a small number of fish, with an unadjusted mean total Hg mean of 0.730±0.031 ppm (Figure 8). Red snapper had a significant length to total Hg association (F = 9.589, df = 19, p = 0.006) with a low unadjusted mean of total Hg of 0.14±0.12 ppm (Figure 9).

Spotted seatrout (unadjusted mean total Hg = 0.39 ± 0.20 ppm) showed a significant relationship between length and total Hg (F = 11.837, df = 29, p = 0.002; Figure 10), and red drum with a lower unadjusted mean (0.23 ± 0.05 ppm) did not exhibit a significant correlation (F = 0.258, df = 28, p = 0.615; Figure 11). The data from these two species were combined to analyze the Sciaenid family (unadjusted mean total Hg = 0.31 ± 0.17 ppm) and no significant relationship between length and total Hg could be determined (F = 0.441, df = 58, p = 0.509; Figure 12). Southern flounder showed a significant correlation between length and total Hg (F = 15.445, df = 28, p < 0.001) with a low unadjusted mean of 0.12 ± 0.04 ppm for the latter (Figure 13).

Great barracuda did not have a significant length to total Hg concentration (F = 0.300, df = 3, p = 0.639) and the unadjusted mean Hg concentration was 0.67 ± 0.31 ppm (Figure 14).

Five of the 19 species sampled were members of the tuna family Scombridae and had some of the highest unadjusted mean concentrations of total Hg. The scombrids exhibited a significantly strong correlation between length and total Hg (F = 14.205, df = 137, p < 0.001) with an adjusted mean concentration of 1.01 ± 0.40 ppm, just over the FDA action level (Figure 15). Little tunny, the largest number of individual fish sampled in this study, showed a significant length to total Hg concentration relationship (F = 28.583, df = 49, p < 0.001) and an adjusted mean of 0.99 ± 0.39 ppm, 0.01 below the FDA action level (Figure 16). The blackfin tuna unadjusted mean equaled the FDA action level at 1.00 ± 0.40 ppm and their length to total Hg concentration was significant (F = 78.477, df = 39, p < 0.001; Figure 17). Only three yellowfin tuna were sampled and they had an insignificant length to total Hg concentration (F = 0.463, df = 2, p = 0.620) for an

unadjusted mean total Hg of 1.35 ± 0.35 ppm (Figure 18). Wahoo had a significant length to total Hg correlation (F = 13.168, df = 4, p = 0.036) for the few fish sampled, with an unadjusted mean total Hg = 0.98 ± 0.35 ppm (Figure 19). The king mackerel mean was over the FDA action level at an unadjusted mean ppm of total mercury at 1.02 ± 0.28 (F = 10.252, df = 39, p= 0.003; Figure 20) with a significant length to total Hg relationship.

The four groups: demersal, pelagic, inshore and offshore each showed a definite correlation between length and total Hg concentration. The demersal group: Atlantic sharpnose, common snook, red snapper, red drum, and southern flounder exhibited an unadjusted mean level of total Hg of 0.19 ± 0.17 ppm and a strong correlation between the two variables (F = 79.665, df = 113, p < 0.001; Figure 21). The largest group (in size and numbers), pelagics, with 13 species (Figure 22), also showed a strong significant relationship between length and total Hg (F = 57.634, df = 213, p < 0.001) with an adjusted mean total Hg of 0.80 ± 0.54 ppm. The inshore group was lower in total Hg with an unadjusted mean of 0.22 ± 0.15 ppm, and length was related to total Hg concentration (F = 4.252, df = 119, p = 0.041; Figure 23). The offshore group with 14 species (Figure 24), had the strongest significant correlation between length and total Hg (F = 65.772, df = 208, p < 0.001) and an unadjusted total Hg mean of 0.80 ± 0.56 ppm, equal to the pelagics.

Comparisons of demersal to pelagic species and inshore to offshore species using the predicted natural logarithm of total Hg concentration in relation to length showed Hg accumulates at the same rates for demersal and pelagic fishes and the inshore and offshore species but at a higher concentration for the pelagic and offshore species than the demersal and inshore fishes (Figures 25 and 26). The same relationship was

exhibited in a comparison of sciaenids and scombrids with scombrids accumulating much higher concentrations of Hg (Figure 27).

Results of total Hg testing on three species: blacktip shark, sailfish and blue marlin were not significant due to the fact only one individual of each species was sampled.

Blue crabs from the Arroyo Colorado were tested and the unadjusted mean total Hg was 0.15 ± 0.08 ppm and the length to total Hg correlation was not significant (F = 3.968, df = 9, p = 0.082; Figure 28).

In summary, the lowest total Hg levels were exhibited by two offshore species (the demersal red snapper and pelagic dolphin) and four inshore species (the pelagic spotted seatrout and three demersals: common snook, red drum, and southern flounder). Higher levels were found in the offshore demersal Atlantic sharpnose and the offshore pelagics: cobia, greater amberjack, great barracuda, little tunny, blackfin tuna, yellowfin tuna, wahoo, and king mackerel (Figure 29). Three offshore species: blacktip shark, sailfish and blue marlin were each represented by a single specimen and all had high levels. Nine species had a significant relationship between length and total Hg concentration: dolphin, greater amberjack, red snapper, southern flounder, spotted seatrout, little tunny, blackfin tuna, wahoo, and king mackerel.

CONCLUSIONS AND RECOMMENDATIONS

Fishing tournaments are an ideal venue to determine Hg exposure of recreational fishermen consuming their own catches. Burger *et.al.* (in press) suggested scientists examining contaminants in fish, collect samples by employing the same methods as consumers to ensure comparable exposure assessment. The average size of commercially caught fish is usually smaller than that of the same species taken by anglers (Van De Broek, 1981; B. Jones, personal communication). For tournament anglers and those receiving fish from the anglers, Hg exposure should be higher than average by nature of the competition resulting in larger sizes of fish.

The EPA has established recommended monthly fish consumption limits for fish containing various levels of MeHg (Table 4). Eleven fish species were determined to have information significant enough to develop a consumption limit table based on unadjusted mean total Hg as a guideline associated with these limits of consumption for these particular species (Table 5). The findings of this study could have potential long term health benefits for the public.

It is imperative to reiterate that the findings of this study are based on larger fishes landed at fishing tournaments, therefore the results and guidelines for limits of consumption are only meant to give us an idea of how tournament caught fish consumption is related to EPA guidelines. The guidelines are not meant to be used as recommendations for fish consumption but only as a guide to help anglers and those who consume tournament caught game fish an idea of their Hg ingestion and help them make healthy choices for fish consumption. Furthermore, the EPA guidelines are based on MeHg rather than total Hg; that ratio is as yet undetermined in the species employed in

this study. This discrepancy is widespread in most data on Hg in fish and necessitates a great need for further research.

The 11 fish species that yielded enough information to develop consumption limit comparisons based on unadjusted means of total Hg concentration, ranged from low to high for mean total Hg. Those species were: common snook, dolphin, greater amberjack, red snapper, southern flounder, spotted seatrout, red drum, little tunny, blackfin tuna, wahoo, and king mackerel. A discussion of each species follows. Common snook did not have a significant length to total Hg concentration relation with one of the lowest levels of Hg possibly indicating a low trophic level or an annual change in diet for the species in this geographic area. Ache et.al. (2002) classified common snook as a demersal "mobile predator" of high trophic level feeding primarily on penaeid shrimp and fish, and cite a higher average Hg concentration. The fish exhibiting the higher concentration were from south Florida and may have had elevated levels similar to those found in other species recently in Tampa Bay (Lowery and Garrett, 2005). Snook can live 20 years (Taylor et. al., 1993). Local expert anglers say the best bait in south Texas for the species is large live shrimp. The year round abundance of shrimp in this area, except for a short period in the winter when snook may become more piscivorous, suggests a diet high in shrimp. Shrimp have been found in all studies surveyed to be very low in Hg. Adult snook were found to feed on fish, crabs, shrimp, and some plant tissues (Fore and Schmidt, 1973). Other fish species reportedly consumed by snook are menhaden (Brevoortia sp.), mojarras (Eucinostomus sp.), mullet (Mugil sp.), pinfish (Lagodon sp.), anchovies (Anchoa sp.), pigfish (Orthopristes chrysoptera), and sailfin

mollies (*Poecilia latipinna*). The insignificant length to Hg relationship may reflect a more opportunistic change in diet during the winter.

Dolphin was a big surprise with the lowest concentration of Hg among all species analyzed having a strong correlation of length to Hg. Considered a pelagic species, dolphin contradicts this classification when compared to all other pelagics that exhibited much higher Hg concentrations. Classified as a surface piscivorous predator, consuming an almost exclusive diet of fish (Allain, 2003), this is a fast growing species, reaching 1 m in one year (Beardsley, 1967), with a high food conversion ratio (Arnold, 2005) which may reflect the lower Hg levels. Pimenta *et. al.* (2001) reported that dolphin captured as bycatch to recreational billfishing off Brazil exhibited the following major items by percentage of individuals in stomach contents: rough scad, (*Trachurus lathami*) 23.2 %, largehead hairtail (*Trichiurus lepturus*) 19.3 %, flyingfish (*Exocoetus volitans*) 15.5%, skipjack tuna (*Katsuwonus pelamis*) 13.5%, and fringed filefish (*Monacanthus ciliatus*) 10.6%. Skipjack is commonly known to be high in Hg which should be reflected in dolphin, but was not in our samples. The fast growth and high food conversion ratio seem the only explanation for the low Hg we found in this study.

Greater amberjack were higher than the prior two species with a significant length to Hg correlation for a small number sampled, which might indicate a slower growing fish with a consistent diet. Amberjack, once considered a trash fish, has become an "haute cuisine" species in the last two decades. This species has a minimum size limit of 55.9 cm in federal waters, where it is taken primarily around oil platforms, much lower than the 98.1 cm mean size we sampled. Andaloro (1997) studying amberjack in the Mediterranean Sea, found squid, (*Loligo spp.*) and fish the most

common prey items. Fable (1980) reported tagged red snapper to be prey of amberjack off Texas. Five data records queried by Ache *et. al.* (2002) showed a Gulf-wide average Hg level of 0.60 ppm. The *Loligo* portion of the diet may temper the Hg concentration since squid is low in Hg. The average Hg concentration for this study seems comparable to other studies (Ache *et. al.*, 2002) considering the large fish landed at tournaments.

Red snapper, the most popular food fish in the Gulf of Mexico, were found to have a higher mean Hg in this study than the Gulf data base, 0.14 vs. 0.03 ppm (Ache *et. al.*, 2002). The higher level may be indicative of the larger tournament fish which averaged five years old for their size according to Patterson *et. al.* (2001). The fish in this study reflected a significant relation between length and Hg concentration which could indicate a stable diet in the offshore environment. Ouzts and Szedmayer (2003) found adult red snapper feed primarily on crabs and fish. The crabs could contribute to the low Hg concentration.

Southern flounder were the second lowest in mean total Hg, with a significant correlation of length to concentration possibly indicating a stable food source low in mercury for this epibenthic demersal. Finger mullet (small striped mullet, *Mugil cephalus*) which scour the shallow flats of the Laguna Madre at night easily fall prey to southern flounder. Mullet are classified as an herbivore low in Hg (Ache *et. al.*, 2002), as are the omnivorous penaeid shrimp, another common food item for flounder. Ache *et. al.* (2002) classified flounder at a high trophic level but our results seem to indicate a medium level shown in this study's lower Hg mean (0.12 ppm) compared to Gulf-wide data (0.23 ppm). Less biomagnification results from feeding on lower trophic level species, which may explain the difference.

Spotted seatrout was classified in this study as a pelagic due to its free range at all depths and its schooling behavior. There was a strong and significant relation between length and Hg concentration and a similar mean Hg found Gulf-wide (Ache *et. al.*, 2002) which could indicate a high trophic level for tournament caught fish. This is the most popular species pursued by anglers in the southeastern United States. The suggested EPA consumption limit of two meals per month (Table 5) based on the gulf wide mean (0.40 ppm; Ache *et. al.*, 2002) and the mean for this study (0.39 ppm), was disconcerting considering the popularity of the fish. This was the highest level for inshore species and cannot be explained by its diet of fish and crustaceans (Minello *et. al.*, 1989). This author has observed large trout ~76 cm (30 in), on three occasions with smaller trout in their digestive tract. This cannibalistic behavior of the larger fish could contribute to elevated Hg levels.

Red drum are a highly sought after demersal on the Laguna Madre seagrass flats that feed mainly on shrimp, crabs and fish. There was no significant length to Hg concentration relation found, possibly indicating an omnivorous opportunistic diet of low trophic level food items. This is confirmed in studies by Simmons and Breuer (1962) who found blue crabs and penaeid shrimp as major constituents of red drum diets in the Laguna Madre. Scharf and Schlight (2000) documented a similar diet with menhaden making up a significant portion of red drum's prey in Galveston Bay. The mean Hg concentration for this study was lower than other Gulf-wide studies (Ache *et. al.*, 2002) and could indicate a pristine Laguna Madre with low ambient Hg levels in the substrate.

Little tunny, colloquially referred to as bonita, is considered inferior food by most anglers but is consumed by some locals. The length to Hg correlation was significant and

corresponded to the regression determined by Lowery and Garret (2005), whose study included some of the same fish. The high mean Hg may be indicative of this being a fast, efficient carnivore. Manooch *et. al.* (1985) found fish the dominant food item in the little tunny diet and Adams (2004) suggests the food items present in its neritic habitat may have higher Hg loads than oceanic prey, possibly contributing to higher loads in the predator

Blackfin tuna is the second most popular tuna consumed in south Texas.

Recreational trollers and shrimp fishermen hand lining off the stern of their vessels, prize the light pink meat especially for barbequing over mesquite charcoal. There are no federal regulations limiting catches and a large school of this small tuna can yield hundreds of fish. Hand liners aboard shrimp vessels will catch large numbers, freeze them whole and give them to family and friends when they return to port. The species had a significant length to Hg concentration relation and high mean total Hg attributed to the same characteristics of little tunny. Blackfin are neritic like little tunny and other fishes are the dominant food item (Manooch and Mason, 1983).

Oceanic wahoo are caught far offshore by trolling and are enjoyed for their rich tasty, white, flakey meat. This species also had a significant length to Hg correlation for a few individuals sampled indicating it is a top carnivore like the other scombrids. It has been found to consume small amounts of mesopelagic prey and is mainly piscivorous, diversifing its diet by eating small quantities of cephalopods and shrimp (Allain, 2003). Its Hg concentration may reflect its primary dietary dependence on fish. The low consumption limit (0.5 servings per month) based on the EPA recommendations (U.S.EPA, 1999; Table 5) was surprising for such a popular fish.

King mackerel is the most notorious and publicized scombrid with warnings on consumption Gulf wide. It had a strong length to Hg concentration correlation probably related to its role as a pelagic carnivore feeding primarily on schooling clupeids. Squid and shrimp were found to make up 33% of the species diet (Beaumarriage, 1973). The consistently high levels of Hg in this species seem inexplicable as to diet. The mean total Hg was in line with other Gulf studies (Ache et. *al.*, 2002). This fish is given away freely at fishing tournaments and frequently to charities, tournament workers and their families.

A future study should investigate this group who work tournaments annually to determine their Hg content via hair analyses. A small commercial fishery still exists for kings in the gulf. Bob Jones (personal communication), executive director of the Southeastern Fisheries Association said commercially caught king mackerel were smaller in average size than recreationally caught kings and had a much lower Hg load.

Seven species were not sampled in enough numbers to yield confident means or consumption limits: Atlantic sharpnose, cobia, blacktip shark, great barracuda, yellowfin tuna, sailfish and blue marlin. Three of these: blacktip shark, sailfish and blue marlin only had one individual sampled. Blacktips are typically high in total Hg (Ache *et. al.*, 2002; Forsyth *et. al.*, 2004) due to their position as an apex predator. Pimenta *et. al.* (2001) reported sailfish and blue marlin captured by recreational anglers off Brazil, preferred seasonally occurring pelagic fish species common to the area of capture, as food items. Blue marlin were more dependent on carangids than sailfish were on that family. Longevity in these species is suspected to be high for blue marlin and sailfish are considered fast-growing (Pesce and Gentile, 2003) which may relate to Hg concentrations in these two species. Atlantic sharpnose were classified for this study as demersal due to

their prevalence as the most commonly caught shark taken bottom fishing on the snapper banks.

Atlantic sharpnose were found to have higher species diversity in their diet than blacktips (Hoffmayer and Parsons, 2003). Four sharpnose had a lower mean total Hg than the one blacktip sampled, possibly reflecting the increased food diversity. This is supported by Forsyth *et. al.* (2004).

Franks *et. al.* (1996) reported fish dominate the diet of juvenile cobia in the northern Gulf of Mexico and Meyer and Franks (1996) found adults in the same area fed primarily on portunid crabs with increasing dependence on fish as they became larger. This diet change and the relatively young age of the fish in this study (3-5 years old), based on the age length key from Franks, *et. al.* (1996) does not support the high Hg levels found in this study. Some other unknown factor may be involved.

Great barracuda feed on fishes, cephalopods and shrimp (Cervignon *et. al.*, 1993). It is opportunistic, hanging around structure and floating *Sargassum* rafts. The moderately high total Hg may represent its omnivorous habits. Fable (1980) reported barracuda preying on tagged red snapper. Large barracuda in this area of the gulf are avoided for consumption due to the risk of ciguatera poisoning.

Filefish (Monacanthidae), rough scad (*Trachurus lathami*) and skipjack tuna (*Katsuwanus pelamus*) were major food items of yellowfin tuna in the Atlantic (Pimenta *et. al.*, 2001) while Allain (2003) found more dependence on crustaceans for yellowfin in the Pacific. Adams (2004) showed relatively low Hg levels for Florida yellowfin (mean ≤ 0.5 ppm total Hg) averaging 84.7 cm fork length. Three yellowfin in this study averaged 154.0 cm with a mean total Hg of 1.35 ppm. This contradicts Adams (2004)

suggestion that the oceanic environment may contribute to lower concentrations than neritic environment. The high Hg levels in these fish remain unexplainable other than the sheer size of our fish compared to Adams'. The yellowfin tuna results indicated high total Hg for the 3 fish sampled which may foreshadow a need for warnings on consumption of this species in Texas, especially the large tournament fish. This is the most popular tuna consumed from the Gulf of Mexico.

The four groups: demersal, pelagic, inshore and offshore, each exhibited Hg levels indicative of habitat, trophic level, and length and Hg concentration. The demersal group: Atlantic sharpnose, common snook, red snapper, red drum, and southern flounder showed a low mean Hg concentration indicating a middle trophic level. The large group of pelagics, with 13 species (Figure 20) having strong relationships between length and Hg concentration, combined with higher Hg concentrations, mirror their life histories as piscivorous pelagic predators. The inshore group (Figure 21) with low mean Hg concentration and significant length correlation to Hg concentration is possibly associated with the low ambient levels of Hg in our local environment. The offshore group with 14 species (Figure 22) and the strongest correlation between length and Hg probably reflects the more stable offshore environment with a consistent food supply, primarily fish. The finding that pelagic and offshore groups accumulated more Hg to length, but at the same rates as demersal and inshore groups can be explained by the scombrids. Scombrids especially tunas have high metabolic demands due to the higher proportion of fast-twitch to slow-twitch muscle (Altringham and Block, 1997). They therefore consume more food to meet the high metablic needs. Tunas and billfish such as blue marlin are known to exhibit endothermy, requiring even more energy. The pelagic and offshore fishes were

larger and therefore consume more food to meet caloric requirements of their bodies.

Large fish are older and the temporal factor cannot be overlooked. Large tunas live between 10 and 15 years while smaller members of the family live only a few years (Pesce and Gentile, 2003). Larger fish exhibited higher Hg loads in this study. The comparison of the sciaenids and scombrids (Figure 27) indicated similar Hg uptake rates for both species but scombrids accumulated much more proportionally which may relate to the larger individual sizes of members of this family.

As time passes the Hg load accumulates to higher levels. Pinedo de Pinho *et. al.* reported longevity in sharks results in longer exposure time attributing their slow metabolic rate to decreased excretion of the metal. They also pointed out predatory behavior further amplifies biomagnification which may explain high Hg levels in upper trophic levels of these carnivorous fish.

Monthly consumption limits were determined for different sizes of the nine fish species with significant length to total Hg relationships: dolphin, greater amberjack, red snapper, southern flounder, spotted seatrout, little tunny, blackfin tuna, wahoo, and king mackerel. The limits were based on predicted total mercury concentration for different length ranges of these species (Tables 6-14). The consumption limits were developed as an indicator for anglers to understand their Hg ingestion in relation to consumption of different sizes of each species. There are definite differences in the consumption limits of each species in most of the size ranges. When the significant relationships are used to determine consumption limits for different size ranges, we obtain a more accurate guide for consumption. Dolphin for example, ranged from a limit of 16 meals per month for the smaller sizes to only 2 meals per month for the largest fish (Table 6). When

comparing this method to that using the unadjusted mean total Hg for the species as in Table 5, the length range estimate is more accurate for determining consumption limits. This should be investigated further by the EPA. This method is a more precise measure of Hg load and has the capacity to encourage higher consumption of the smaller fish of each species and avoidance of retention and ingestion of larger individuals to the delight of fishery managers.

The need to quantify the amount of MeHg in relation to total Hg is imperative with the increasing importance of seafood consumption in the United States. Results of MeHg analyses combined with assessment of all species consumed could lead to better knowledge of consumption limits than those we have today. Mercury is omnipresent and an absence of hot spots in south Texas is fortuitous. However, this study's results are sobering when one looks at the consumption limits, especially if you love to eat fish.

This study confirms the larger the fish the heavier the mercury load and that is more significant primarily for offshore pelagic fish. Differences between measuring fork length vs. total length did not seem to affect the length to total Hg concentration for the comparisons in this study. Fisheries managers need to take note of the size to load relationship and manage species not only for maximum economic benefit but also for the health of those who consume them. Many decry the loss of larger size fishes due to overfishing, but this may have an added health benefit by reducing the mean Hg concentrations in the fish we eat.

In conclusion, relating Hg concentration in fish to one factor is difficult and size tends to be the best indicator of higher levels especially in offshore pelagics. The findings of this study could have dire economic consequences for the guides whose

livelihoods depend on offshore fishing. The recommended limits for consumption developed by the EPA for the species we had enough information to analyze are eye opening and anglers and their clientele who will be amazed, especially when they are able to relate their own catches to their consumption. On the contrary, the potential health benefits may outweigh the negative impact and help anglers and other consumers to be able to make informed decisions on fish consumption and their health.

LITERATURE CITED

- Ache, B.W., J.D. Boyle and C.E. Morse. 2000. A survey of the occurrence of mercury in the fishery resources of the Gulf of Mexico. Prepared by Battelle for the U.S. Gulf of Mexico Program, Stennis Space Center, MS. January, 2000.
- Adams, D.H. 2004. Total mercury levels in tunas from offshore waters of the Florida Atlantic coast. Marine Pollution Bulletin 49:659–667.
- Al-Hashimi, A.H. and M.A. Al-Zorba. 1991. Mercury in some commercial fish from Kuwait: a pilot study. The Science of the Total Environment. 106:71-82.
- Allain, V. 2003. Diet of mahi-mahi, wahoo and lancetfish in the western and central Pacific. Standing Committee on Tunas and Bilfishes. TB16 Working Paper. BBRG-6.
- Altringham, J.D. and B.A. Block. 1997. Why do tuna maintain elevated slow muscle temperatures? Power output of muscle isolated from endothermic and ectothermic fish. The Journal of Experimental Biology 200:2617–2627.
- Andaloro, F. 1997. Food and feeding habits of the amberjack, *Seriola dumerili* in the central Mediterranean Sea during the spawning season. Cahiers-de-Biologie-Marine. 1997; 38(2):91-96
- Anderson, H.A., L.P. Hanrahan, A. Smith, L. Draheim, M. Kanarek, and J. Olsen. 2004. The role of sport-fish consumption advisories in mercury risk communication: a 1998-1999 12-state survey of women 18-35. Environmental Research. 95(3):315-324.
- Arnold, C. 2005. Professor Emeritus University of Texas Marine Science Institute. Personal communication.
- Britton, J.C. and B. Morton. 1989. *Shore Ecology of the Gulf of Mexico*. Austin: University of Texas Press. 387 pp.
- Brooks, B. 2005. Personal Communication. Hawaii Department of Health.
- Beaumariage, D.S. 1970. Current status of biological investigations of Florida's mackerel fisheries. Proclamations of the Gulf and Caribbean Fisheries Institute., 22nd Annual Meeting, 1969:79-86.
- Burger, J., M. Gochfeld, S. Burke, C.W. Jeitner, S. Jewett, D. Snigaroff, R. Snigaroff, T. Stamm, S. Harper, M. Hoberg, H. Chenelot, R. Patrick, C.D. Volz, J. Weston. (In Press) Do scientists and fishermen collect the same size fish? Possible implications for exposure assessment. Environmental Research, Accepted 13 July, 2005.
- Carpi A. 1997. Methyl mercury contamination and emission to the atmosphere from soil amended with municipal sewage sludge. Journal of Environmental Quality.

- 26(6):1650-1655.
- Cervigón, F., 1993. Los peces marinos de Venezuela. Volume 2.. Fundación Científica Los Roques, Caracas, Venezuela. 497 pp.
- Cizdziel, J.V., T.A. Hinners and E.M. Heithmar. 2002. Determination of Total Mercury in Fish Tissues using Combustion Atomic Absorption Spectrometry with Gold Amalgamation. Water, Air, and Soil Pollution 135:355-370.
- Clarkson, T.W. 1997. The toxicology of mercury. Critical Review of Clinical Lab Science, 334(4):369-403.
- Fable Jr., W.A. 1980. Tagging studies of red snapper (*Lutjanus campechanus*) and vermilion snapper (*Rhombopolites aurorubens*) off the south Texas coast. Contributions-in-Marine-Science. 1980; 23:115-121
- Federal Register. 44: 3990. January 19, 1979.
- Ferrara, R., B.E Maserti, M. Anderson., H. Edner, P. Ragnarson, S. Svanberg, and Hernandez. 1998. Atmospheric mercury concentrations and fluxes in the Almaden District (Spain). Atmosphere Environment. 32(22):3897-3904.
- Foulke, J.E. 1994. Mercury in fish: cause for concern? FDA Consumer, 28(7):5-8.
- Fore, P. L., and T. W. Schmidt. 1973. Biology of juvenile and adult snook, *Centropomus undecimalis*, in the Ten Thousand Islands. Pages SVI-l-SVI-18 in Ecosystems analysis of the Big Cypress Swamp and Estuaries. U.S. Environmental Protection Agency Survey and Analysis Division, Athens, Ga.
- Forsyth, D.S., V. Casey, R.W. Dabeka and A.M. McKenzie. 2004. Methylmercury levels in predatory fish species marketed in Canada. Food Additives and Contamination. 21(9):849-856.
- Franks, J. S., N. K. Garber, and J. R. Warren. 1996. Stomach contents of juvenile cobia, Rachycentron canadum, from the northern Gulf of Mexico. Fish Bull. 94(2):374-380.
- Grandjean P, P. Weihe, and R.F. White, 1997. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. Neurotoxicology Teratology. 19:417-428.
- Hall, B.D., R.A. Bodaly, R.J. Fudge, J.W.M. Rudd, and D.M. Rosenberg. 1997. *Water Air and Soil Pollution.* 100:13-24.
- Hibbeln, J.R and N. Salem, Jr. 1995. Dietary polyunsaturated fatty acids and depression: when cholesterol does not satisfy. American Journal of Clinical Nutrition, 62:1-9.
- Higueras, P., R. Oyarzun, J. Lillo, J.C. Sanchez-Hernandez, J.A. Molina, J.M. Esbri, and

- S. Lorenzo. 2006. The Almadén district (Spain): Anatomy of one on the world's largest HG-contaminated sites. Science of Total Environment. 356:112-124.
- Hoffmayer, E.R. 2003. Food habits of three shark species from the Mississippi Sound in the northern Gulf of Mexico, Southeastern Naturalist. 2(2):271-280.
- Horowitz, A.J., K.A. Elrick, and J.J.Smith. 2001. Annual suspended sediment and trace element fluxes in the Mississippi, Columbia, Colorado and Rio Grande basins. *Hydrological Processes.* 15:1169-1207. John Wiley and Sons.
- Ipinmoroti, K.P., A.A. Oshodi, and R.A. Owolabi. 1997. Comparative studies of metals in fish organs, sediment and water from Nigerian fresh water fish ponds. Pakistan Journal of Science and Industry Resources. 40(5-12):70-74.
- Inskip, M.J., and J.K. Piotrokowski. 1985. Review of the health effects of methylmercury. Journal of Applied Toxicology. 5(3):113-133.
- Javor, B. 1989. *Hypersaline Environments: microbiology and biogeochemistry*. New York: Springer Verlag. 328 pp.
- Jones, B. 2001. Methylmercury: a fisherman's point of view. Southeastern Fisheries Association. April 11, 2001.
- Jones, B. 2006. Personal Communication. Executive Director, Southeastern Fisheries Association.
- Latham, P., K. Lund, J.C. Brown, and I.T. Johnson. 2001. Effects of cellular redox balance on induction of apoptosis by eicosapentaenoic acid in HT29 colorectal adenocarcinoma cells and rat colon in vivo. Gut 49:97-105 (July).
- Lebel, J., D. Mergler, F. Branches, M. Lucotte, M. Amorim, F. Larribe, and J. Dolbec. 1998. Neurotoxic effects of low-level methylmercury contamination in the Amazonian Basin. Environmental Research. 79(1):20-32.
- Lesikar, B. and T. Lockamy, T. 1993. Land application of biosolids in semi-arid regions of the state. Texas Agricultural Extension Service, The Texas A&M University System, Result Demonstration Report, Cameron County, Texas.
- Lopez, G. 2005. Personal Communication. Department of Biological Sciences. The University of Texas at Brownsville.
- Lowery, T. 2005. Personal Communication. NOAA Fisheries, National Seafood Inspection Laboratory. U.S. Department of Commerce.
- Lowery, T. and E.S. Garrett III. 2005. Report of findings- Synoptic survey of total

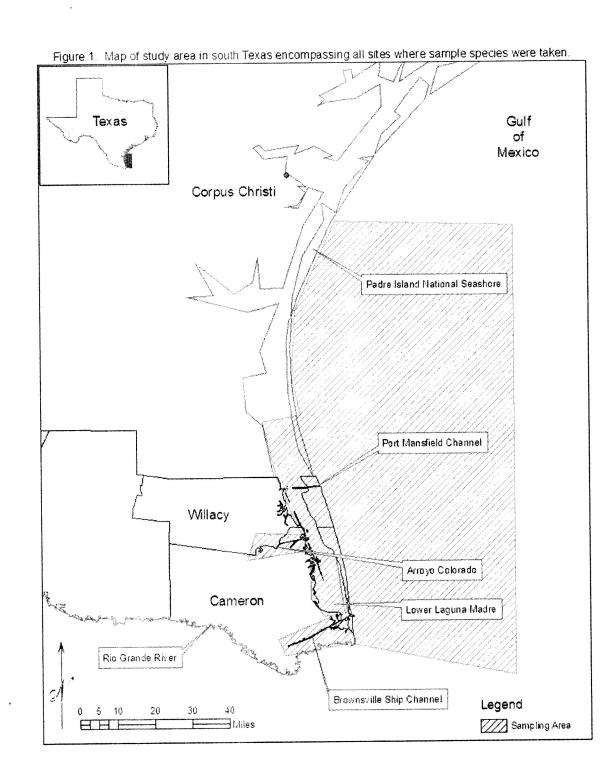
- Mercury in recreational finfish of the Gulf of Mexico. NOAA Fisheries Office of Sustainable Fisheries, National Seafood Inspection Laboratory, Pascagoula, MS. June, 2005.
- MacDougal, K.C., M.D. Johnson, & K.G. Burnett. 1996. Exposure to mercury alters early activation events in fish leucocytes. Environmental Health Perspectives. 104(10):1102-1106.
- Mahaffey, K. 2006. Personal communication. U.S. EPA
- Mahaffey, K.R. 2004. Fish and shellfish as dietary sources of methymercury and the ω-fatty acids, eicisahexanoic acid and docosaheanoic acid:risks and benefits. Environmental Research. 95:414-428.
- Mahaffey, K.R., R.P. Clickner, and C.C. Bodurow. 2004. Blood organic mercury and dietetic mercury intake: national health and nutrition examination survey, 1999 and 2000. Environmental Health Perspectives.112(5):562–570.
- Manooch III, C.S. and D.L.Mason. 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.
- Meyer, G. H., and J. S. Franks. 1996. Food of cobia, *Rachycentron canadum*, from the northcentral Gulf of Mexico. Gulf Research Reports. 9(3):161–167.
- Minello, T.J., R.J. Zimmerman and T.E. Czapla. 1989. Habitat-related differences in diets of small fishes in Lavaca Bay, Texas, 1985-1986.. NOAA Technical. Memorandum. SEFC- NMFS-236:1-16.
- Moore, C.J. 2000. A review of mercury in the environment (its occurrence in marine Fish). South Carolina Department of Marine Resources, Marine Resources Division, Office of Environmental Management. 22 pp.
- Myers, G.J., P.W. Davidson, C. Cox, C.F. Shamlaye, D. Palumbo, E. Cernichiari, J. Sloane-Reeves, G. E Wilding, J. Kost, L. Huang, and T.W. Clarkson. 2003. Prenatal methylmercury exposure from ocean fish consumption in the Seychelles child development study. The Lancet, 361, May 17, 2003.
- National Research Council. 2000. *Toxicological effects of methylmercury*. National Academy Press. Washington D.C. 344 pp.

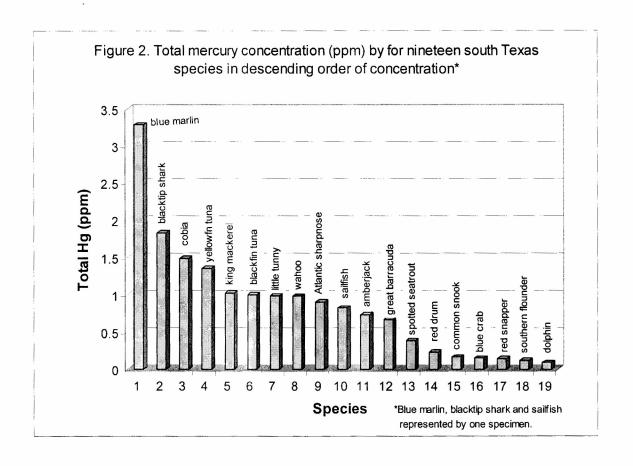
- Neff, J.M. 2002. Fates and effects of mercury from oil and gas exploration and production operations in the marine environment. Washington D.C.: American Petroleum Institute.
- Ouzts, A.C. and S.T. Szedmayer. 2003. Diel Feeding Patterns of Red Snapper on Artificial Reefs in the North-Central Gulf of Mexico. Transactions of the American Fisheries Society. 132 (6):1186-1193.
- Paull, G. 2006. Personal communication. Chairman Chemistry and Environmental Sciences Department. University of Texas at Brownsville.
- Patterson III, W.F, J..H. Cowan Jr., C.A. Wilson, and R. L. Shipp. 2001. Age and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area off Alabama in the northern Gulf of Mexico. *Fishery Bulletin* 99(4):617-627.
- Pesce, M. and M. Gentile. 2003. Biological characteristics of tunas and tuna-like species. Fisheries Global Information System. Food and Agriculture Organization, United Nations, Fisheries Information Global Information System. http://www.fao.org/figis/servlet/static?dom=root&xml=speciesgroup/data/tunalike.xml
- Pirrone, N., G. J. Keeler and J. O. Nriagu. 1996. Regional differences in worldwide emissions of mercury to the atmosphere. Atmospheric Environment. 30 (17):2981-2987.
- Pimenta E.G., F.R. Marques, G.S. Lima and A.F. Amorim. 2001. Marlin project: Tagand-release, biometrics and stomach content of billfish in Cabo Frio City, Rio de Janeiro, Brazil. Col. Vol. Sci. Pap. ICCAT, 53:371-375.
- Puffer, H. 1981. Consumption rates of potentially hazardous marine fish caught in the metropolitan Los Angeles area. EPA Grant #R807 120010. as cited in the U.S. EPA (1991). Exposure Factors Handbook. EPA/600/8-89/043.
- Richardson, A.J. and Paul Montgomery. 2005. The Oxford-Durham study: A randomized, controlled trial of dietary supplementation with fatty acids in children with developmental coordination disorder. Pediatrics 115(5):May, 2005.
- Roegge, C.S. and S. L. Schantz. 2006. Motor function following developmental exposure to PCBS and/or MEHG. Neurotoxicology and Teratolology. Accepted 20 December, 2005.
- Rupp, E.M., F.I.Miller, and C.F.Baes III. 1980. Some results of recent surveys of fish and shellfish consumption by age and region of U.S. residents. Health Physiology 39(2):165-175.
- Salomen, J.T., K. Seppnen, K. Nyssonen, J. Kauhanan, M. Kantola, J. Tuomilehto,

- H. Esterbauer, F. Tatzber, and R. Salonen. 1995. Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular, and death in eastern Finnish men. Circulation. 91 (3):645-655.
- Sarica, J., M. Amyot, L. Hare, M. Doyon, and L.W. Starfield. 2004. Salmon derived mercury and nutrients in a Lake Ontario spawning stream. Limnology and Oceanography..49(4):891-899.
- Scharf, S.F. and K.K. Schlight. 2000. Feeding habits of red drum (*Sciaenops ocellatus*) in Galveston Bay, Texas: seasonal diet variation and predator-prey size relationships. Estuaries. 23(1);128–139. February 2000.
- Schmidt, C.J., J.E. Hinck, V.S. Blazer, N.D. Denslow, G.M. Dethloff, T.M. Bartish, J.L. Coyle, and D.E. Tillitt. 2005. Environmental contaminants and biomarker responses in fish from the Rio Grande, and its U.S. tributaries: spatial and temporal trends. Science of Total Environment. 350:161-193.
- Schultz, C.D., D. Crear, J.E. Pearson, J.E. Rivers, and J.W. Hylin. 1976. Total and organic mercury in Pacific blue marlin. Bulletin of Environmental Toxicology. Feb:15(2):230-234.
- Simmons, E.G. and J.P. Breuer 1962. A study of redfish, *Sciaenops ocellata* Linnaeus and black drum, *Pogonias cromis* Linnaeus. Publications of the Institute of Marine Science 8:189–211.
- Slemr, F. and E. Langer. 1992. Increase in global atmospheric concentrations of mercury inferred from measurements over the Atlantic Ocean. Nature: 355:434-437.
- Takeuchi, T., K. Eto, Y. Kinjo and H. Tokunaga. 1996. Human brain disturbance by methylmercury poisoning, focusing on the long term effect on brain weight. Neurotoxicology 17(1):187-190.
- Taylor, R. G., J. A. Whittington, and H. J. Grier. 1993. Biology of common snook from the east and west coasts of Florida. Study 3, Section 1. *In* Investigations into nearshore and estuarine gamefish distributions and abundance, ecology, life history, and population genetics in Florida. R. E. Crabtree, T. M. Bert, and R. G. Taylor, eds. FDNR/FMRI Rep. No. F0165-F0296-88-93-C. U. S. Department of the Interior, Fish and Wildlife Services, Washington, D. C. pp.1-51.
- TDHSSD. (Texas Department of Health Seafood Safety Division). 2004. Fish consumption advisories & bans 2004. 32 pp.
- TX.GLO (Texas General Land Office). 1995. Rio Grande coastal impact monitoring program final project report. October 1995. 173 pp.
- Therriault, T.W. & D.C. Schneider. 1998. Predicting change in fish mercury

- concentrations following reservoir impoundment. Environmental Pollution 101(1): 33-42.
- Tollefson, L.and F. Cordle. 1986. Methylmercury in fish: a review of residue levels, fish consumption and regulatory action in the United States. Environmental Health Perspectives 68: 203-208.
- Trudel, M. and J.B. Rasmussen. 1997. Modeling the elimination of mercury by fish. Environmental Science and Technology. 31(6): 1716-1722.
- Tunnell Jr., J.W. and F.W. Judd. 2002. Editors. *The Laguna Madre of Texas and Tamaulipas*. College Station: Texas A&M University Press
- U.S. DHHS and U.S. EPA (Department of Health and Human Services and U.S. Department of Agriculture). *Dietary Guidelines for Americans*, 2005. 6th Edition, Washington, DC: U.S. Government Printing Office, January 2005.
- U.S. EPA. 1997. Mercury study report to Congress. Vol. IV: An assessment of exposure to mercury in the United States. EPA-452/R-97-006.
- U.S. EPA. 1998. Mercury in solids or solutions by thermal decomposition, amalgamation, and atomic absorption spectrophotometry. Method 7473. U.S. Environmental Protection Agency, Washington, D.C., U.S.A.
- U.S. EPA. 1999. Fact sheet mercury update: Impact on fish advisories. 13 pp.
- U.S. EPA 1999. Integrated risk information system (IRIS) on methylmercury. National Center for Environmental Assessment, Office of Research and Development, Washington, DC. 1999.
- U.S. EPA. March, 2004. What you need to know about mercury in fish and shellfish, 2004 EPA and FDA advice for: women who are pregnant, nursing mothers, and young children. EPA-823-R-04-005.
- Van Der Broek and D.M. Tracy. 1981. Concentration and distribution of mercury in the flesh of orange roughy (*Hoplostenthus atlanticus*). New Zealand Journal of Marine and Freshwater Research. 15:255-260.
- Ward, J.A., E. Fonken, L. Williams, and J.F. Villanacci. 2000. Health consultation: Brownsville Ship Channel. Texas Department of Health. December 8, 2000. 8pp.
- WHO. 1990. Methyl mercury. Vol. 101. Geneva, Switzerland: World Health Organization, International Programme on Chemical Safety.
- Wiles, K. 2005. Personal Communication. Texas Department of State Health Services.

FIGURES





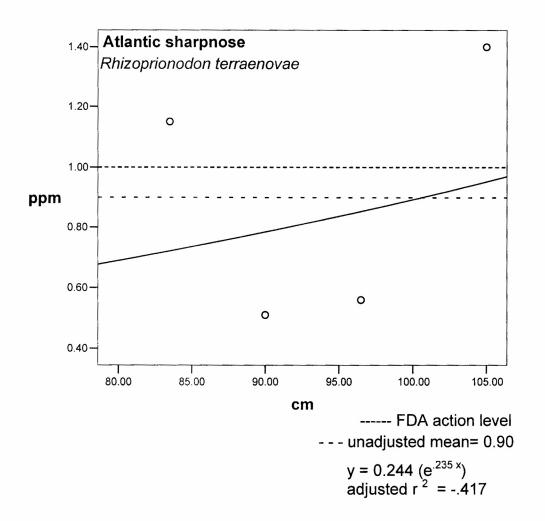


Figure 3. Atlantic sharpnose (*Rhizoprionodon terraenovae*) total length (cm) vs.total mercury (ppm) regression (solid line) (p= 0.76), scatterplot (n=4), FDA action level, and unadjusted mean ppm.

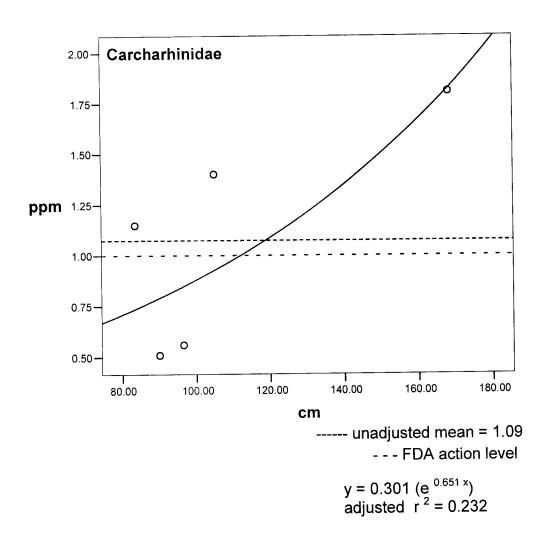


Figure 4. Total length (cm) vs. total Hg, regression (solid line), (p = 0.232), scatterplot (n = 5), unadjusted mean ppm, and FDA action level for the family Carchrarhinidae.

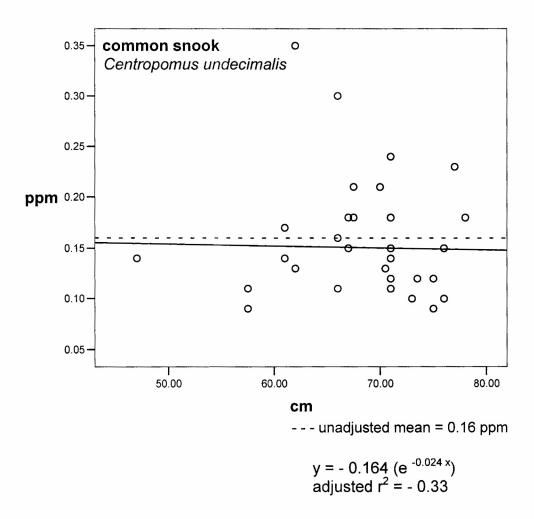


Figure 5. Snook (*Centropomus undecimalis*) total length (cm) vs. total mercury (ppm), regression (solid line) (p= 0.896) scatterplot (n=32), and unadjusted mean ppm

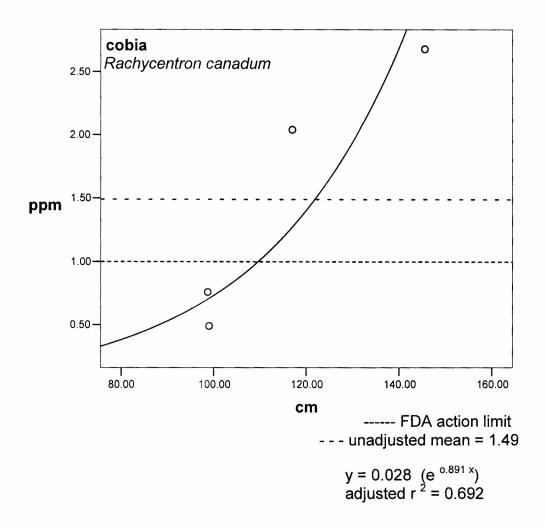


Figure 6. Cobia (*Rachycentron canadum*) total length (cm) vs. total mercury concentration (ppm), regression (solid line), (p = 0.109),scatterplot (n=4), FDA action level and unadjusted mean ppm.

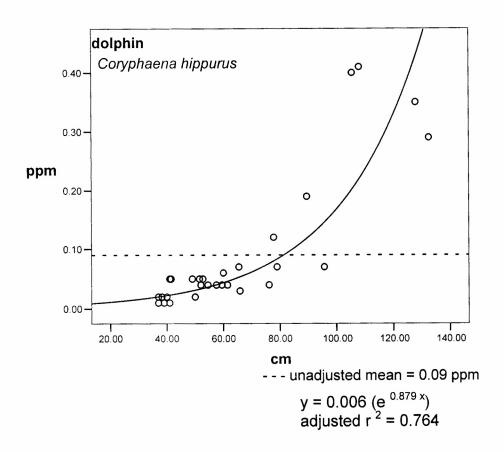


Figure 7. Dolphin (*Coryphaena hippurus*) curved fork length (cm) vs. total mercury concentration (ppm) regression (solid line)' (p < 0.001), scatterplot (n=30), and unadjusted mean (ppm).

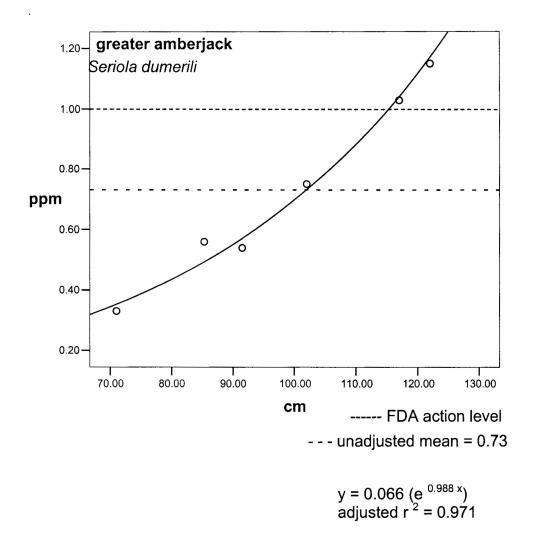
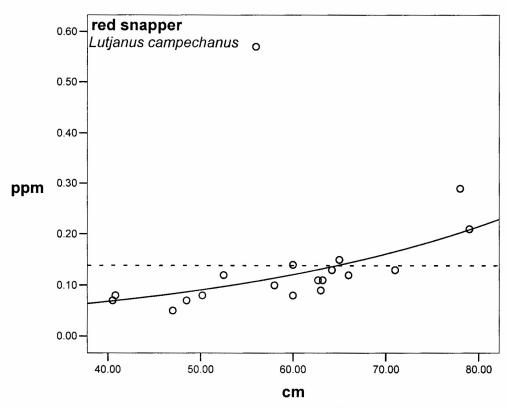


Figure 8. Greater amberjack (*Seriola dumerili*) curved fork length (cm) vs.total mercury concentration (ppm), regression (solid line), (p < 0.001), scatterplot (n=6), FDA action level and unadjusted mean ppm.



--- unadjusted mean = 0.14 ppm

 $y = 0.009 * 10^{0.590 x}$ adjusted $r^2 = 0.311$

Figure 9. Red snapper ($Lutjanus\ campechanus$) total length (cm) vs. total mercury (ppm, regression (solid line), (p = 0.006), scatterplot (n=20) and unadjusted mean ppm.

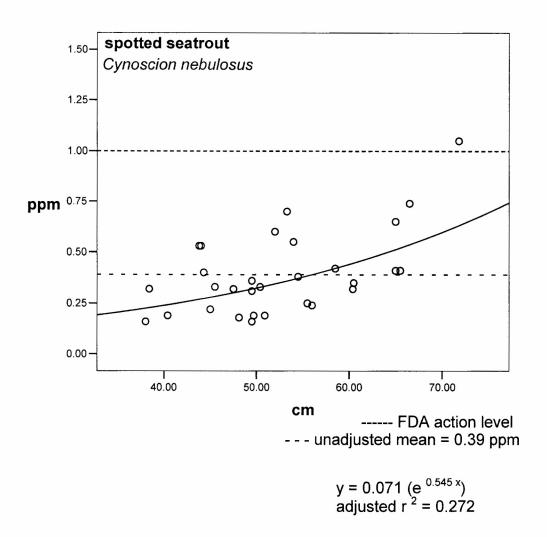


Figure 10. Spotted seatrout (*Cynoscion nebulosus*) total length (cm) vs. total mercury (ppm), regression (solid line) (p = 0.002), scatterplot (n=30),FDA action level and unadjusted mean ppm.

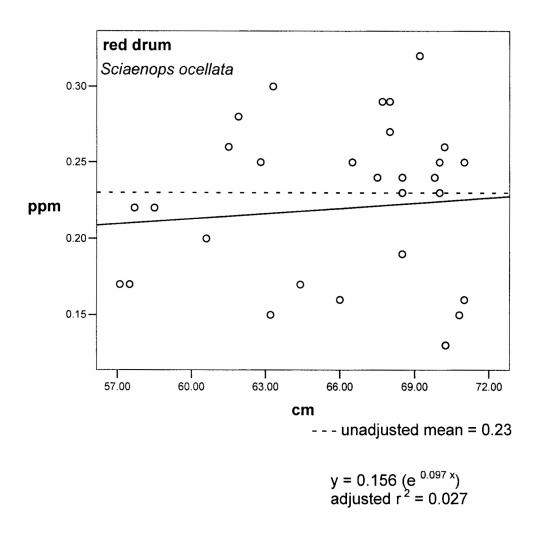


Figure 11. Red drum (*Sciaenops ocellata*) total length (cm) vs. total mercury (ppm) ANOVA table, regression (solid line), (p = 0.615), scatterplot (n=29) and mean ppm.

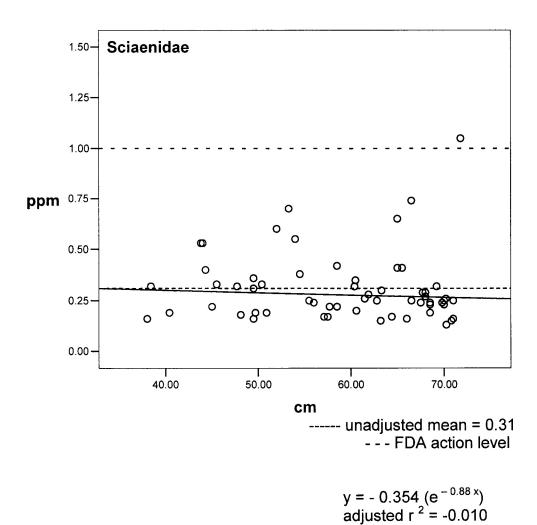


Figure 12. Total lengths (cm) vs. total mercury (ppm), regression (solid line) (p = 0.509), scatterplot (n = 59), unadjusted mean ppm, and FDA action level for the family Sciaenidae.

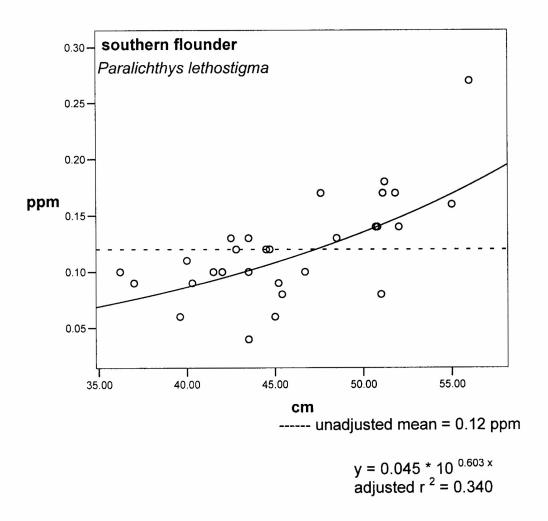


Figure 13. Southern flounder (*Paralichthys lethostigma*) total length (cm) vs. total mercury (ppm), regression (solid line), (p < 0.001), scatterplot (n=29) and unadjusted mean ppm.

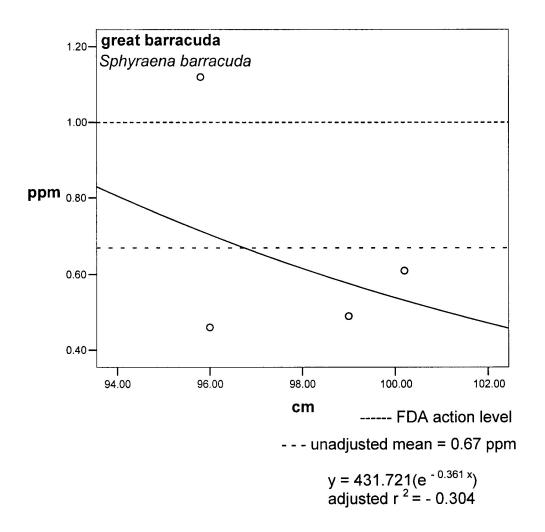


Figure 14. Great barracuda (*Sphyraena barracuda*) total length (cm) vs. total mercury (ppm), regression (solid line), (p = 0.639), scatterplot (n=4), FDA action level and unadjusted mean ppm.

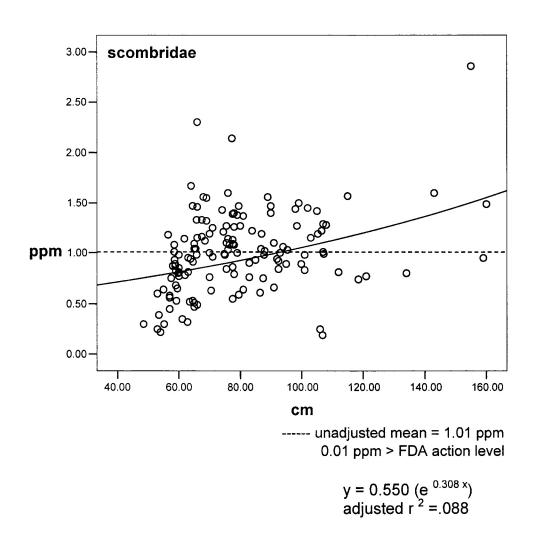


Figure 15. Curved fork lengths (cm) vs. total mercury (ppm), regression (solid line) (p < 0.001), scatterplot (n = 138), and unadjusted mean ppm for the family Scombridae.

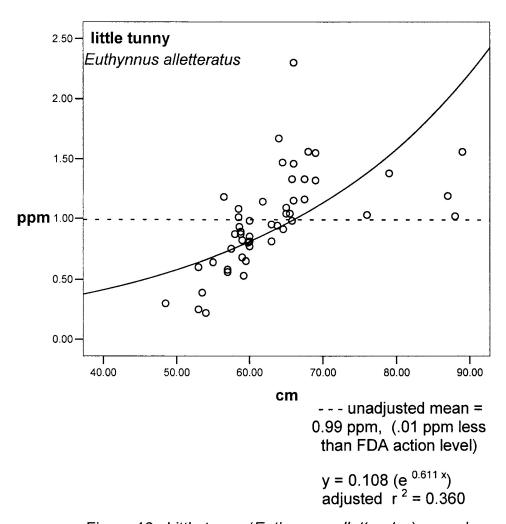


Figure 16. Little tunny (*Euthynnus alletteratus*) curved fork length (cm) vs. total mercury (ppm), regression (solid line), (p < 0.001), scatter plot (n=50), and unadjusted mean ppm.

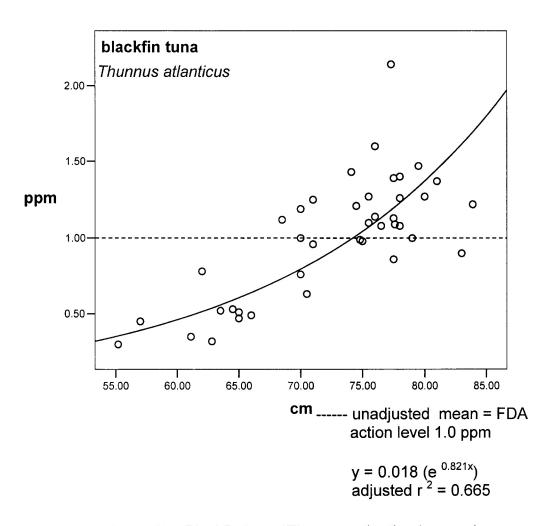


Figure 17. Blackfin tuna (*Thunnus atlanticus*) curved fork length (cm) vs. total mercury (ppm) ANOVA table, regression (solid line) (p < 0.001), scatterplot (n=40), and FDA action level and mean ppm..

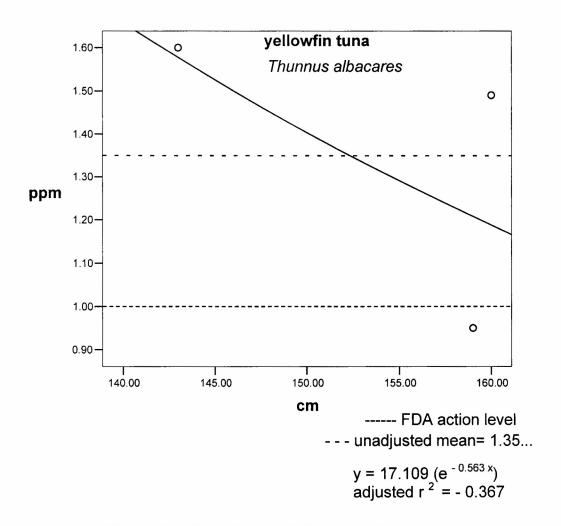


Figure 18. Yellowfin tuna (*Thunnus albacares*) curved fork length (cm) vs. total mercury (ppm) ANOVA table, regression (solid line) (p = 0.620) scatterplot (n=3), FDA action level and mean ppm.

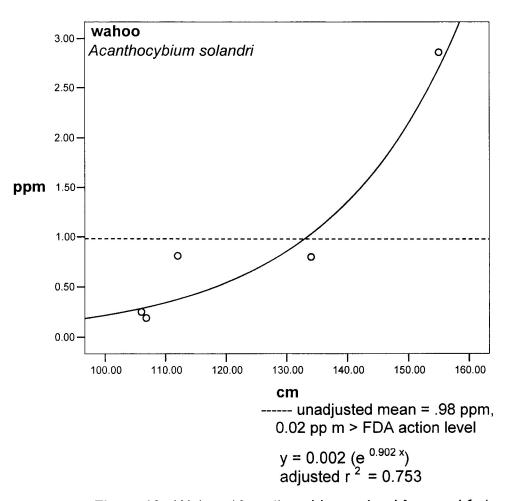
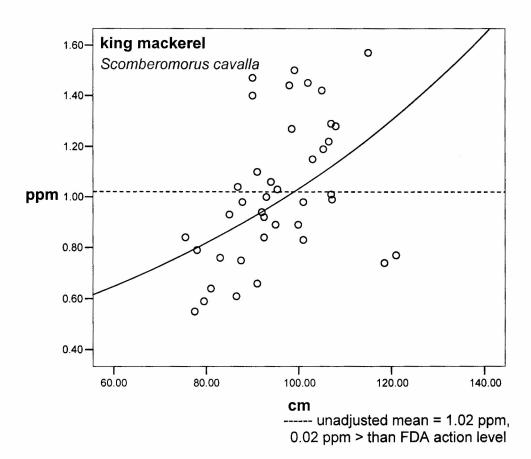


Figure 19. Wahoo (*Acanthocybium solandri*) curved fork length (cm) vs. total mercury (ppm), regression (solid line), (p = 0.036), scatterplot (n=5), and unadjusted mean ppm in relation to FDA action level.



$$y = 0.323 (e^{0.461 x})$$

adjusted $r^2 = .192$

Figure 20. King mackerel (*Scomberomorus cavalla*) curved fork length (cm) vs. total mercury (ppm), regression (solid line), (p = 0.003), scatterplot (n=40), and unadjusted mean ppm in relation to FDA action level.

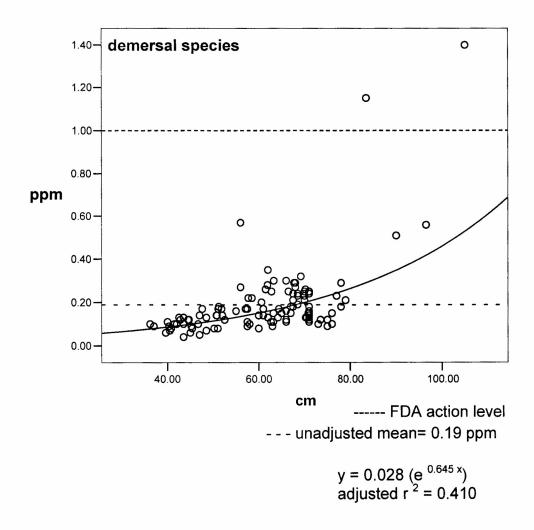
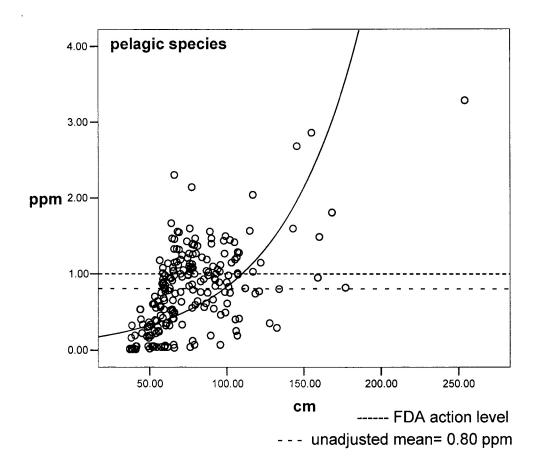


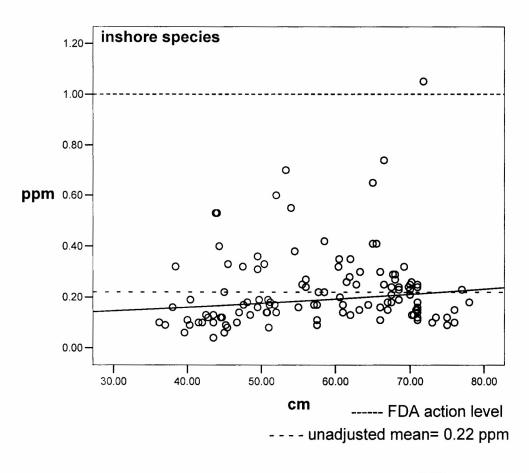
Figure 21. Total lengths (cm) vs. total mercury (ppm), regression (solid line), (p< 0.001), scatterplot (n=114), FDA action level and unadjusted mean ppm for five demersal species: Atlantic sharpnose, common snook, red snapper, red drum and flounder,



$$y = 0.126 (e^{0.462 x})$$

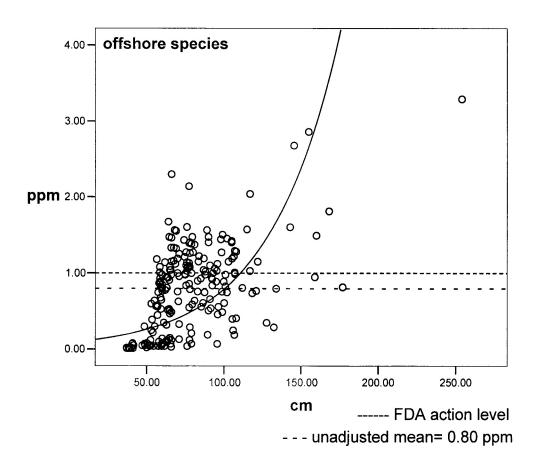
adjusted $r^2 = 0.210$

Figure 22. Lengths (cm) vs. total mercury (ppm), regression (solid line), (p< 0.001), scatterplot, (n= 214), FDA action level and unadjusted mean ppm.for thirteen pelagic species: blacktip shark, cobia, dolphin, greater amberjack, spotted seatrout, great barrcuda, little tunny, blackfin tuna, yellowfin tuna, wahoo, king mackerel, sailfish and blue marlin.



 $y = 0.111 (e^{0.186 x})$ adjusted $r^2 = 0.027$

Figure 23. Total length (cm) vs. total mercury (ppm) ANOVA table, regression (solid line) (p= 0.041), scatterplot (n=120), FDA action level and mean ppm for four inshore species: common snook, spotted seatrout, red drum and southern flounder.



$$y = 0.087 (e^{0.491 x})$$

adjusted $r^2 = 0.237$

Figure 24. Length (cm) vs. total mercury (ppm), regression (solid line), (p< 0.001), scatterplot (n= 209), FDA action level and unadjusted mean ppm for fourteen offshore species: Atlantic sharpnose, blacktip shark, cobia, dolphin, greater amberjack, red snapper, great barracuda, little tunny, blackfin tuna, yellowfin tuna, wahoo, king mackerel, sailfish, and blue marlin.

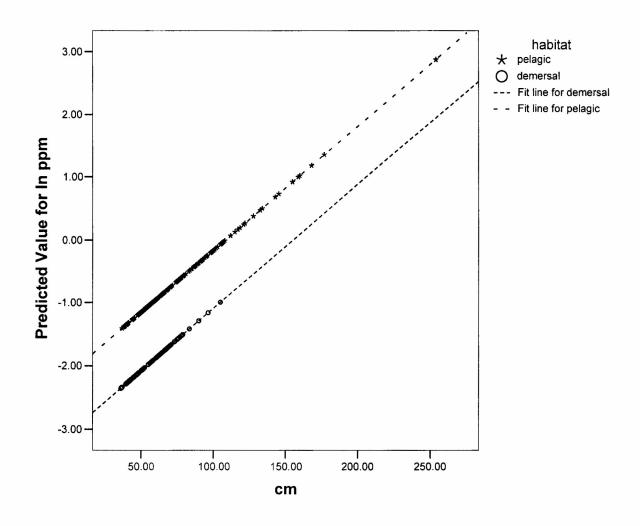


Figure 25. Comparison of predicted values of In total Hg concentration vs. length for all demersal and pelagic species analyzed in this study. Demersal species are: Atlantic sharpnose, red drum, snook, red snapper, and southern flounder. Pelagic species are: blacktip shark, cobia, dolphin, greater amberjack, spotted seatrout, great barracuda, little tunny, blackfin tuna, yellowfin tuna, wahoo, king mackerel, sailfish, and blue marlin.

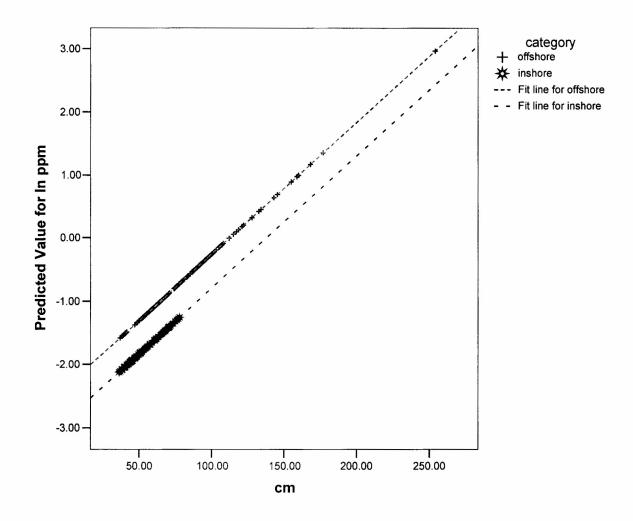


Figure 26. Comparison of predicted values of In total Hg concentration vs. length for all inshore and offshore fish species analyzed in this study. Inshore species are: spotted seatrout, red drum, southern flounder, and snook. Offshore species are: Atlantic sharpnose, blacktip shark, cobia, dolphin,greater amberjack, red snapper, great barracuda, little tunny, blackfin tuna, yellowfin tuna, wahoo, king mackerel, sailfish, and blue marlin.

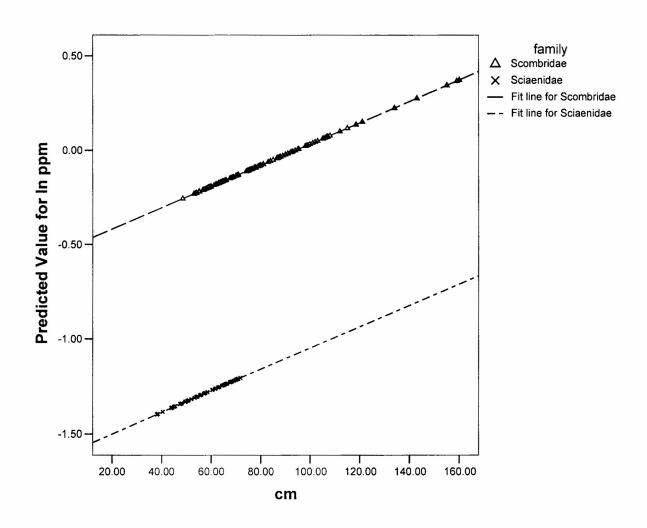
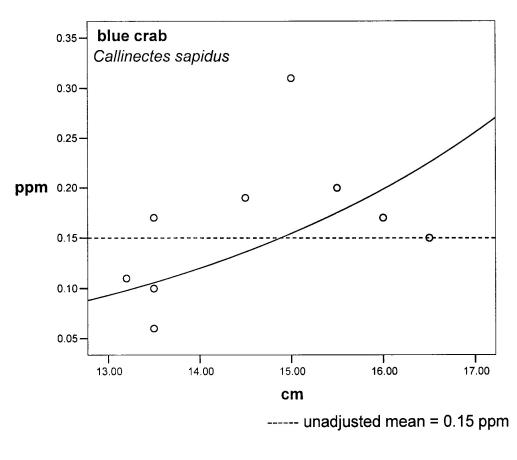


Figure 27. Comparison of predicted values of In total Hg concentration vs. length for two families of species, Scombridae and Sciaenidae.



 $y = 0.004 (e^{0.576 x})$ adjusted $r^2 = 0.248$

Figure 28. Blue crab (*Callinectes sapidus*) carapace length (cm) vs.total mercury (ppm) ANOVA table, regression (p = 0.601), scatterplot (n=10) and mean ppm.

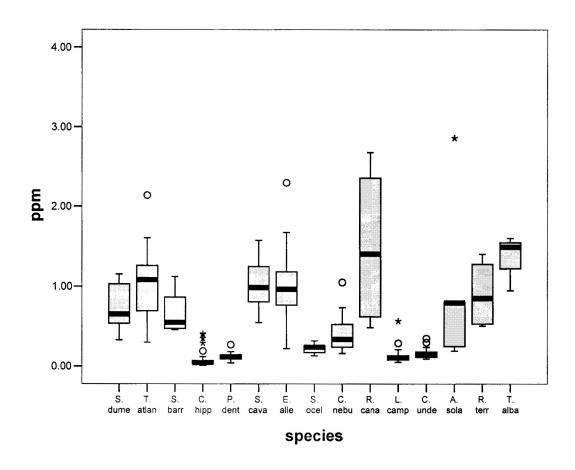


Figure 29. Boxplot comparisons of total mercury concentration (ppm) medians and ranges of individual total Hg concentrations (ppm) for fifteen fish species: greater amberjack (Seriola dumerili), blackfin tuna (Thunnus atlanticus), great barracuda (Sphyraena barracuda), dolphin (Coryphaena hippurus), southern flounder (Paralichthys lethostigma), king mackerel(Scomberomorus cavalla), little tunny(), red drum (Sciaenops ocellatus), spotted seatrout (Cynoscion nebulosus), cobia (Rachycentron canadum), red snapper (Lutjanus campechanus),common snook (Centropomus undecimalis), wahoo (Thunnus albacares), Atlantic sharpnose (Rhizoprionodon terraenovae) and yellowfin tuna (Thunnus albacares).

TABLES

Table 1. List of species, common and scientific names, analyzed for total mercury.

common name scientific name

Atlantic sharpnose Rhizoprionodon terraenovae

blacktip shark Carcharhinus limbatus

common snook Centropomus undecimalis

cobia Rachycentron canadum

dolphin Coryphaena hippurus

greater amberjack Seriola dumerili

red snapper Lutjanus campechanus

spotted seatrout *Cynoscion nebulosus*

red drum Sciaenops ocellatus

great barracuda Sphyraena barracuda

little tunny Euthynnus alletteratus

blackfin tuna Thunnus atlanticus

yellowfin tuna Thunnus albacares

wahoo Thunnus albacares

king mackerel Scomberomorus cavalla

southern flounder Paralichthys lethostigma

sailfish Istiophorus albicans

blue marlin Makaira nigricans

blue crab Callinectes sapidus

Table 2. Species classifications by group for demersal, pelagic, inshore, and offshore.

• Denotes group.

common name	scientific name	demersal	pelagic	inshore	offshore
Atlantic sharpnose blacktip shark	Rhizoprionodon terraenovae Carcharhinus limbatus	•	•		•
_					
common snook	Centropomus undecimalis	•		•	
cobia	Rachycentron canadum		•		•
dolphin	Coryphaena hippurus		•		•
greater amberjack	Seriola dumerili		•		•
red snapper	Lutjanus campechanus	•			•
spotted seatrout	Cynoscion nebulosus		•	•	
red drum	Sciaenops ocellatus	•		•	
great barracuda	Sphyraena barracuda		•		•
little tunny	Euthynnus alletteratus		•		•
blackfin tuna	Thunnus atlanticus		•		•
yellowfin tuna	Thunnus albacares		•		•
wahoo	Acanthocybium solandri		•		•
king mackerel	Scomberomorus cavalla		•		•
southern flounder	Paralichthys lethostigma	•		•	
sailfish	Istiophorus albicans		•		•
blue marlin	Makaira nigricans		•		•
blue crab	Callinectes sapidus	•		•	

Table 3. Common and scientific names, mean concentrations of total mercury**, mean lengths*, size range, and number sampled for nineteen south Texas marine species.

common name Atlantic	scientific name Rhizoprionodon	mean total Hg (ppm) 0.90	mean length (cm) 93.81	size range (cm) 83.5-105.0	individuals sampled 4
sharpnose blacktip shark	terraenovae Carcharhinus limbatus	1.81 ⁵	168.2 ^{1,4}	168.2	1
common snook	Centropomus undecimalis	0.16	68.3 ¹	47.0-78.0	32
cobia	Rachycentron canadum	1.49	115.0 ¹	98.7-145.5	4
dolphin	Coryphaena hippurus	0.09	64.7 ²	37.0-132.5	30
greater amberjack	Seriola dumerili	0.73	98.1 ²	71.0-122.0	6
red snapper	Lutjanus campechanus	0.14	58.3 ¹	40.5-79.0	20
spotted seatrout	Cynoscion nebulosus	0.39	52.4 ¹	38.0-71.8	30
red drum	Sciaenops ocellatus	0.23	65.9 ¹	57.1-71.0	29
great barracuda	Sphyraena barracuda	0.67	97.8 ¹	95.8-100.2	4
little tunny	Euthynnus alletteratus	0.99	63.2^2	48.4-89.0	50
blackfin tuna	Thunnus atlanticus	1.00	72.5 ²	55.2-83.9	40
yellowfin tuna	Thunnus albacares	1.35	154.0	143.0-160.0	3
wahoo	Acanthocybium solandri	0.98	122.8 ²	143.0-160.0	5
king mackerel	Scomberomorus cavalla	1.02	95.7 ²	75.5-121.0	40
southern flounder	Paralichthys lethostigma	0.12	45.8 ¹	36.2-56.0	29
sailfish	Istiophorus albicans	0.82 ⁵	177.0 ^{1,4}	177.0	1
blue marlin	Makaira nigricans	3.29^{5}	254.0 ^{1,4}	254.0	1
blue crab	Callinectes sapidus	0.15	14.5 ³	13.2-16.5	10

^{* &}lt;sup>1</sup> Total length, ² Curved fork length, ³ Carapace length, ⁴ Length of one individual, ** ⁵ Total Hg concentration based on one individual

Table 4. EPA recommended monthly (30.44 d) fish consumption limits (number of .227 kg (8 oz.) portions) of fish containing various levels of MeHg for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

Concentration in fish tissue MeHg (ppm)	Fish meals/month (8 ounce portions) .227 kg
>0.03 - 0.06	16
>0.06 - 0.08	12
>0.08 - 0.12	8
>0.12 - 0.24	4
>0.24 - 0.32	3
>0.32 - 0.48	2
>0.48 - 0.97	1
>0.97 - 1.9	0.5
>1.9	NONE

Table 5. Monthly consumption limits for eleven tournament caught fish species based on unadjusted means and EPA recommendations.

Species	Consumption limits* based on number of 8 oz. (.227 kg) portions per month recommended by the EPA**
common snook	4
dolphin	8
greater amberjack	1
red snapper	4
southern flounder	4
spotted seatrout	2
red drum	4
little tunny	0.5
blackfin tuna	0.5
wahoo	0.5
king mackerel	0.5

^{*} number of .227 kg (8 oz.) portions of fish

**for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001 mg/kg-d of body weight (EPA, 1999)

Table 6. Monthly consumption limits of **dolphin** based on predicted total mercury concentration for different length ranges of tournament caught fish.

curved fork length range (cm)	predicted mean total mercury for size range (ppm)	monthly consumption limits* based on EPA recommendations**
≥37.0 to <47.0	0.02	no limit
≥47.0 to <57.0	0.04	16
≥57.0 to <67.0	0.05	16
≥67.0 to <77.0	0.07	12
≥77.0 to <87.0	0.10	8
≥87.0 to <97.0	0.13	4
≥97.0 to <107.0	0.18	4
\geq 107.0 to <117.0	0.26	3
≥117.0 to <127.0	0.36	2
\geq 127.0 to \leq 132.5	0.46	2

^{*} number of .227 kg (8 oz.) portions of fish

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

Table 7. Monthly consumption limits of greater amberjack based on predicted total mercury concentration for different length ranges of tournament caught fish.

curved fork length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
≥71.0 to <81.0	0.40	2
\geq 81.0 to <91.0	0.51	1
\geq 91.0 to <101.0	0.64	1
\geq 101.0 to <111.0	0.80	1
\geq 111.0 to \leq 122.0	1.04	0.5

^{*} number of .227 kg (8 oz.) portions of fish

Table 8. Monthly consumption limits of red snapper based on predicted total mercury concentration for different length ranges of tournament caught fish.

total length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
≥40.5 to <50.0	0.08	12
≥50.0 to <60.0	0.11	8
≥60.0 to <70.0	0.14	4
≥70.0 to ≤79.0	0.18	4

^{*} number of .227 kg (8 oz.) portions of fish

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

Table 9. Monthly consumption limits of **southern flounder** based on predicted total mercury concentration for different length ranges of tournament caught fish.

total length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
≥36.2 to <46.0	0.09	8
\geq 46.0 to \leq 56.0	0.14	4

^{*} number of .227 kg (8 oz.) portions of fish

Table 10. Monthly consumption limits of **spotted seatrout** based on predicted total mercury concentration for different length ranges of tournament caught fish.

total length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
≥38.0 to <48.0	0.26	3
\geq 48.0 to <58.0	0.36	2
≥58.0 to <68.0	0.48	1
\geq 68.0 to \leq 71.8	0.60	1

^{*} number of .227 kg (8 oz.) portions of fish

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

Table 11. Monthly consumption limits of little tunny based on predicted total mercury concentration for different length ranges of tournament caught fish.

curved fork length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
≥48.5 to <58.0	0.64	1
≥58.0 to <68.0	0.91	1
≥68.0 to <78.0	1.27	0.5
\geq 78.0 to \leq 89.0	1.81	0.5

^{*} number of .227 kg (8 oz.) portions of fish

Table 12. Monthly consumption limits of blackfin tuna based on predicted total mercury concentration for different length ranges of tournament caught fish.

curved fork length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
≥55.2 to <65.0	0.48	2
≥65.0 to <75.0	0.82	1
\geq 75.0 to \leq 81.0	1.24	0.5

^{*} number of .227 kg (8 oz.) portions of fish

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

Table 13. Monthly consumption limits of **wahoo** based on predicted total mercury concentration for different length ranges of tournament caught fish.

curved fork length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
\geq 106.0 to <116.0	0.37	2
≥116.0 to <126.0	0.58	1
≥126.0 to <136.0	0.92	1
≥136.0 to <146.0	1.46	0.5
\geq 146.0 to \leq 155.0	2.24	NONE

^{*} number of .227 kg (8 oz.) portions of fish

Table 14. Monthly consumption limits of king mackerel based on predicted total mercury concentration for different length ranges of tournament caught fish.

curved fork length range (cm)	predicted total mercury range (ppm)	monthly consumption limits* based on EPA recommendations**
≥75.5 to <85.0	0.82	1
≥85.0 to <95.0	0.92	1
\geq 95.0 to <105.0	1.03	0.5
≥105.0 to <115.0	1.16	0.5
\geq 115.0 to \leq 121.0	1.28	0.5

^{*} number of .227 kg (8 oz.) portions portions) of fish

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

^{**}for an individual weighing 72kg (159 pounds) in order to not exceed the recommended RfD of 0.0001mg/kg-d of body weight (EPA, 1999)

APPENDIX

Protocols from National Seafood Inspection Laboratory (Lowery and Garrett, 2005):

Sampling Kit

The sampling kits and high efficiency coolers will be delivered to each Sampler personally by the Field Coordinator during his/her training trips to the Samplers' laboratories.

The following items will be contained in each Sampler's sampling kit:

- 1. handheld GPS
- 2. 3 meter long measuring tape
- 3. a plastic L bracket (approx. 6 inch, by 6 inch, by 3 inch) to duct tape to the deck or rail for use as a place to butt the nose of the fish to in order to get consistent length measurements,
- 4. 3 black permanent ink pens
- 5. phone numbers to the Field Coordinator
- 6. pre-labeled Fedex box to ship binder to Data Manager
- 7. pre-printed Fedex label to ship the cooler to Sample Custodian
- 8. binder with per species for geographic area being sampled: species identification information, measuring instructions, tissue extraction instructions, data recording spreadsheets, and sample labels,
- 9. one medium sized high efficiency ice cooler
- 10. small Ziplock bags for tissue samples
- 11. medium Ziplock bags to group small Ziplock bags per species for freezing
- 12. large Ziplock bags to group medium Ziplock bags per geographic location for transport
 - 13. one stainless steel fillet knife
 - 14. one box of Wet Wipes to clean fillet knife and hands between samples
 - 15. one roll of duct tape to tape the bracket down on the ends to make it lay flat
 - 16. one roll of paper towels to clean hands and work area
 - 17. backpack for carrying supplies in field

Sampler's Management of Samples

The strategy for managing the samples and their associated data follows: Each geographic location to be sampled (e.g., estuary, section of open Gulf waters) will have a limited set of species that will be sampled. For each species being sampled for a given geographic location the sampler should attempt to collect 10 samples from 10 different individual fish for each of three fish size categories (i.e., 10 small, 10 medium, 10 large). Each fish sampled will have the following information recorded in the sampling binder or equivalent spreadsheets: 1) date,

2) length of fish measured, 3) latitude and longitude of capture, and 4) sampler's initials. The information will be recorded on pre-printed laminated plastic spreadsheets for the given species and geographic location using waterproof ink pens. Information on the trip and sampler will be recorded on a separate spreadsheet page.

A single muscle tissue sample (approximately 1 inch cube of meat) is to be extracted from above the left pectoral fin of the collected individual fish using the stainless steel fillet knife provided in the sampling kit. The individual muscle tissue sample will be placed in a small ziplock bag and labeled with a provided pre-printed label that corresponds to the sample binder's (or equivalent) spreadsheet data row. The small ziplock bags for a given species will be stored in an ice slurry in the field. Alternatively, the whole fish may be placed on ice and brought back to the laboratory, and the muscle tissues extracted and placed into the small ziplock bags at the laboratory.

At the Sampler's laboratory, prior to placement in a freezer for storage, the small ziplock bags containing samples for a given species will be placed into a medium ziplock bag to group the samples for the given species and given geographic location. The medium ziplock bags will be labeled with provided pre-printed labels indicating geographic location and species. The medium ziplock bags will be placed in a single large ziplock bag labeled with a provided pre-printed label indicating the geographic location. As new muscle tissue samples are collected during the course of the Survey, their information will be entered into the sample binder and the samples are to be placed into a labeled small ziplock bag, and placed in the appropriate medium and large ziplock bags according to their species and geographic location. The large ziplock bag, and enclosed medium ziplock bags, and muscle tissue containing small ziplock bags are to be stored in the Sampler's laboratory freezer and shall be maintained in a hard frozen state during additions of any new samples (the samples are not to be allowed to thaw and be refrozen).

Sample Shipment

The initial shipment of samples for a given geographic location will contain the bulk of the samples for the given geographic location (e.g., 312 of the 330 Mobile Bay samples). Subsequent shipments will be to fill in samples not provided in the initial shipment (e.g., multiple shipments of smaller quantities of samples may come in to fill out the Mobile Bay sample quota). At the Field Coordinator's discretion, after reviewing the status of the sample collection, and confirming the availability of the Sample Custodian to receive a shipment, the Onsite Sample Coordinator will be instructed to Fedex overnight the frozen samples. These samples must be packed in the coolers with dry ice along with a hardcopy list of samples contained in the cooler, and be shipped to the Sample Custodian. Alternatively, the Field Coordinator may arrange to have the analytical laboratory's staff pick up and transport the frozen samples (packed in the coolers with dry ice) to the analytical laboratory. The Field Coordinator will give the Sample Custodian notice that a shipment is on the way along with the expected delivery date and time. Both the Field Coordinator and Sample Custodian will be on standby to receive and check-in the

samples. The Sample Custodian will be responsible for checking on the arrival of Fedex deliveries.

Receipt of Main Shipment of Samples

Attending to incoming samples and ensuring that they stay frozen is the Sample Custodian and Field Coordinator's highest priority. All other tasks will cease as soon as the samples arrive and are not to be resumed until the samples have been logged-in and placed in cold storage. Upon receipt of the samples, the Sample Custodian and Field Coordinator will jointly open the cooler, log in the samples and place them in an ultralow freezer as quickly as possible. The Sample Custodian and Field Coordinator will log-in each shipment by cross checking the received samples against the hardcopy list of samples accompanying the shipment and previously obtained copies of the Sampler Binder or equivalent data pages.

In order to keep the frozen samples from thawing the shipment log-in must be done quickly. Individual samples will not be removed from their small ziplock bags during log in. One medium ziplock bag will be removed from the cooler at a time by the Sample Custodian while the others are kept in the cooler. The Sample Custodian will remove the sample containing small ziplock bags and lay them out in the order of their size and number sequence. The Field Coordinator will then log them in and fill out the hardcopy Sample Receipt form (see page 39) that corresponds to the given geographic location and species of the samples.

The Sample Custodian will confirm the completed Sample Receipt Form against the laid out samples and instruct the Field Coordinator to make corrections to the Sample Receipt Form if needed. The Field Coordinator will use the Sample Receipt Form to verify that the samples have been received and, if needed, to request the Field Samplers to collect and ship additional "fill-in" samples to replace any missing, spoiled, mislabeled, or otherwise unusable samples.

After logging the samples in, the Sample Custodian will place the individual small ziplock bags back into their medium ziplock bag (i.e., species bag) and large ziplock bag (i.e., geographic location) that they were received in and place them back into the cooler, until all of the samples have been logged-in. After logging-in all the samples received, the Sample Custodian will seal the large ziplock bag containing the medium ziplock bags which contain the small ziplock bags containing the samples, and place them into a locked ultra-low freezer for storage until they are checked out for analyses.

Both the Sample Custodian and Field Coordinator will maintain copies of the Sample Receipt Forms in a Sample Receipt log (e.g., large three ring binder) for documentation and retrieval.

Receipt of Fill-in Samples

The Field Coordinator will notify the Sample Custodian of any fill-in samples being shipped. The procedure for logging in the fill-in shipments will be the same as the procedure for the initial shipment log-in, with the following modifications. Since the original large ziplock bag and medium ziplock bags have previously been shipped, logged-in, and placed in storage in an ultra-low freezer, the fill-in samples will arrive in individual ziplock bags that have been placed in unlabelled medium ziplock bags. Therefore the log-in procedure was modified to accommodate this difference in shipping preparation.

Upon receipt of a fill-in shipment, the Sample Custodian will remove the fill-in shipment's small ziplock bags from their medium ziplock bags and place the samples contained in the small ziplock bags out according to species, size, and number. The Field Coordinator will cross check the presence of the sample containing small ziplock bags against the hardcopy list of the samples that accompanied the shipment. The Field Coordinator will complete a blank Sample Receipt Form for each specie and geographic location sample received. The Sample Custodian will check the newly completed Sample Receipt Forms and instruct the Field Coordinator to make any necessary corrections.

After the fill-in samples are logged-in by the Sample Custodian and Field Coordinator they will jointly locate the ultra-low freezer containing the large ziplock and medium ziplock bags that the Fill-in samples' small ziplock bags belong in, and place the sample containing the small ziplock bags into their corresponding medium ziplock bags per species and large ziplock bag per geographic location.

An annotation that the fill-in sample(s) was placed in an ultra-low freezer in its corresponding geographic location and species bag(s) will be recorded in the "Notes" section of the fill-in Sample Receipt Form. The Sample Custodian will make copies of the fill-in Sample Receipt Form and provide copies to the Field Coordinator and Lead Chemist. The Sample Custodian and Field Coordinator will archive and maintain the copies of the fill-in Sample Receipt Form in the Sample Receipt log by stapling the fill-in Sample Receipt Form(s) to the backs of the main shipment's Sample Receipt Forms.

Upon completion of the sampling in the field, the Field Coordinator will instruct the Onsite Sampling Coordinator to ship the Sample Binder to the Data Entry Manager (or transmit the final copy of the Excel spreadsheet, if used as an alternative to the Sample Binder). Prior to shipping the Sample Binder, the Onsite Sample Coordinator will photocopy the data sheets and the Sample Binder as a backup (in case the binder is lost during shipment). After copying the Sample Binder, the Onsite Sample Coordinator will Fedex the Sample Binder to the Data Entry Manager, in the Fedex packaging provided by the Field Coordinator. The Survey's Field Coordinator will notify the Survey's Data Entry Manager that the binder has been shipped and provide the expected delivery date and time. The Data Entry Manager will inform the Field Coordinator when the binder has arrived.

Alternatively, if Excel spreadsheets are used instead of hardcopies, the Field Coordinator will acquire the Excel spreadsheets via e-mail and forward the spreadsheets to the Data Entry Manager for data entry with the total mercury data after the Chemists complete their analyses.

The Sample Custodian will inform the Lead Chemist when samples have arrived and provide him/her copies of the Sample Receipt Forms. The Lead Chemist will use the copies of the Sample Receipt Forms to determine the availability of samples for analyses. To acquire a batch of samples (i.e., one medium ziplock bag) for analyses, the Lead Chemist will be required to check the batch out of the ultra-low freezer by requesting the batch from the Sample Custodian. The Sample Custodian will maintain a "Sample Check-Out Log" for the batches noting: time of check out, date of check out, batch checked out, ultra-low freezer checked out from, etc.

After the analyses have been completed, the Lead Chemist will return the non-used portions of the samples to the Sample Custodian. The Sample Custodian will verify that the correct number of sample remains have been returned, and that they are contained in the bags that they were checked out in (i.e., correct sample in correct small, medium and large ziplock bags). The Sample Custodian will assign these sample remains to an ultralow freezer for long-term storage (other than the one used for the un-analyzed samples) and record in the "Sample Remains Log" the freezer that the sample remains were placed in. The Sample Custodian will archive and maintain this log in the Records Binder for the assigned geographical location.

Sample Remains Re-analyses

If needed, the Lead Chemist will request samples for re-analyses from the Sample Custodian. The Sample Custodian will retrieve the requested sample remains and check them out to the Lead Chemist. The Sample Custodian will use the "Remains Log" to record sample remains check out and check in transactions. The Sample Custodian will archive and maintain this log in the Records Binder for the assigned geographical location.

The Survey's Program Coordinator will notify the Sample Custodian by written instruction when sample remains are to be disposed. Upon receiving the instruction from the Program Coordinator, the Sample Custodian will transfer the sample remains to the Laboratory Safety Officer for disposal. The Sample Custodian will record this transaction in the Remains log, and attach the written request from the Program Coordinator. The Sample Custodian will archive the Record Binders and its contents.

Lead Chemist Sample Tracking

The Lead Chemist will be responsible for the sample tracking and scheduling of analyses. The Lead Chemist will maintain a "Batch Log" to track the batches' location, changes in location, person changing the location, and date and time of location changes to avoid miss-placing samples. The Lead Chemist and Chemists will maintain check off list(s) on

a clip-board in the mercury analyses room(s) to track the batches that have been analyzed and batches being thawed for analyses. This is to avoid duplication of analyses and neglecting to analyze batches. The Lead Chemist will maintain archived hardcopies of the check off lists and Batch Log.

Chemist Sample Handling for Mercury Analyses

The Lead Chemist will check out, from the Sample Custodian, selected batches (i.e., medium ziplock bags containing samples) from the ultra-low freezer(s), where they were checked-in and placed by the Sample Custodian. The checked out batch will be thawed in one of the laboratory's lockable refrigerators in a room other than the room where the total mercury analyses will be performed. The Lead Chemist will check out enough batches to provide the Chemist with ample samples to be analyzed during the following workday. In order to minimize microbiological degradation of the samples, the Lead Chemist will schedule the thawed samples be analyzed within two days of being checked out from the ultra-low freezers.

There will be two mercury workstations in the mercury analyses room where the samples are to be analyzed. One Chemist will be assigned to one mercury analyses workstation, while the other Chemist is assigned to the other mercury analyses workstation. Each station will have its own refrigerator, sample prep work area, and one Milestone, Inc. DMA-80 Direct Mercury Analyzer with scales and associated software interface computer (DMA).

Prior to performing the mercury analyses the Chemist will check out one batch of thawed samples from the Lead Chemist and transport that batch to their workstation's refrigerator. Only one batch of thawed samples is to be present at a mercury analyses workstation at any given time. All samples and sample prep will be restricted to the workstation of the Chemist assigned to carry out the analyses of the batch of thawed samples. At no time are the samples assigned to one Chemist to be placed into the workstation of the other Chemist.

The thawed samples will remain refrigerated at all times with the following exceptions: 1) in order to move the samples from the Lead Chemist refrigerator into the mercury analyses workstations' refrigerators, 2) in order to prepare the samples for placement into the sample boats and weighing on the DMA, 3) in order to place the samples into the DMA's autoloader,

4) while the sample is in the DMA's autoloader, 5) in order to place the non-used portion of the inter-cube back into its sample bag, or 6) in order to transport the samples back to the Sample Custodian.

The samples should not be allowed to sit outside of the refrigerator for more than 5 minutes prior to weighing them on the DMA. This is to minimize the sample losing weigh via either evaporation or moisture weeping from the tissues due to cellular disruption caused during freezing.

The Chemist will pull the small ziplock bags from one medium ziplock bag and put the small ziplock bags onto three separate trays. This is in addition to organizing and processing the samples prior to analyses.

Tray one will contain in sequence the small ziplock bags #1-#10. Tray two will contain in sequence the small ziplock bags #11-#20. Tray three will contain in sequence the small ziplock bags #21-#30.

The Chemist will follow the procedures for carrying out total mercury analyses as per the Milestone, Inc. DMA-80 Direct Mercury Analyzer Manual of Operation, U.S. EPA Method 7473* and Cizdziel et al, 2002**. This procedure includes entering data into the DMA spreadsheet data fields in order to identify the analyses with the sample or standard. The DMA loading sequence is as follows: a third analysis is run only on samples duplicates that are >14.9% different in their total mercury results. The requirement for running a third analyses for samples with differences >14.9% is waved for samples with both duplicates having total mercury values <0.009 ppm.

EXAMPLE SAMPLE RECEIPT FORM Sample Binder Shipment

Slot Position	ID	Slot Position	ID
1.	Inst Blank (no boat)	1.	Inst Blank (no boat)
2.	Blank (empty boat)	2.	Blank (empty boat)
3.	Tuna Std	3.	Tuna Std
4.	Dorm Std	4.	Dorm Std
5.	Blank (empty boat)	5.	Blank (empty boat)
6.	Small 1	6.	Medium 6
7.	Small 1	7.	Medium 6
8.	Small 2	8.	Medium 7
9.	Small 2	9.	Medium 7
10.	Small 3	10.	Medium 8
11.	Small 3	11.	Medium 8
12.	Small 4	12.	Medium 9
13.	Small 4	13.	Medium 9
14.	Small 5	14.	Medium 10
15.	Small 5	15.	Medium 10
16.	Small 6	16.	Large 1
17.	Small 6	17.	Large 1
18.	Small 6	18.	Large 2
19.	Small 7	19.	Large 2
20.	Small 7	20.	Large 3
21.	Small 8	21.	Large 3
22.	Small 8	22.	Large 4
23.	Small 9	23.	Large 4
24.	Small 10	24.	Large 5
25.	Small 10	25.	Large 5
26.	Blank (empty boat)	26.	Blank (empty boat)
27.	Tuna Std	27.	Tuna Std
28.	Dorm Std	28.	Dorm Std
29.	Blank (empty boat)	29.	Blank (empty boat)
30.	Medium 1	30.	Large 6
31.	Medium 1	31.	Large 6
32.	Medium 2	32.	Large 7
33.	Medium 2	33.	Large 7
34.	Medium 3	34.	Large 8
35.	Medium 3	35.	Large 8
36.	Medium 4	36.	Large 9
37.	Medium 4	37.	Large 9
38.	Medium 5	38.	Large 10
39.	Medium 5	39.	Large 10
40.	Tuna Std	40.	Tuna Std

Note: These are the "ideal" loading positions. Blanks/Standards/Samples positions may be modified.

^{*}U.S. EPA. 1998. Mercury in solids or solutions by thermal decomposition, amalgamation, and atomic absorption spectrophotometry. Method 7473. U.S. Environmental Protection Agency, Washington, D.C., U.S.A.

^{**}Cizdziel, J.V., T.A. Hinners and E.M. Heithmar. 2002. Determination of Total Mercury in Fish Tissues using Combustion Atomic Absorption Spectrometry with Gold Amalgamation. Water, Air, and Soil Pollution 135: 355-370.

The Chemist will use one spatula exclusively for loading the DORM Standard into the DMA sample boats and will use a second spatula exclusively for loading the TUNA Standard into the DMA sample boats. The Chemist will use a third spatula for loading the tissue samples into the DMA sample boats. The knife and spatula will be cleaned by the Chemist between each sample by wiping the blades with wet wipes and drying them with paper towels. Fresh wet wipes and paper towels will be used to clean the blades between samples.

The Chemist will use a stainless steel knife to cut approximately 1/4 inch off all six sides of the sample cubes to remove the tissues that were most likely to have suffered freezer burn which could affect the weight of the tissues. The Chemist will use the tissue from the inner-cube for the DMA analyses. The preparation of the inner-cube, cutting a portion of it for placement on the DMA sample boats and weighing on the DMA, should take no longer than five minutes per sample. The portion of the inner-cube not used for the DMA analyses is to be returned to its original labeled sample bag and placed back into the refrigerator. The non-used portion of the inner-cube should not be allowed to remain out of the refrigerator for more than five minutes. This is to avoid microbiological degradation of the non-used portion of the inner-cube that would cause weight changes due to cellular disruption and associated moisture weeping from the tissues that could affect later re-analyses.

At the end of the DMA run for the three trays (i.e., small, medium, large samples for a given species and geographic location), the Chemist will place the small ziplock bags containing the remains of the inter-cube back into their medium bag and check the batch back in with the Lead Chemist who will check the sample remains in with the Sample Custodian for archiving in an ultra-low freezer other than the one used for the unanalyzed samples. The Sample Custodian will maintain a "Remains Log" of the checking in of the sample remains and location of the sample remains.

Data Transfer and Entry

After each day of analyses, the Chemists will provide copies of their DMA data sheets to the Lead Chemist. The Chemists will archive and maintain their original data sheets. The Lead Chemist will data enter the Chemist's DMA data sheets information (total mercury ppm per sample) into an Excel spreadsheet, and provide an electronic copy of the spreadsheet to the Chemist for QA. After passing the Chemist's QA, the Lead Chemist will provide an electronic copy of the data to the Data Entry Manager. Thereafter, the Data Entry Manager assigns one of the Data Entry Staff to data enter the samples' corresponding data and information from the original previously shipped Sample Binder (or alternative sample spreadsheet) into the spreadsheet containing the total mercury provided by the Lead Chemist. The Data Entry Manager will provide the Lead Chemist and Field Coordinator with copies of the entered data for QA. After QA electronic copies of the spreadsheets will be provided to the Data Manager who will check the files for problems and archive the files on multiple computers and CDs. The Data Entry Manager will keep a log of the data sheets and binder's received from the Lead Chemist and Field

Coordinator and of their approval of the QA of the entered data. The Data Entry Manager and Data Manager will maintain an electronic archive of the spreadsheets.

Data Analyses

The Data Manager will provide copies of the total mercury and length spreadsheets for the various geographic locations and species to the Data Analysts. The Data Analysts will generate scatter plots of the total mercury and length data to evaluate the comparability of the species' mercury concentrations as observed from the different geographic locations. The Statistician will fit regressions to evaluate the total mercury and length data relationships per species. The Data Analyst and Statistician will provide the graphs of the scatter plots with regression lines per species with each geographic locations' data keyed for identification on the graphs.

Report Generation

The Program Coordinator will generate a draft of a Report of Findings. This Report will be Quality Assured and edited by the Laboratory Director and editorial staff.

CURRICULUM VITAE

E. ANTHONY REISINGER, JR.

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Education:

Master of Science

Interdisciplinary Studies

Biology	The University of Texas at Brownsville	2006
Bachelor of Science, Zoology	University of Georgia	1974
Associate of Science	Brunswick Junior College	1971

Professional Experience:

July 1982 to Present: Cameron County Marine Extension Agent, Texas Sea Grant, Texas Cooperative Extension

September 1979 to July 1982: Marine Resources Specialist III, University of Georgia, Marine Extension Service, Brunswick, Georgia

January 1974 to September 1979: Marine Biologist II - Georgia Department of Natural Resources, Coastal Resources Div., Coastal Fisheries Section, Brunswick, GA.

Selected Publications:

- Ellis, DK, Nickelson, R III: Holt, . BL, Reisinger, T. 1984. Developing vessel level grade quality standards for the shrimp industry. Proc. Ninth Annual Trop. and Subtrop.Fish.Conf of Amer. TAMU-SG-85-106 pp. 94-99. Nov..1984.
- Haby, MG., Edwards, RA, Reisinger, EA, Tillman RT, Younger, WR. 1993. The importance of seafood linked employment and payroll in Texas. Texas Sea Grant Publication. TAMU-SG-93-503. (May,1993)
- Harrington, DL, Christian, PA, Reisinger, E A. 1984. Using shrimp boats for finfishing. A summary of Georgia's cooperative finfish development and fishing demonstration project for 1982. Mar. Ext. Bull. No. 6,Georgia Sea Grant College Program. Univ. of Ga., Athens.
- Hasson KW, Fan Y-P, Venuti J, Reisinger T, Varner PW (in press) White spot syndrome virus (WSSV) introduction into the Gulf of Mexico and Texas freshwater systems through imported frozen bait shrimp. Dis Aquat Org
- Reisinger, E A. 1985. Harvesting cultured shrimp. P. IV-49 to IV-56. In Chamberlain, G. W., M. G. Haby and R. J. Miget (eds.) Texas shrimp farming manual . TX Ag. Ext. Serv. Pub. of invited papers presented at the TX Shrimp Farming Workshop, Nov. 19-20, 1985. Corpus Christi, Tx.

Special Training and Experience:

Conducted numerous educational programs in super fibers for shrimp trawl construction, bycatch reduction, TED installation and use, sport fishing, aquaculture, and shrimp marketing and preparation. Conducted demonstrations on board commercial fishing vessels for super fiber shrimp trawl performance, bycatch reduction and TED .performance

Certified Texas Parks and Wildlife Department Shrimp Farm and Hatchery Inspector

Certified Weighmaster-Instructor with the Tournament Directors Foundation of Texas

National Association of Underwater Instructors and YMCA SCUBA certifications with 90 hours of open ocean diving, fish population counts and maintenance dives.

Commercial fishing experience -shrimp and fish trawling, gill netting, fish trapping, swordfish and snapper/grouper longlining, certification in commercial electronic fish finding techniques.

Net making skills: trawl construction repair and design, gill net and seine design and construction, trammel net construction and design, and cast net construction and fishing methods.

Fishing tournament weighmaster, Port Mansfield Fishing Tournament and Ladies Kingfish Tournament, South Padre Island, TX

Honors:

Hockaday Service Award, 1987, for outstanding Service to the Texas International Fishing Tournament

Distinguished Service Award, 1993, Texas County Agricultural Agents
Association

Team Superior Service Award. 2005. Texas Cooperative Extension.

Superior Service Award, 2006. Texas County Agricultural Agents Association

Vice Chancellors Team Award for Excellence in Agriculture for trade adjustment assistance to the shrimp industry. 2006. Texas A&M University.

Award for Academic Excellence, Dept. of Biological Sciences, Master of Science. 2006. The University of Texas at Brownsville

Memberships:

Brownsville/Port Isabel Shrimp Producers Assn. Advisory Board

Laguna Madre Fly Fishing Assn. Advisory Board

Lower Laguna Madre Foundation Advisory Board

Texas Aquaculture Assn. Shrimp Section Advisory Member

Texas Hazardous Algal Bloom Working Group

Texas Tournament Directors Foundation Advisory Board

Valley Sportsman Club Advisory Board

Texas International Fishing Tournament Advisory Board

International Game Fish Association