Rhode Island Recreational Fishing Advancement Grant

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Final Report

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Project Title: Mercury contamination in scup (*Stenotomus chrysops*) from Rhode Island waters

Objectives: The principal objectives of this research project were to:

(1) Measure mercury concentrations in the filet (muscle) tissue of scup, and analyze the results as a function of fish body size in order to assess mercury bioaccumulation patterns across habitats (Narragansett Bay vs. Rhode Island Sound/Block Island Sound).

(2) Evaluate scup mercury levels relative to the threshold values established by the U.S. Food and Drug Administration (FDA) and U.S. Environmental Protection Agency (EPA)[1,2], and compare these results to health risks associated with consuming other finfish (e.g., striped bass, bluefish, tautog, black sea bass, summer flounder, and winter flounder).

(3) Work collaboratively with the Rhode Island Department of Health (RI DOH) to develop meaningful consumption advisories for RI residents, including recreational anglers.

Summary: The main findings and outcomes of this research were:

(1) Scup mercury concentrations ranged from 0.015 to 0.532 ppm wet weight (mean mercury = 0.106 ± 0.082 ppm wet weight).

(2) Irrespective of habitat, the mercury content of scup was positively related to body length, indicating the bioaccumulation of the contaminant. Scup collected from Narragansett Bay (NB), however, had higher mercury concentrations at a given length than conspecifics from Rhode Island Sound/Block Island Sound (RIS/BIS).

(3) No scup of legal size (10 inch minimum), irrespective of habitat, had mercury concentrations exceeding the U.S. FDA threshold level of 1.0 ppm. For NB, 14.5% of legal-size scup exceeded the U.S. EPA threshold level of 0.3 ppm, whereas no scup from RIS/BIS exceeded this level.

(4) The mean mercury concentration of legal-size scup was relatively low when compared to other legal-size recreational fish (striped bass and bluefish > tautog and black sea bass > scup and summer flounder > winter flounder).

(5) Collectively, scup have low mercury concentrations and present minimal risk to human consumers.

(6) Dr. Taylor is currently working collaboratively with the RI DOH to develop more species- and site-specific mercury consumption advisories for RI.

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1. Introduction

Mercury is a widespread and toxic environmental contaminant that adversely affects human health, and exposure occurs mainly through the consumption of contaminated fish.[1] To minimize mercury exposure, U.S. federal and state agencies issue consumption advisories to inform the public of the possible health risks of eating fish. However, consumption advisories are limited by several key factors. First, advisories are frequently predicated on nationally aggregated data that broadly estimate fish mercury concentrations.[1,2] Therefore, advisories often lack the appropriate detail to accurately report contamination risks of fish collected from a specific body of water or human demographic. This concern is especially warranted for the northeastern U.S., a region that relies heavily on local commercial and recreational fisheries. Second, national advisories emphasize fish species that are identified as high-risk for mercury, and thus, there is a paucity of information for low-risk species. The latter, consequently, undermines the health benefits provided by fish that pose little threat to the health of fish-consuming citizens.[3-5]

The Rhode Island Department of Health (RI DOH) has issued consumption advisories for freshwater fish based on species- and site-specific estimates of mercury concentrations. With respect to estuarine and marine fish, however, the RI DOH refers to the issued warnings from the U.S. Food and Drug Administration (FDA) for fish consumption.[2] By default, RI has based advisories on nationally aggregated data, and recommends not eating swordfish, shark, bluefish, and striped bass (note that advisories for bluefish and striped bass are for organic contaminants, not mercury). Until recently, it was unknown whether these species in RI waters contain mercury levels consistent with national averages, and therefore justify their inclusion in the advisories. Conversely, edible fishes not recognized as significant health risks, and therefore excluded from consumption advisories, may have mercury levels exceeding FDA action levels. Recent work by Dr. Taylor, Associate Professor of Marine Biology at Roger Williams University (Bristol, RI), has elucidated mercury bioaccumulation patterns in recreational fisheries from RI coastal waters. Here, Dr. Taylor concluded that the mercury content of these fish (e.g., striped bass, bluefish, tautog, black sea bass, summer flounder, and winter flounder), in many instances, do not reflect nationally aggregated data.[6-8] To this end, current RI consumption advisories for saltwater fish may be overly or insufficiently protective in limiting mercury exposure.

The purpose of this study was to examine mercury contamination in scup *Stenotomus chrysops* – a coastal finfish species that supports an important recreational fishery in RI waters. The specific objectives of this study were threefold: (1) Analyze mercury concentrations in scup as a function of body size in order to assess bioaccumulation patterns, (2) Evaluate scup mercury levels relative to the threshold values established by the U.S. FDA and U.S. Environmental Protection Agency(EPA)[1,2], and compare

these results to health risks associated with consuming other finfish, and (3) Work collaboratively with the RI DOH to develop meaningful consumption advisories for RI residents, including recreational anglers. Acquiring such data will support public health risk assessments and risk management decisions related to the issuance of fish consumption advisories.

2. Justification

Relative to the general population, specific U.S. subpopulations are more susceptible to mercury toxicity because of their elevated rates of fish consumption. For example, economic status, ethnic and cultural identity and practices, and coastal residency are important factors governing fish consumption, and thus, mercury exposure.[9-11] Recreational anglers in the U.S. are also a subpopulation of concern because they are high-end consumers of fish and fishery products.[12-17] This concern is especially warranted for RI residents, where the state supports an extensive saltwater recreational fishery. In 2012, for example, the annual recreational landing of 1,393,721 kg in RI constituted ~ 13% of the total recreational landings in the North Atlantic.[18] Further, nearly 38,000 RI residents (4% of the state's population) purchased saltwater fishing licenses in 2011, a relatively high number considering that saltwater licenses have only been required in the state for the past few years.[19] These data indicate that RI residents, especially recreational anglers, are a more highly exposed group to mercury toxicity relative to the national average.

The focal species in this study is the scup *Stenotomus chrysops*. Scup support a lucrative recreational fishery in RI with a 2012 annual landing equal to 252,217 kg, which represents ~ 18% of the total recreational catch in the state.[18] Moreover, Dr. Taylor recently disseminated a food frequency questionnaire (FFQ) to RI recreational anglers to obtain more accurate estimates of fish eating habits of the state's residents. Of the 373 responses received from the FFQ, 27.9% of the individuals reported eating scup in the summers of 2012 and 2013. Scup may therefore represent an important source of mercury for fish-consuming individuals, given the prominence of this species as a dietary resource in RI.

3. Objectives

The objectives of this study were threefold:

(1) Measure mercury concentrations in the filet (muscle) tissue of scup, and analyze the results as a function of fish body size in order to assess mercury bioaccumulation patterns across habitats (Narragansett Bay vs. Rhode Island Sound/Block Island Sound).

(2) Evaluate scup mercury levels relative to the threshold values established by the U.S. FDA and EPA[1,2], and compare these results to health risks associated with consuming other finfish (e.g., striped bass, bluefish, tautog, black sea bass, summer flounder, and winter flounder).
(3) Work collaboratively with the RI DOH to develop meaningful consumption advisories for RI residents, including recreational anglers.

4. Methods

4.1. Sample collection and preparation

From 2006 to 2013, scup were collected from Narragansett Bay (NB) and Rhode Island Sound/Block Island Sound (RIS/BIS) using otter trawls and hook & line (Fig. 1). Scup collected in the field were either processed immediately after capture or put on ice for transportation and frozen at -20˚C in the laboratory for subsequent analysis. The processing of scup included measuring individuals for whole body wet weight (g) and total length (cm), and excising ~ 1 g wet weight of muscle tissue from the dorsal region above the operculum (i.e., gill cover). All muscle-tissue samples were freeze-dried for 48 h (Labconco FreeZone 4.5-L Benchtop Freeze-Dry System), homogenized with clean stainless-steel spatulas, and stored at room temperature in borosilicate vials.

4.2. Mercury analysis

Total mercury concentrations in mg/kg dry weight (ppm) was measured in homogenized muscle-tissue samples of scup (~ 0.03 g dry weight) using automated combustion atomic absorption spectrometry (AC-AAS) (DMA-80 Direct Hg Analyzer, Milestone, Inc., Shelton, Connecticut, USA), with a detection limit of 0.01 ng Hg (US EPA, 1998). The mercury analyzer was calibrated using certified reference materials (CRMs) of known mercury concentrations, and included solid standards (TORT-1: lobster hepatopancreas; DORM-2: dogfish muscle) and aqueous standards prepared by the National Research Council Canada, Institute of Environmental Chemistry (Ottawa, Canada) and the National Institute of Standards and Technology (Gaithersburg, Maryland, USA), respectively. Calibration curves were highly linear (mean $R^2 = 1.00$; range $R^2 = 0.99\text{-}1.00$; $p < 0.0001$), and the recovery of independently analyzed samples of TORT-1, DORM-2, and PACS-2 (marine sediment) CRMs ranged from 91.9% to 107.5% (mean = 96.2%). All samples were analyzed as duplicates, and an acceptance criterion of 10% was implemented. Duplicate samples with < 10% error were averaged for subsequent analysis (mean absolute difference between duplicates = 4.8%). Samples with > 10% error were reanalyzed to achieve the

acceptance criterion or were eliminated from further analysis. For additional quality control, blanks were analyzed every 10 samples to assess instrument accuracy and potential drift. Further, two previous studies determined that AC-AAS used in this study produced statistically equivalent results to isotope dilution gas chromatography-inductively coupled plasma mass spectrometry, with R^2 values ranging from 0.902 and 0.946 between the two methods.[6,7]

4.3. Data analysis

Prior to statistical analysis, total mercury data were converted to wet weight using a wet/dry ratio measured for each scup tissue sample (~ 77% water content). For each habitat (NB and RIS/BIS), the effect of total length (cm) on scup mercury concentrations were analyzed with least-squares (non-linear) exponential regressions. An analysis of covariance (ANCOVA) model was subsequently used to assess differences in Hg bioaccumulation rates in scup collected in NB and RIS/BIS, with total length as the covariate and habitat as the discrete explanatory variable. Prior to the ANCOVA, the interaction effect between length and habitat was examined with a two-way analysis of variance (ANOVA) model. No significant interaction effect was detected (2-way ANOVA: Length × Habitat; $F = 0.83$, $df = 1, 202$, $p = 0.363$), and the assumption of homogeneity of slopes was verified. Moreover, to evaluate potential risks to human consumers, habitat-specific scup mercury data were analyzed relative to the U.S. FDA and EPA mercury action levels of 1.0 ppm and 0.3 ppm, respectively.

Dr. Taylor has performed comprehensive studies of mercury contamination in other recreational fishes from Narragansett Bay, including striped bass, bluefish, tautog, black sea bass, summer flounder, and winter flounder.[6-8] In this study, scup mercury contamination was statistically compared to these other species. Specifically, a one-way ANOVA model was used to assess differences in mercury concentrations among (legal-size) fish species. The post hoc separation of mean differences in mercury across 7 levels of fish species were contrasted with a Ryan-Einot-Gabriel-Welsch (Ryan's Q) multiple comparison test.

5. Results and Conclusions

5.1. Scup mercury concentrations and bioaccumulation patterns

Total mercury concentrations in the dorsal muscle tissue of scup ($n = 203$) ranged between 0.015 to 0.532 ppm wet weight (Table 1). Of these samples, the mean mercury content of scup from NB was 60.6% greater than values measured for conspecifics in RIS/BIS. Note that some of this discrepancy in

mercury contamination may be explained by the different sized scup analyzed in each habitat (mean total length in NB and RIS/BIS = 29.8 and 20.3 cm, respectively). Irrespective of habitat, the mercury content of scup was positively related to body length (ANCOVA: Length; $F = 570.6$, $df = 1, 202$, $p < 0.0001$) (Fig. 2), indicating the bioaccumulation of the contaminant. Scup collected from NB, however, had higher mercury concentrations at a given length than conspecifics from RIS/BIS (ANCOVA: Habitat; $F = 20.6$, $df = 1, 202$, $p < 0.0001$). The cumulative results indicate that: (1) scup mercury concentrations vary significantly over relatively small spatial scales (5 km); (2) site-specific scup mercury concentrations are related to the anthropogenic contaminant sources in NB; and (3) the effect of habitat-type (e.g., estuary vs. ocean) must be examined to accurately assess intra-species mercury contamination.

5.2. Scup mercury concentrations relative to government action levels

For this portion of the study, data were analyzed with respect to the legal-size limit of scup, i.e., minimum catch size for scup in RI is equal to 25.4 cm (10 inches).[22] The mean total mercury concentration of legal-size scup from NB was 0.195 ± 0.084 ppm wet weight ($n = 62$), of which 14.5% exceeded the U.S. EPA advisory level. For legal-size scup from RIS/BIS, the mean total mercury concentration was 0.104 ± 0.040 ppm wet weight ($n = 45$), and none of the fish had mercury levels above 0.3 ppm. The mercury-length exponential regression models also predicted that scup from both habitats had relatively low mercury concentrations at their legal size limit (0.102 and 0.081 ppm for NB and RIS/BIS, respectively) (Fig. 2). The cumulative results further suggest that human consumption of scup poses minimal risk to health.

5.3. Scup mercury concentrations relative to other recreational finfish

The mean mercury concentration of legal-size fish differed significantly across species (1-way ANOVA: $F = 22.7$, $df = 6, 369$, $p < 0.0001$) (Fig. 3). According to the Ryan's Q multiple comparison test, striped bass and bluefish had the highest levels of mercury contamination, followed by tautog, black sea bass, scup, summer flounder, and winter flounder (Fig. 3).

5.4. Developing mercury consumption advisories and recommendations

Dr. Taylor is continuing to work collaboratively with the RI DOH to update and improve their fish consumption advisories (Robert Vanderslice, Chief of the Office of Environmental Health Risk, *personal communication*), as well as promoting species that are deemed safe for human consumption (i.e.,

recommendations). Advisories and recommendations are in the process of being created for the focal species of this project (scup), as well as other premier recreational fishes (striped bass, bluefish, tautog, black sea bass, summer flounder, and winter flounder). Advisories and recommendations will be based on data from this project and Dr. Taylor's previous research because of their comprehensiveness with respect to species- and location-specific information.

5.5. Outreach: Communicating research results to the scientific community and public

The project described herein provided a research opportunity for a Roger Williams University undergraduate student (Sean Maiorano). Specifically this project served as the focal point of a summer undergraduate research fellowship and culminated into two professional presentations (delivered by S. Maiorano as first author).

Maiorano, S., Taylor D.L. 2013. Mercury concentration in scup (*Stenotomus chrysops*). Biology New England South Undergraduate Research Meeting, Bristol, RI, December 6 (poster presentation)

Maiorano, S., Taylor D.L. 2013. Mercury concentration in scup (*Stenotomus chrysops*). Rhode Island Summer Undergraduate Research Fellows Conference & Faculty Retreat, Kingston, RI, August 2 (poster presentation)

Dr. Taylor has been active in the RI community, disseminating results of his on-going mercury studies to local recreational anglers. Examples of these outreach activities include Dr. Taylor and his research team designing and operating a display booth at the 10th Annual New England Saltwater Fishing Show (NESFS) (Providence, RI; March 28-30, 2014); coordinated by the RI Saltwater Anglers Association (RISAA). The display booth was largely dedicated to Dr. Taylor's mercury research in local fisheries, and this information was presented to the convention attendees. Dr. Taylor has also presented his mercury research to locals at the Galilee Fishing Tournament and Seafood Festival (Port of Galilee, Narragansett, RI; September 7-8, 2013); an event again coordinated by RISAA. The outreach activities initiated by Dr. Taylor, and facilitated by the positive relationship with RISAA.

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Table 1. Summary of mean (±1 standard deviation) total length, whole body wet weight, and total mercury concentration (Hg) of scup collected from Narragansett Bay (NB) and Rhode Island Sound/Block Island Sound (RIS/BIS). The percent of scup samples (*n*) that exceeded the U.S. Environmental Protection Agency mercury threshold level (0.3 ppm) and the predicted Hg concentration of scup at the RI minimum size limit (10 inches) are also reported. Values in parentheses represent ranges.

	Habitat	
	NB	RIS/BIS
Sample size (n)	77	126
Total length (cm)	29.8 ± 5.6 (17.8-42.0)	20.3 ± 7.0 (6.5-34.0)
Weight (g)	434.8 ± 211.7 (102.3-973.0)	249.9 ± 201.4 (6.0-872.0)
Hg (ppm wet weight)	0.170 ± 0.093 (0.040-0.532)	0.067 ± 0.041 (0.015-0.209)
Percent samples > 0.3 ppm	14.5	0.0
Predicted Hg at minimum size	0.102	0.081

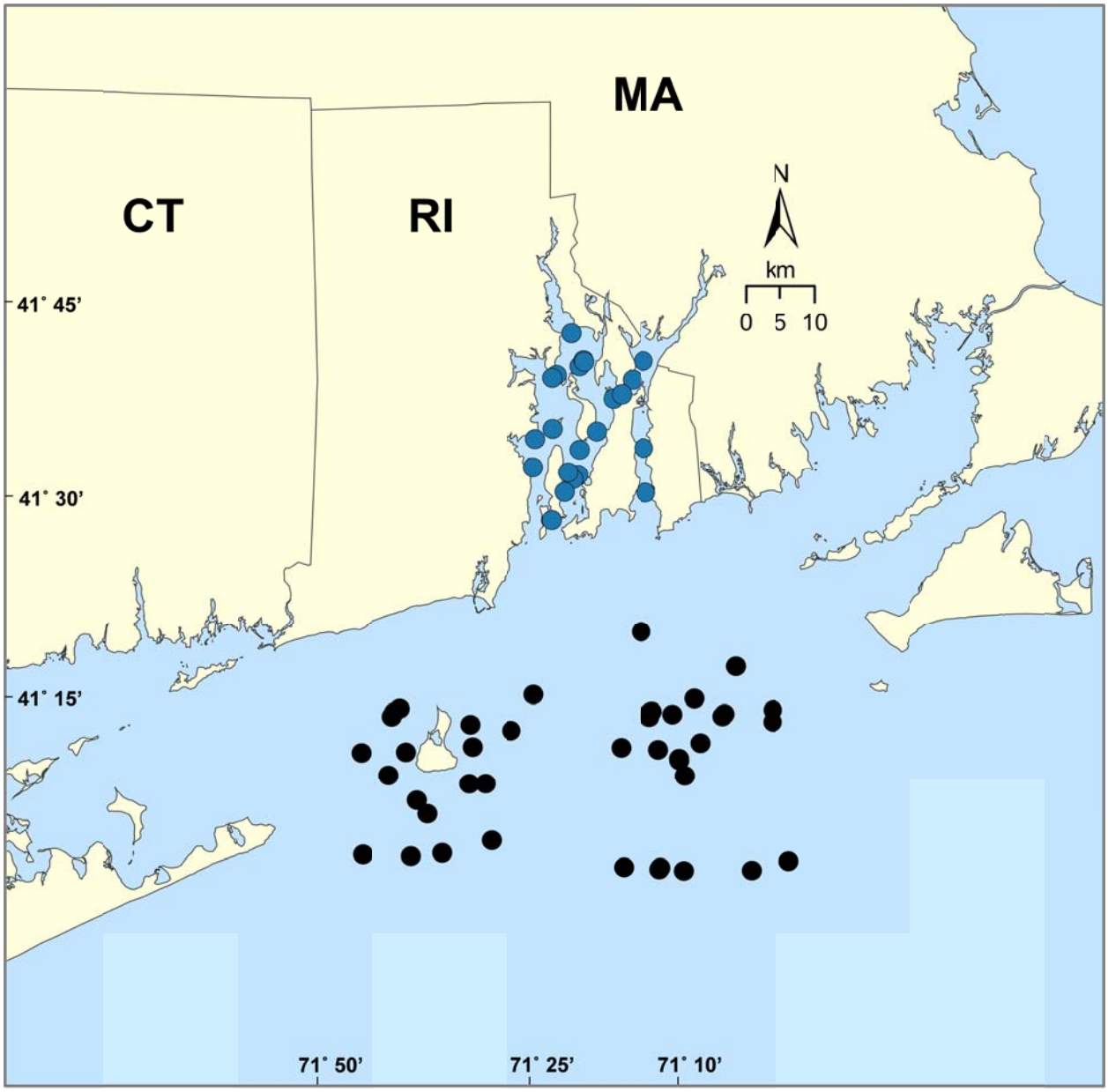

Figure 1. Map demarcating location of scup sampling locations (Narragansett Bay = blue points and Rhode Island/Block Island Sound = black points).

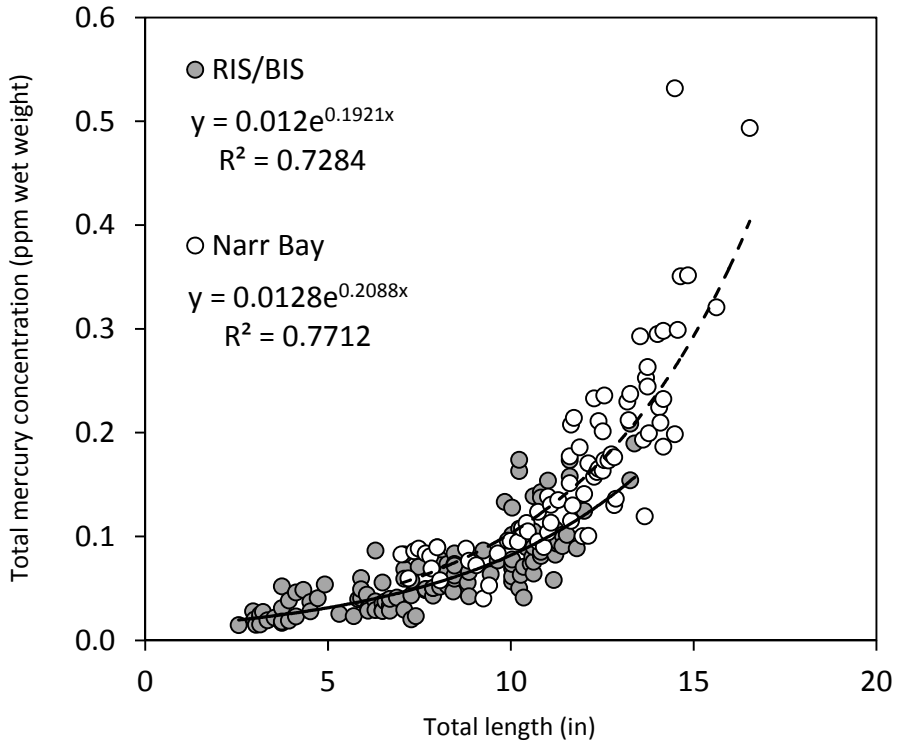

Figure 2. Total mercury concentrations (ppm wet weight) of scup as a function of total length (inches). Scup collected from Rhode Island/Block Island Sound (RIS/BIS) and Narragansett Bay (Narr Bay) are denoted by solid and open circles, respectively. Exponential regression models were fit to habitat-specific data.

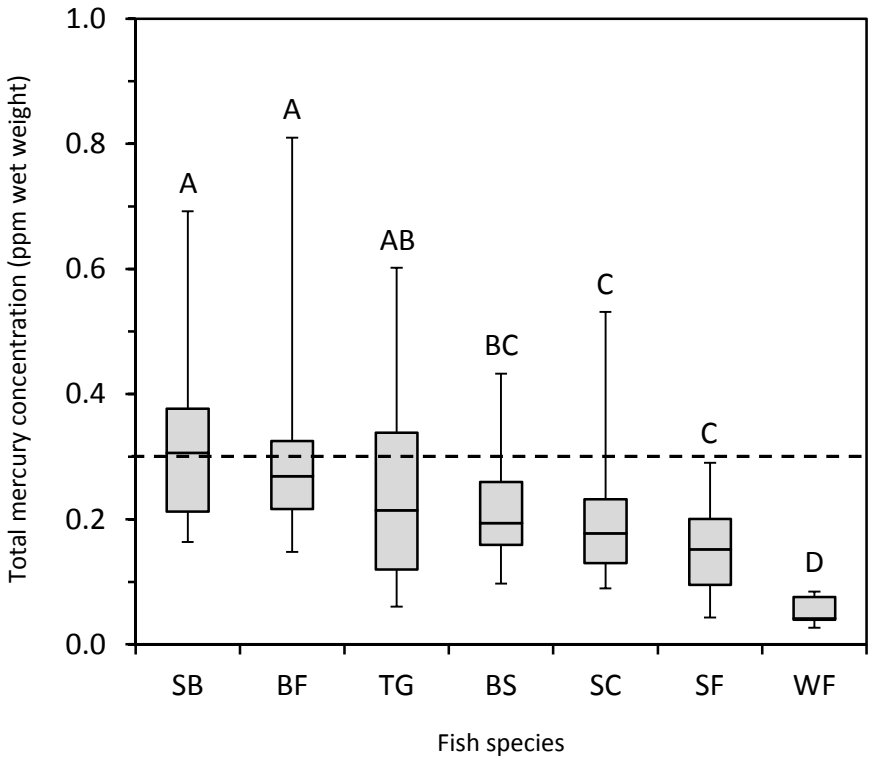

Figure 3. Total mercury concentrations (ppm wet weight) of recreationally-important finfish collected from Narragansett Bay (box plot illustrating median, 1st and 3rd quartiles, and maximum and minimum values), including striped bass (SB), bluefish (BF), tautog (TG), black sea bass (BS), scup (SC), summer flounder (SF), and winter flounder (WF). Data are only presented for legal-size fish, and in RI the minimum size limits for each fish are: black sea bass = 13 inches (in); bluefish = no size limit (default length of 24 in used for analysis); scup = 10 in; striped bass = 28 in; summer flounder = 18 in; tautog = 16 in; winter flounder = 12 in.[22] The horizontal dashed lines represent the U.S. EPA action level of 0.3 ppm. Note that 58% of striped bass, 44% of bluefish, 33% of tautog, 14% of scup, 13% of black sea bass, 3% of summer flounder, and 0% of winter flounder had mercury greater than 0.3 ppm. Unique letters above each box plot denote statistical differences in mean mercury values (Ryan's Q multiple comparison test).