PREDICTED BIOACCUMULATION OF PCBs AND TOXAPHENE IN BOTTLENOSE DOLPHINS (TURSIOPS TRUNCATUS): THE CONTRIBUTION OF CONTAMINATED PREY

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Introduction

Residues of two organochlorines (OCs) -- Aroclor 1268 (a highly chlorinated PCB formulation) and toxaphene (a DDT-replacement pesticide) -- are major persistent contaminants in St. Simons Sound near Brunswick, Georgia, USA[1]. Although studies have recently documented OC levels in Brunswick area fish that are routinely consumed by humans[2,3], little is known about organochlorine body burdens in resident marine mammals. Sub-populations of the bottlenose dolphin *(Tursiops truncatus)*, an abundant odontocete of the coastal mid-south Atlantic and Gulf of Mexico regions, have recently been shown to exhibit a limited home range and site fidelity in a northern Florida estuary[4], underscoring the need to assess the impact of OCs in individuals exposed via their natural prey (i.e. contaminated fish).

Materials and Methods

Croakers (*Cynoscion nebulosus, Leiostomus xanthurus*), mullet (*Mugil cephalus*) and perch (*Bairdiella chrysoura*), favored prey species for *T. tursiops*[5], were collected using gill, trammel and cast nets during the spring and fall of 2003. To impart realism into the dolphin bioaccumulation predictive model, prey fish retained for analysis were limited to size ranges reported in dolphin gut contents[6].

Fish were collected in each of three estuaries along the Georgia-Florida Atlantic coastline – Savannah River (SR), Turtle/Brunswick River (TB) and the St. Johns

River (SJ) (Fig. 1). The TB estuary has been impacted by discharge of PCBs, toxaphene and mercury from industrial sites for several decades. Whereas the Savannah and St. Johns estuaries also have been impacted by anthropogenic activities, the severity of PCB and toxaphene contamination is less than that for TB.

Fish of the same species were composited (5-30 individuals depending on size) and homogenized in a solvent-rinsed stainless steel blender. Homogenates were extracted in triplicate using a Dionex 200 ASE system with CH_2Cl_2 under elevated temperature and pressure. After gravimetric lipid determination, sample extracts were cleaned up using gel permeation and Florisil column chromatography. Extracts were exchanged to pesticide grade hexane and reduced to 1.0 ml using a TurboVap II followed by a gentle stream of high purity N_2.

Extracts were analyzed using a Varian 3400 GC with electron capture detection (GC-ECD) with analytes confirmed using a HP 6890 GC coupled to a 5973 MSD operating in the electron capture negative ion (ECNI) mode. Thin-film, narrow bore DB-XLB (30 or 60m x 0.25 mm x 0.25 m) capillary columns were used to separate target analytes.

Commercially available standard mixtures of PCB (NIST and AccuStandard, USA) and toxaphene (Dr. Ehrenstorfer, Augsburg, Germany) congeners were used to calibrate the GCs. Total PCBs and toxaphene (PCBs and TOX, respectively) in procedural blanks were 0.80$\pm$0.98 ng/g and <20 ng/g, respectively. The mean recovery of surrogates (DBOFB and -HCH) was 79$\pm$10%. The mean recoveries of PCB analytes in fish tissue matrix spikes and a certified reference material (CARP-2, NRC Canada) were 101$\pm$18% and 110$\pm$12%, respectively. Target analyte concentrations were computed using Microsoft Excel and statistical comparisons were performed using SAS.

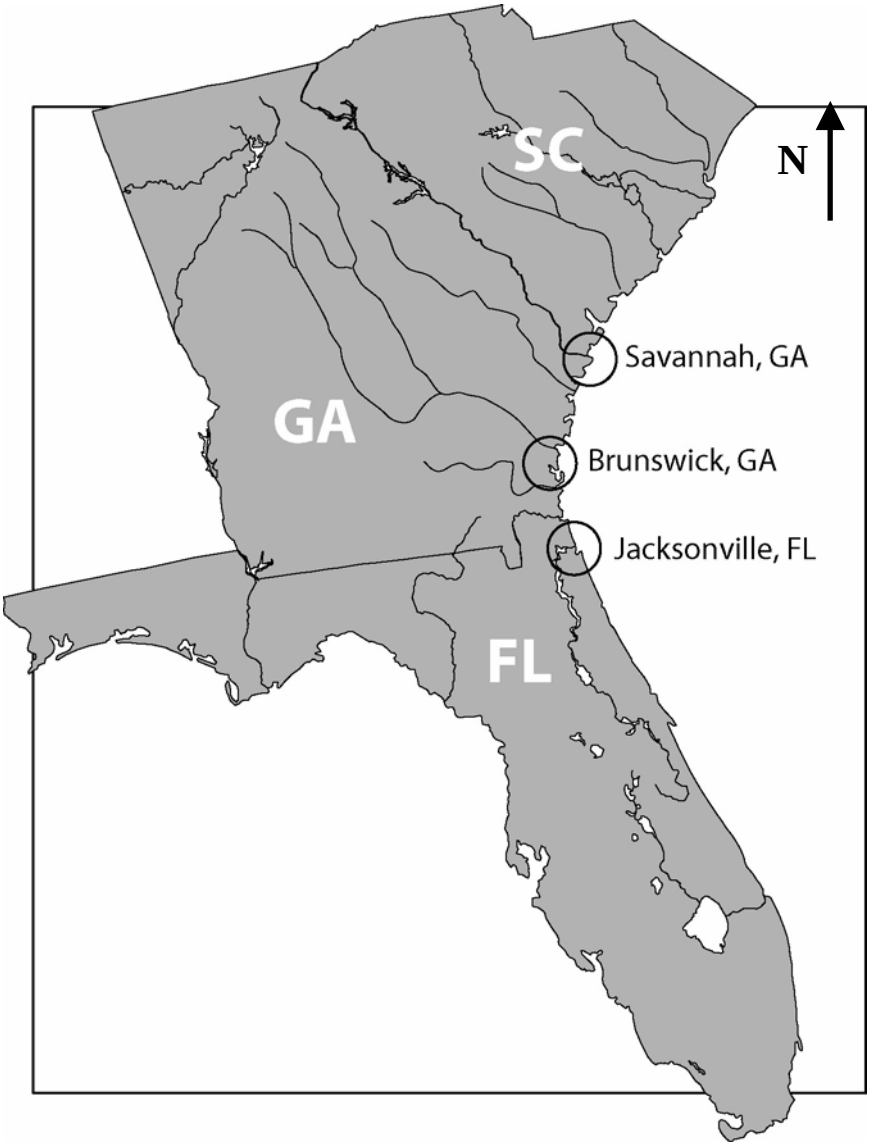

Fig. 1. Map of study area (Georgia-Florida Atlantic coastline, USA). The Turtle/Brunswick (TB) River estuary is home to several industrial/USEPA Superfund sites, including two that emitted PCBs (as Aroclor 1268) and toxaphene.

Results and Discussion

The mean total length of collected fish ranged between 13.9 to 20.9 cm, well within the range consumed by *T. truncatus tursiops* [5,6]. The coefficient of variation (CV) for total length among individuals for a given species was <20%. Mean lipid content ranged between 1.06 to 7.21%; it is not known why the range of lipid content among estuaries for *M. cephalus* was especially broad (Table 1).

Table 1. Sample size, length and extractable lipid content of study fish.

ESTUARY	SPECIES	n	N	TOTAL LENGTH	%LIPID
				(cm)	
Savannah	Striped mullet *(Mugil cephalus)*	6	96	20.9±3.22	7.21±2.49
River (SR)	Spotted seatrout *(Cynoscion nebulosus)*	3	24	30.1±1.58	3.02±0.35
Turtle/Brunswick	Spot *(Leiostomus xanthurus)*	2	22	16.2±1.25	4.14±1.00
River (TB)	Striped mullet *(Mugil cephalus)*	3	60	13.9±1.73	1.06±0.50
St. Johns	Silver perch *(Bairdiella chrysoura)*	6	110	15.2±1.88	1.55±0.17
River (SJ)	Striped mullet *(Mugil cephalus)*	3	60	19.6±3.49	1.77±0.55

N = number composites

N = total number individuals

Using ANOVA, there was no significant difference in ΣPCBs among species within an estuary; therefore data for all species for a given estuary were pooled (Fig. 2). As a result, ΣPCBs (both wet and lipid basis) were significantly different for all 3 estuaries, with TB (1400±840 ng/g wet) > SJ (12±7.5 ng/g) > SR (1.8±1.5 ng/g).

Because the lack of differences in prey fish ΣPCBs obviated the need for a species weighted dietary exposure model for *T. truncatus*, a simple predictive model based on mean ΣPCBs in prey and a mean biomagnification factor (BMF) for the 12 primary constituents of Aroclor 1268[7] indicated that bioaccumulation potential was highest for *T. truncatus* in the TB estuary (**Table 2**). Assuming that these animals feed exclusively on contaminated fish, the maximum predicted level (22 μg/g wet) exceeds published thresholds associated with impaired marine mammal health[8], suggesting that OCs may pose a health risk to resident TB dolphins.

Although this predicted PCB load is 2-4 times higher than in *T. truncatus* recently biopsied in other southeastern U.S. locations[9], it is consistent with mean blubber concentrations reported for adult males and juveniles biopsied elsewhere in the region[10]. In addition, mean liver PCB concentrations (92 μg/g wet; n=6) from specimens of the same species stranded along the Florida coast during the period 1989-1994 were 4 times higher than our maximum predicted level[11]. Furthermore, the liver PCB profile for a single animal ("BN-1"; ΣPCBs = 71 μg/g) from this latter study showed strong evidence of Aroclor 1268 contamination. Predicted biomagnification of PCBs due to consumption of locally abundant prey for resident St. Johns and Savannah River sub-populations of *T. truncatus* is expected to be several orders of magnitude lower than for resident Turtle/Brunswick animals (**Table 2**). Future efforts will focus on quantifying toxaphene residues in prey fish, monitoring inshore animal residence times and locations, securing blubber samples from Brunswick (GA) area resident *T. truncatus* for OC analyses, and refining biomagnification models.

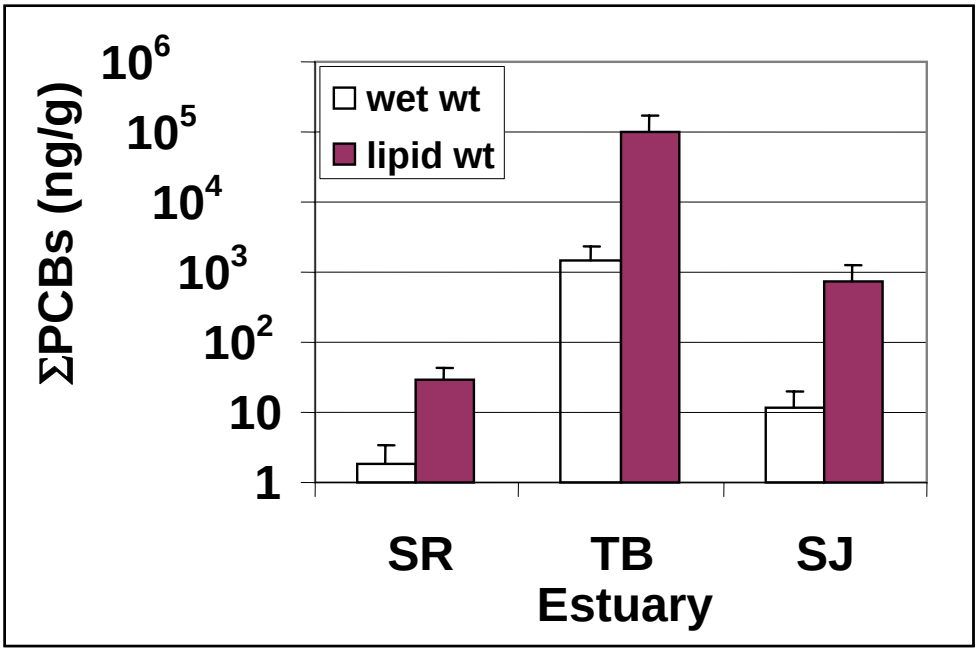

Fig. 2. Mean total PCB concentrations (ΣPCBs) for prey fish were significantly different among the 3 study estuaries ($p<0.0001$). No difference in ΣPCBs among species within a given estuary was observed (data not shown). Error bars represent 1σ.

Table 2. Predicted total PCB concentration (ΣPCBs) in resident inshore bottlenose dolphins (*Tursiops truncatus*) due to biomagnification from locally abundant prey species.

Estuary	ΣPCBs fish ng/g wet	Avg. BMF[1]	ΣPCBs dolphin ng/g wet
Savannah River (SR)	1.80	15.2	27
Turtle/Brunswick River (TB)	1430	15.2	22000
St. Johns River (SJ)	12.0	15.2	180

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