ADDENDUM 01

Characterization of Potential Health Effects Associated with Consumption of Fish from Ellison Creek Reservoir

Morris County, Texas
August 2007

INTRODUCTION

For the initial Ellison Creek Reservoir (ECR) study in May 2005 the Texas Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG) collected 30 fish tissue samples to assess public health implications of consuming fish from ECR. Two of 30 samples collected were white crappie. Laboratory results indicated that white crappie tissues contained 0.033 mg/kg and 0.057 mg/kg polychlorinated biphenyls (PCBs). The mean concentration of PCBs in the two white crappie samples was 0.045 mg/kg. Because one of two samples exceeded the SALG guideline (Health Assessment Comparison Value [HAC value] for assessing systemic human health effects of regular or prolonged oral exposure to PCBs (0.047 mg/kg) and the mean was close to the SALG guideline, DSHS SALG concluded that consumption of white crappie collected from ECR constitutes an indeterminate public health hazard because the sample size (two fish from one site) was not large enough to definitively project hazards to human health. Therefore, the DSHS SALG recommended collecting additional samples of white crappie from ECR to better characterize PCB contamination of this species of fish from this water body and to test crappie for dioxins and furans because dioxins and furans can co-exist in fish exposed to PCBs from industrial sources.

This addendum summarizes PCBs and polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (dioxins/furans; PCDD/PCDFs; dioxin) found in 10 additional crappie samples collected in November 2006 from ECR, compares combined 2005 and 2006 PCB fish tissue data (N=40) and 2006 crappie data (N=10), addresses public health implications of consuming contaminated crappie from the reservoir, and suggests potential actions to protect humans from possible adverse health effects of consuming contaminated crappie from this water body.

METHODS

Study methodology not described in the methods section of Addendum 01 may be found in the methods section of the report entitled Characterization of Potential Health Effects Associated with Consumption of Fish from ECR Morris County, Texas, November 2005, Revised July 2007 beginning on page 6.

Fish Sampling Methods and Description of the ECR 2006 Sample Set

In November 2006, the SALG staff worked cooperatively with the Texas Parks and Wildlife Department (TPWD) during their routine fall trap net crappie survey to collect 10 crappie samples from ECR (Table 1). Risk assessors used data from crappie to examine the potential for human health risks from consuming environmentally-contaminated crappie taken from ECR in 2006, emphasizing analysis and interpretation of PCBs and dioxins in crappie.

The DSHS SALG set 10 trap nets throughout ECR to provide spatial coverage of the study area (see Figure 1 for SALG trap net locations). The general approach used by the field team was to set trap nets and fish them overnight. The trap nets were set in locations to maximize available cover and habitat in the reservoir. The SALG staff in cooperation with TPWD field staff set five trap nets used for their routine fall sampling of crappie in ECR. The TPWD uses a random sample design to determine their sample sites or net locations (see Figure 1 for TPWD trap net locations). To keep crappie samples from different sample sites/trap nets separated, captured crappie were retrieved from the trap nets and placed in an individual, labeled mesh bag and stored on wet ice until they were processed. The remaining live fish, culled from the catch, were returned to the reservoir. Any dead fish were disposed of in an appropriate manner.

SALG staff processed all fish onsite at the ECR public boat ramp or at TPWD Inland Fisheries District Office in Marshall, TX. SALG staff weighed each fish sample to the nearest gram and measured total length (tip of nose to tip of tail fin) to the nearest millimeter. After weighing and measuring a sample, staff filleted skin-off samples on a cutting board covered with aluminum foil. Staff then wrapped the left and the right fillets in double layers of aluminum foil and placed wrapped fillets in pre-labeled plastic freezer bags that were then stored on wet ice in ice chests. The SALG staff transported tissue samples on wet ice to headquarters in Austin, TX, temporarily storing the samples in a locked freezer. The SALG shipped frozen tissue samples on wet ice by common carrier to the Texas A&M University Geochemical and Environmental Research Group laboratory (GERG laboratory) for analysis.

Analytical Laboratory Information

The GERG laboratory, using established EPA methodology, analyzed crappie fillets (skin off) for all 209 individual PCB congeners by high resolution mass spectrometry (HRMS) and low resolution mass spectrometry (LRMS). DSHS routinely requests only the LRMS method for PCB congener quantification. However, for this assessment DSHS requested both the LRMS and HRMS analytical methods for method comparisons. The HRMS method (MDL ~ 0.000002 mg/kg) is a more precise method as compared to the LRMS method (MDL ~ 0.0005 mg/kg). The laboratory also analyzed crappie collected in November 2006 from ECR for dioxins and furans by HRMS.

Calculation of Toxicity Equivalent Concentrations (TEQs) for Dioxins

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (dioxins/furans; PCDD/PCDFs; dioxin) are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures differ not only with respect to the number and position of

chlorines on the parent molecule. Toxicity varies with the number of chlorine atoms, increasing with chlorine numbers up to four atoms, decreasing thereafter with increasing chlorine number up to a maximum of eight chlorines. Those congeners of PCDD/PCDFs having chlorine atoms in the 2, 3, 7, and 8 positions appear more toxic than other PCDD/PCDF congeners. The most toxic of all PCDDs/PCDFs is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). To gain some measure of toxicity equivalency, 2,3,7,8-TCDD has been designated the standard against which the toxicity of other congeners is measured. Scientists from the World Health Organization (WHO) have developed toxicity equivalency factors (TEFs) to compare the relative toxicity of other dioxins or dioxin-like compounds to that of 2,3,7,8-TCDD, which is assigned a TEF of 1.0.[1,2]

In order to compare laboratory data to HAC values, SALG risk assessors calculated dioxin congener toxicity equivalents (TEQs) in crappie from the present survey by multiplying a congener's concentration by its TEF to produce a concentration roughly equivalent in toxicity to that of a given concentration of 2,3,7,8-TCDD (concentration × TEF). The total TEQ for any given sample is defined as the sum of the TEQs for each of the congeners in the sample, calculated according to the following formula:[3]

$$\text{Total TEQs} = \sum_{i=1}^{n} (\text{CI} \times \text{TEF})$$

CI = concentration of a given congener
TEF = toxicity equivalency factor for the given congener
n = # of congeners
i = initial congener

RESULTS

Laboratory Analytical Results

The GERG laboratory electronically transmitted the results of chemical analyses of the ECR crappie samples between late March and May 2007. The laboratory reported the analytical results for PCBs by HRMS, PCBs by LRMS and dioxin and furans by HRMS for 10 crappie samples.

Summary results of PCBs by HRMS, PCBs by LRMS, and dioxins and furans in crappie collected in November 2006 from ECR are presented in Tables 2 and 3. Table 2 presents summary statistics for PCBs by HRMS and PCBs by LRMS. Table 3 presents summary statistics for dioxins and furans. The table summaries utilize mean concentration ±1 standard deviation unless stated otherwise.

Organic Contaminants

Polychlorinated biphenyls (PCBs)

Table 2 contains summary statistics for PCBs measured in crappie samples collected in 2006 from ECR. The laboratory analyzed all samples for each of 209 PCB congeners by HRMS and LRMS methods. All fish from ECR contained one or more of the 209 PCB congeners for each analysis method. No sample contained all 209 congeners. Generally, the concentrations reported for the HRMS method were higher than those reported for the LRMS method. The mean concentration in crappie for the HRMS method was 0.089 ± 0.067 mg/kg (Table 2). The minimum and maximum crappie PCB concentrations reported for the HRMS method were 0.026 mg/kg and 0.244 mg/kg, respectively. The HRMS method mean concentration for all fish collected during the 2005 and 2006 sampling events (combined 2005-2006) was calculated using the 2006 HRMS method crappie data (N=10) combined with the 2005 LRMS method data (N=30). The mean concentration in all fish combined 2005-2006 (N= 40) for the LRMS (2005 data) and HRMS (2006 data) methods was 0.252 ± 0.335 mg/kg. The mean concentration in crappie for the LRMS method was 0.041 ± 0.025 mg/kg (Table 2). The minimum and maximum crappie PCB concentrations reported for the LRMS method were 0.016 mg/kg and 0.086 mg/kg, respectively. The LRMS method mean concentration for all fish combined 2005-2006 was calculated using the 2006 LRMS method crappie data (N=10) combined with the 2005 LRMS method data (N=30). The mean concentration in all fish combined 2005-2006 (N=40) for the LRMS method was 0.240 ± 0.340 mg/kg.

Dioxin (PCDDs/PCDFs)

Before generating summary statistics, dioxin and furan congeners were converted to concentrations equivalent in toxicity (TEQs) to that of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD; see methods section for details). Dioxins were detected in four of 10 crappie samples. Not all congeners of PCDDs/PCDFs were contained in all samples. The mean concentration in crappie was 0.207 ± 0.252 pg/g (Table 3).

DISCUSSION

PCB Analytical Methods (HRMS and LRMS)

The concentrations reported for individual samples by the HRMS method were generally higher than those reported by the LRMS method for the same samples. Part of this difference can be explained because the HRMS method has lower detection limits and uses more surrogate compounds to quantify the PCB congeners. The non-homogeneity of the samples — as seen by the LRMS ECR51 sample duplicate which contains two times the PCB concentration reported in the original ECR51 sample — is another possible contributor. However, the probability is low that each and every sample would bias to higher analytical results because of sample non-homogeneity. Based on laboratory QA/QC data, both the HRMS and LRMS methods provide acceptable results for a standard reference material that is known to be homogeneous.

Characterization of Possible Systemic (Noncancerous) Health Effects Related to Consumption of Crappie from ECR

Whether analyzed by LRMS or HRMS, all 10 crappie samples collected in November 2006 from ECR contained PCBs. Measured by LRMS, the average PCB concentration in crappie from 2006 was 0.041±0.025 mg/kg. By HRMS, the average concentration of PCBs in 2006 crappie was 0.089±0.067 mg/kg, more than double (2.2 times) the concentration measured by LRMS.

Several conclusions can be made from these data. First, when measured by LRMS, the mean PCB concentration in 2006 crappie (0.041 mg/kg; N=10) was very similar to the mean concentration in the crappie analyzed by LRMS in 2005 (0.045 mg/kg, N=2), findings that validate both the LRMS procedure and the PCB concentrations in crappie measured on two different occasions, the second of which contained 5 times as many crappie as the number of samples analyzed in 2005. Second, although neither the 2005 nor the 2006 PCB concentrations in crappie measured by LRMS (0.045 mg/kg vs. 0.041 mg/kg) exceeded the HAC_{nonca} for PCBs (0.047 mg/kg), PCBs in crappie sampled in 2006 and measured by HRMS did exceed the HAC_{nonca} for PCBs. Table 4 shows the hazard quotient (HQ) for PCBs in HRMS crappie to be greater than 1.0, while those measured by LRMS is less than 1.0, although only minimally (0.9). Third, when 2005 PCB fish data (LRMS; N=30) are combined with 2006 PCB crappie data (HRMS; N=10) the hazard quotient is 5.4 - hardly different from the hazard quotient generated from PCBs in fish measured in 2005 and 2006 by the LRMS method (HQ =5.1). Both HQs generate a suggested number of meals of approximately 0.2 meals per week, or less than one meal per month. This finding again validates the LRMS method of measuring PCBs in fish. When the mean concentration measured by LRMS is higher than the HAC_{nonca} in fish, the method is as reliable as HRMS for making risk management decisions, confirming that risk management decisions can likely be made with similar confidence from PCB concentrations in fish measured by the LMRS as from those measured with the HRMS method. The caveat here is that, if PCB concentrations measured by LMRS are lower than the HAC_{nonca} for PCBs, or when the concentrations are equivocal, risk managers may wish to confirm the concentrations by HRMS.

The laboratory also analyzed the crappie sampled in 2006 for polychlorinated dibenzofurans and polychlorinated dibenzo-p-dioxins (always measured by HRMS). Four of 10 fish so examined contained one or more PCDD or PCDF congener, ranging from 2,3,7,8-TCDF to octachlorinated dibenzo-p-dioxin. However, after converting the raw concentrations of PCDDs/PCDFs to 2,3,7,8-TCDD TEQ's, no single contaminant exceeded the HAC_{nonca} for dioxins (2.33 pg/g tissue) nor did the total concentration of PCDDs/PCDFs in the four fish exceed the HAC_{nonca} for PCDDs/PCDFs (Table 3).

Characterization of the Possibility of Excess Lifetime Cancer Risk from Consumption of Crappie from ECR

To assess the probability of increases in the lifetime excess cancer risk from consumption of PCB-contaminated crappie collected in 2006 from ECR, the DSHS SALG calculated the theoretical lifetime excess cancer risk for people who consume PCB-contaminated crappie from the ECR. Table 5 shows that crappie collected from ECR in 2006 did not exceed the DSHS

SALG's guideline for protection of humans from excess cancers (1 excess cancer in 10,000 equally exposed persons), either when PCBs were measured with LRMS (excess cancer risk from 2006 crappie = 1.5E-5 or 1 excess cancer in 66,170 exposed persons) or when PCBs were measured by HRMS (1 excess cancer in 30,544 equally exposed persons). What is striking, however, is that cancer risk is double when PCBs are measured by HRMS than when LRMS is utilized.

As with noncarcinogenic effects, the presence of PCDDs/PCDFs in crappie taken from ECR did not increase the likelihood of cancer in those who would eat fish from this reservoir. However, crappie are small, short-lived fish with low lipid content. Had other fish species with higher lipid content or longer lives been tested for PCDDs/PCDFs, the results could have been quite different.

As an exercise, the DSHS SALG derived a mean concentration of PCBs in all species of fish from 2005 and 2006 (N=40), finding very little difference in the overall cancer risk between all fish measured by LRMS samples from 2005 combined with 2006 crappie measured via HRMS when compared to all 2005 LRMS-measured fish plus 2006 LRMS-measured crappie (Table 5). All fish combined (2005-2006) measured by LRMS generated a theoretical lifetime excess risk of 1 in 11,535 equally exposed persons, compared those measured in 2005 by LRMS combined with 10 crappie measured in 2006 by HRMS resulted in a theoretical lifetime excess risk of 1 excess cancer in 11,335 equally exposed people. Results of this exercise are similar to those found with noncarcinogenic effects: the effect of measuring PCBs by HRMS is not so much more precise that it must be used for risk managers to make management decisions for a water body containing contaminated fish that have the capacity to impact the health of those who consume those fish.

Characterization of Cumulative Systemic Health Effects and Cumulative Excess Lifetime Cancer Risk from Consumption of Crappie from ECR

Two different classes of toxic polychlorinated aromatic hydrocarbons (PCBs and PCDDS/PCDFs) were reported present in crappie samples examined in fish collected in 2006 from ECR. Both classes of compounds may affect one or more target organs; for instance, both affect the liver and both suppress immune function. Thus, cumulative toxic effects must be considered for the two classes of compounds. The DSHS SALG assumes that if the exposure is present, the toxic effects would be additive, so SALG risk assessors added the hazard quotients for PCBs to those generated for PCDDS/PCDFs . The characterization of cumulative effects did not increase the overall toxicity expected from consuming fish from ECR containing PCBs at concentrations similar to those found in fish tissues. Thus, the likelihood is remote that cumulative effects of these two classes of compounds will have any significant cumulative effect on systemic adverse health outcomes in those who eat crappie from the ECR.

CONCLUSIONS

This study addressed the public health implications of consuming crappie from ECR. Risk assessors from the SALG and the Environmental and Injury Epidemiology and Toxicology Branch (EIETB) conclude from the present characterization of potential adverse health effects associated with consumption of fish from ECR.

1. That crappie collected from ECR in 2006 and analyzed for PCBs by LMRS **pose an indeterminate human health risk.** The rationale for this conclusion is not because the sample size was too small – as was the case with the 2005 samples – but because the mean concentration of PCBs in 10 crappie measured by LMRS is extremely close to the HAC_{nonca} for PCBs, making it difficult to make a definitive decision as to the toxicity of long-term regular or bolus consumption of crappie containing PCBs at these levels.

2. That those same crappie, collected from ECR in 2006 and measured with HRMS, exceed the HAC_{nonca} for consumption of PCBs in fish, having manifested a hazard quotient of 1.9. Therefore, HRMS, in this case, clearly confirms that crappie collected in 2006 from ECR **pose an apparent hazard to human health**.

3. That crappie collected from ECR in 2006, when added to the 30 fish collected from this reservoir in 2005, do not affect the overall conclusion made from fish of different species measured with LRMS that fish from ECR **pose an apparent hazard to human health** if consumed regularly, over a long period, or, perhaps, in bolus doses.

4. That PCDDs/PCDFs in crappie from the ECR **do not pose a hazard to human health** because concentrations are far below guidelines used by the DSHS to protect human health from systemic or carcinogenic effects of these toxic compounds.

5. That PCDDs/PCDFs in other species pose an **indeterminate human health risk** because no other species were analyzed for dioxins and furans in either the 2005 or 2006 assessment.

RECOMMENDATIONS

The SALG and EIETB of DSHS conclude from this risk characterization that consuming crappie from ECR poses an **apparent hazard to public health**. Therefore, the SALG and the EIETB recommend

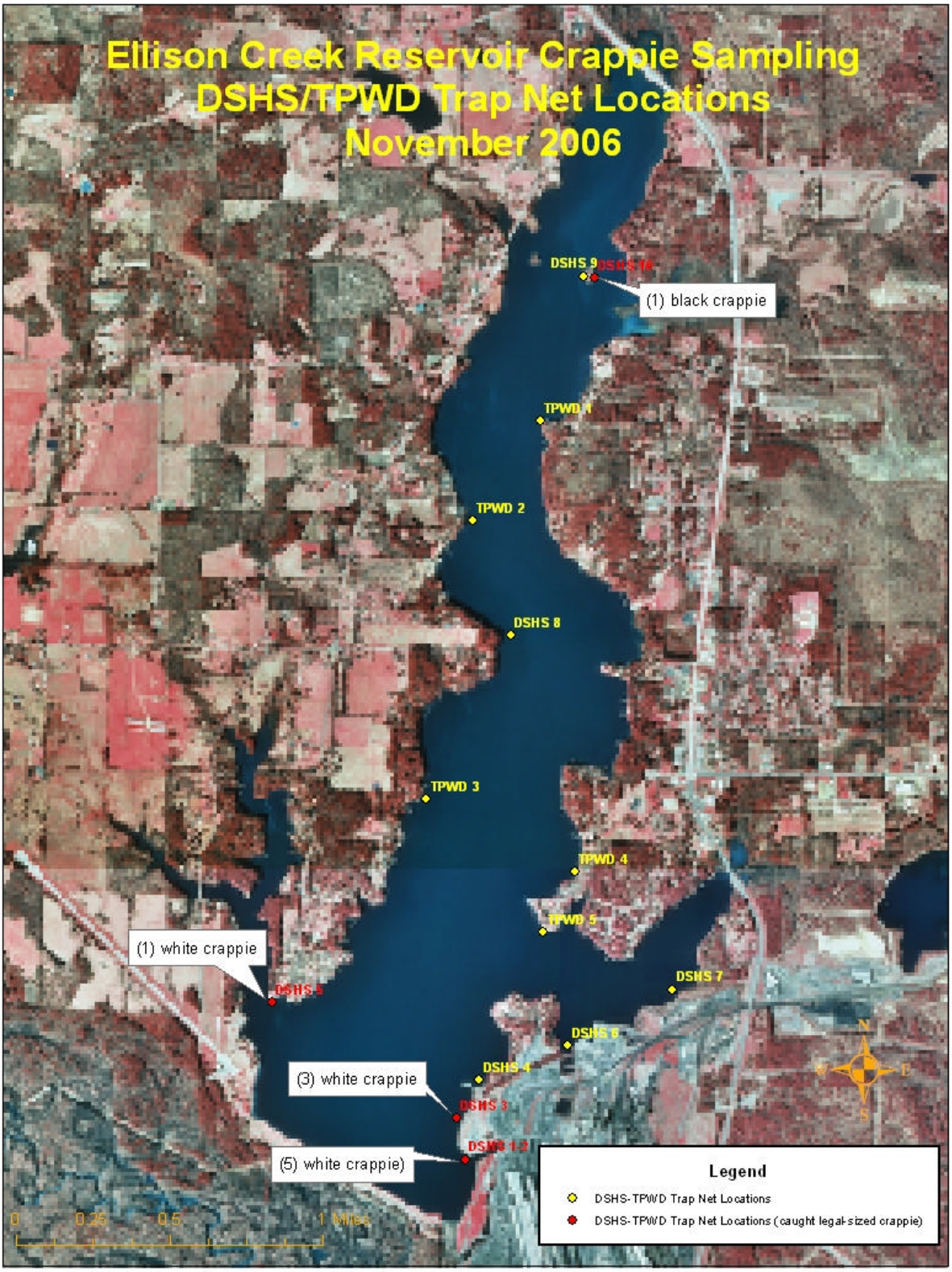
1. That the DSHS continues the consumption advisory presently in place for all species of fish from ECR (see original risk characterization, 2005 as revised 2007) until such time as PCBs are shown to have decreased to levels that are unlikely to pose a risk to human health.

2. That the DSHS emphasizes that consumption of crappie from ECR may be as likely to cause adverse human health effects to those who consume this fish species as might

consumption of other fish species from ECR and therefore should not be omitted from the extant advisory issued in 2005 that covers consumption of all species of fish from ECR.

3. That the DSHS SALG continues to monitor crappie and other species of fish from Ellison Creek for the presence and concentrations of PCDDs/PCDFs because higher levels of these contaminants are possible in other species. Higher concentrations of PCDDs, some of which are confirmed human carcinogens, may pose a carcinogenic risk to those exposed through consumption of fish from ECR.

Figure 1: ECR 2006 Crappie Sampling Trap Net Locations.



TABLES

Table 1. Crappie collected from ECR between November 13 and November 16, 2006. Sample number, species, length, and weight were recorded for each sample collected.

Sample Number	Species	Length (mm)	Weight (g)
ECR51	White Crappie	321	459
ECR52	White Crappie	320	514
ECR53	White Crappie	329	497
ECR54	White Crappie	315	479
ECR55	White Crappie	298	390
ECR57	Black Crappie	255	238
ECR58	White Crappie	326	503
ECR59	White Crappie	312	496
ECR60	White Crappie	327	468
ECR61	White Crappie	301	386

Table 2. PCBs (mg/kg) by HRMS and LRMS methods in crappie collected in 2006 and all fish combined 2005-2006 from ECR.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)[a]	Basis for Comparison Value
PCBs by HRMS[b] ***Crappie (N=10) samples collected in November 2006.***				
Crappie	10/10	0.089 ± 0.067 (0.026-0.244)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg/day EPA slope factor: 2.0 per mg/kg/day
PCBs by HRMS + LRMS[c] ***The 2006 HRMS crappie data (N=10) was combined with the 2005 LRMS data (N=30) to calculate mean values for all fish combined 2005-2006 (N=40)***				
All Fish Combined 2005-2006	40/40	0.252 ± 0.335 (0.026-1.547)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg/day EPA slope factor: 2.0 per mg/kg/day
PCBs by LRMS ***Crappie (N=10) samples collected in November 2006. The 2006 LRMS crappie data (N=10) was combined with the 2005 LRMS data (N=30) to calculate mean values for all fish combined 2005-2006 (N=40) and labeled PCBs by LRMS.***				
Crappie	10/10	0.041 ± 0.025 (0.016-0.086)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg/day EPA slope factor: 2.0 per mg/kg/day
All Fish Combined 2005-2006[c]	40/40	0.240 ± 0.340 (0.016-1.547)		

[a] *Derived from the MRL or RfD for noncarcinogens or the USEPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of $1x10^{-4}$.*

[b] *High Resolution Mass Spectrometry (HRMS)*

[c] *Low Resolution Mass Spectrometry (LRMS)*

Table 3. Dioxin and furan toxic equivalent concentrations (pg/g) in crappie collected in 2006 from ECR.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)[d]	Basis for Comparison Value
Crappie	4/10	0.207 ± 0.252 (ND[e]-0.904)	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day

Table 4. Hazard quotients (HQ) for PCBs in fish by analysis method collected from ECR in 2005-2006. Table 3 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[f]

Species	PCBs by HRMS		PCBs by LRMS	
	Hazard Quotient	Meals per Week	Hazard Quotient	Meals per Week
Crappie	**1.9**[g]	**0.5**	0.9	1.0
All Fish Combined 2005-2006	**5.4**	**0.2**	**5.1**	**0.2**

[d] *Derived from the MRL or RfD for noncarcinogens or the USEPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of* $1x10^{-4}$.

[e] *ND: "Not Detected"- used to indicate that a compound was not present in a sample at a concentration greater than the method detection limit (MDL).*

[f] *DSHS assumes that children under the age of 12 years and/or those who weigh less than 35 kg eat 4-ounce meals.*

[g] **Bold***type indicates that a fish species contains more PCBs per kg edible tissue than is recommended by DSHS for unlimited consumption. Fish species that do not contain PCBs at levels exceeding the* HAC_{nonca} *for PCBs (0.047 mg/kg) may be consumed without limitation.*

Table 5. Theoretical lifetime excess cancer risk for consumption of PCB-contaminated fish from ECR. The table lists calculated theoretical excess lifetime cancer risk by PCB analysis method for fish collected in 2005-2006 and suggested weekly eight-ounce meal consumption rates for 70-kg adults.

Species	Theoretical Lifetime Excess Cancer Risk		Meals per Week
	Risk	1 excess cancer per number exposed	
PCBs by HRMS and LRMS			
Crappie	3.3×10^{-5}	30,554	2.8
All Fish Combined 2005 (LRMS)-2006 (HRMS)	9.3×10^{-5}	10,796	1.0
PCBs by LRMS			
Crappie	1.5×10^{-5}	66,170	6.1
All Fish Combined 2005-2006	8.8×10^{-5}	11,335	1.0

LITERATURE CITED

[1] De Rosa, CT, D. Brown, R. Dhara et al. Dioxin and Dioxin-like Compounds in Soil, Part 1: ATSDR Interim Policy Guideline. Toxicol. Ind. Health. 13(6):759-768, 1997. http://www.atsdr.cdc.gov/dioxindt.html

[2] The World Health Organization Project for the Re-evaluation of Human and Mammalian Toxic Equivalency Factors (TEFs) of Dioxins and Dioxin-Like Compounds web page. http://www.who.int/ipcs/assessment/tef_update/en/ (Accessed May 10, 2007).

[3] De Rosa, CT, D. Brown, R. Dhara et al. Dioxin and Dioxin-like Compounds in Soil, Part 1: ATSDR Interim Policy Guideline. Toxicol. Ind. Health. 13(6):759-768, 1997. http://www.atsdr.cdc.gov/dioxindt.html