

MULTIPLE LINES OF EVIDENCE RISK ASSESSMENT OF BELTED KINGFISHER EXPOSED TO PCDD/DFs IN THE TITTABAWASSEE RIVER FLOODPLAIN, MI, USA

THE TITTABAWASSEE RIVER FLOODPLAIN, MI, USA

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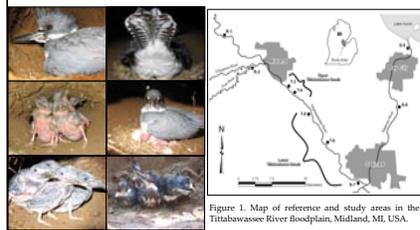
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Abstract

Dietary-based exposure, tissue concentrations, and population health metrics of the belted kingfisher (*Ceryle alcyon*; KF) were incorporated as lines of evidence in the multiple lines of evidence approach utilized in the site-specific ecological risk assessment of the Tittabawassee River floodplain, Michigan, USA. Mean concentrations of polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) in soils and sediments of the Tittabawassee River floodplain downstream of Midland, MI have previously been shown to be 10- to 40-fold greater than those in associated areas upstream. The KF, a highly territorial species with a limited foraging range and trophic status near the top of the aquatic food web, makes an appropriate receptor species to investigate compounds with bioaccumulative potential, such as PCDD/DFs. Dietary exposure was estimated using site-specific concentrations of representative dietary items, including forage fish, crayfish, and amphibians. The dietary exposure model included both site-specific and literature-based dietary compositions. Kingfisher eggs and nestlings were collected from nests in both reference (RA) and study areas (SA) during the 2005-2007 breeding seasons. In addition, measures of reproductive success were also taken for each nest. Concentrations of the seventeen 2,3,7,8-substituted PCDD/DFs were quantified in eggs and whole-body nestling homogenates and converted to 2,3,7,8-dibenzo-p-dioxin equivalents (DF-TEQs) using WHO avian TEFs. DF-TEQs in KF eggs collected from SA nests (n=19) were 2- to 6-fold greater than those from RA nests (n=6) while DF-TEQs were approximately 20-fold greater in SA nestlings (n=12) than those from RA nests (n=5). Clutch size, hatching success, and fledging success were similar between RA and SA. Findings from each line of evidence suggest that KF residing within the Tittabawassee River floodplain are not likely to experience adverse effects from their exposure to PCDD/DFs. The integration of these multiple lines of site-specific evidence greatly reduced the amount of uncertainty inherent in a risk assessment, and provided high quality information for use in making decisions regarding the future of the contaminated site and resident wildlife.

Dietary Exposure



Site-specific dietary composition was 90.2% forage fish, 5.4% crayfish, and 4.4% frogs, on a biomass basis.

Dietary items (n=188), including frogs, crayfish, and forage fish composites, were collected and analyzed for PCDD/DFs (13 forage fish composites also analyzed for PCBs).

Concentrations of DF-TEQs in dietary items were 22- to 180-fold greater in TR reaches and 3- to 33-fold greater in SR compared to RA (Figure 2).

DF-TEQs contribute greatly to total TEQs in TR forage fish (~80%) while PCB-TEQs are more predominant in forage fish from RA and the SR.

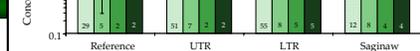


Figure 2. Concentration of TEQs in dietary items, presented as geometric mean with 95% confidence intervals, clustered by reach. Sample size (n) indicated in each bar. For sites with only 2 samples, only the mean is presented.

Table 2. Predicted daily dietary dose of DF-TEQs and total TEQs (ng/kg bw/d) for belted kingfisher breeding during 2004 - 2006 within the Chippewa and Tittabawassee river floodplains, based on geometric mean (95% confidence interval) of site-specific dietary items.

Location	DF-TEQs	Total TEQs*
Reference Area	0.46 (0.44-0.53)	1.2 (1.1-1.4)
Upper Tittabawassee	70 (60-83)	91 (80-110)
Lower Tittabawassee	88 (34-230)	110 (39-290)
Saginaw River	16 (9.5-32)	46 (15-140)

* Total TEQs based on 100% fish diet due to lack of PCB data for other taxa.

Potential daily dose calculated using equation 4-3 from USEPA [5] and included incidental sediment ingestion.

Due to similarity of total TEQs concentrations among prey item taxa within a sampling location, dietary composition had little influence on predicted daily dose.

Dietary exposure to total TEQs was 75- to 86-fold greater along the TR and 37-fold greater along the SR when compared to the RA (Table 2).

Tissue Exposure

A total of 25 KF eggs and 17 nestlings were collected and analyzed for PCDD/DFs (14 KF eggs and 13 nestlings were also analyzed for PCBs).

Concentrations of DF-TEQs in KF eggs and nestlings were 4- to 7-fold and 19-fold greater, respectively, in TR reaches compared to RA (Table 3).

Total TEQs in KF tissues from TR reaches are primarily attributable to DF-TEQs, compared to RA which have a greater contribution from PCB-TEQs (Table 3).

Predominant congeners contributing to DF-TEQs in KF tissues were TCDD (36%) and 12378-PeCDD (25% to 34%) in the RA and 23478-PeCDD (46% to 68%) and TCDF (11% to 29%) in TR reaches.

PCB-126, -77, and -81 were the predominant congeners contributing to PCB-TEQs in KF eggs and nestlings from all reaches.

Table 3. Concentrations of TEQs in belted kingfisher tissues collected during 2005-2007 from the Chippewa and Tittabawassee river floodplains, Midland, MI, USA. Values (ng/kg, ww) given as geometric mean (sample size) over the 95% confidence interval.

Location	Kingfisher Eggs		Kingfisher Nestlings	
	DF-TEQs	PCB-TEQs	DF-TEQs	PCB-TEQs
Reference Area	15 (6)	29 (3)	5.0 (5)	6.0 (4)
	6.3-35	12-74	2.9-8.6	3.8-9.6
Upper Tittabawassee	67 (8)	100 (4)	96 (3)	* (2)
	37-120	29-570	25-360	9.4-38
Lower Tittabawassee	98 (11)	48 (7)	95 (9)	41 (7)
	70-140	34-69	70-130	13-130

* When n<3, range is reported rather than geometric mean and confidence interval.

Concentrations of PCDD/DFs were 4- to 5-fold and 15- to 48-fold greater in KF eggs and nestlings collected along the TR compared to RA, respectively (Figure 3).

PCB-118 and -105 were the predominant congeners present on a mass basis in PCBs in KF eggs and nestlings from all reaches.

Population Condition

A total of 37 KF nests were located, accessed, and monitored during 2005 - 2007.

A greater number of KF nests were located and monitored along the TR compared to RA, likely due to differences in habitat characteristics.

Clutch size, hatch success, and fledging success were similar between TR and RA (Table 4) and comparable to values available in the literature [6].

No morphological abnormalities observed in KF nestlings.

Several of the banded breeding adults monitored in the LTR were observed producing fledglings over multiple years.

Table 4. Reproductive effort of belted kingfisher nesting within the Chippewa and Tittabawassee river floodplains, Midland, MI, USA during 2005-2007. Values are mean ± st. dev. (sample size).

Location	Nests Accessed	Clutch Size	Hatch Success	Fledging Success
Reference Area	9	6.340.52 (6)	0.7540.50 (22)	0.8340.29 (10)
Tittabawassee River	28	6.940.34 (16)	0.7440.43 (55)	0.7140.36 (55)

Note: A nest attempt was excluded from calculations after nest predation or abandonment.

Exposure Comparisons

Trends in dietary and tissue based exposure assessments for DF-TEQ concentrations and congener profiles are in agreement (Figure 3).

KF residing downstream of Midland MI have greater exposures to 2,3,7,8-TCDF and 2,3,4,7,8-PeCDF than upstream birds (Figure 3).

Similarity of congener patterns and DF-TEQ concentration spatial trends between egg and nestling suggests that the contaminant burden of collected KF eggs are site-specific (Figure 3).

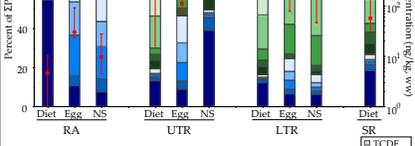


Figure 3. Percent mean PCDD/DF congener profile of kingfisher dietary exposure and tissues collected from the reference (RA), upper Tittabawassee River (UTR), lower Tittabawassee River (LTR), and Saginaw River (SR) reaches. Only dietary items were collected from the SR. Geometric mean PCDD/DF concentrations plotted in each bar with the error bars representing 95% confidence intervals (secondary axis on right in log scale).

Hazard Assessment

Tissue HQs based on mean egg concentrations were less than 0.2 across all sites while diet HQs based on mean dietary item concentrations ranged between <0.01 and 7.5 (Figure 4).

Diet HQs for KF residing downstream of Midland, MI based on mean dietary item concentrations and the LOAEC TRV were all less than 1.0 but were as great as 20 when using the more conservative NOAEC TRV and 95% UCL of dietary item concentrations (Figure 4).

Diet HQs were generally an order of magnitude greater than egg-based HQs from the same site, likely due to uncertainty associated with dietary TRVs and site use.

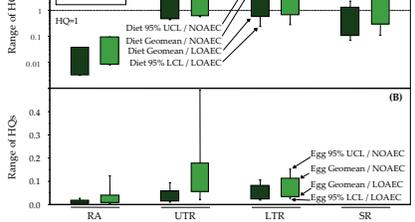


Figure 4. Range of hazard quotients (HQs) based on KF dietary exposure (A) and KF eggs (B) collected from the reference (RA), upper Tittabawassee River (UTR), lower Tittabawassee River (LTR), and Saginaw River (SR) reaches. Only dietary items were collected from the SR.

Discussion

DF-TEQs contributed a greater proportion of total TEQs to dietary items and KF tissues collected from the Tittabawassee River than those collected in reference areas, reiterating that the source of contamination is located in Midland, MI.

Although KF are a migratory species, the spatial similarities in DF-TEQ concentrations and congener profiles between site-specific KF eggs and both site-specific dietary exposure and KF nestlings supports the hypothesis that PCDD/DFs in KF eggs collected during this study are from local sources.

The ~10 fold difference between dietary- and tissue-based HQs is likely the result of greater uncertainty and conservatism associated with the dietary HQs including predictions of dietary exposure and selected dietary TRVs.

Dietary exposure calculation assumes 100% site use while water clarity measures suggest less.

Dietary TRV is based on ring-necked pheasant which is considered to be more sensitive to the toxic effects of dioxin-like compounds than KF [7] and the dosing was done via intra-peritoneal injections rather than true dietary exposure which may result in greater absorption efficiency.

Tissue exposure HQs may also be conservative as the TRVs were derived from an egg injection study which may not be representative of natural in ovo exposure. Additionally, the study was based on the double-crested cormorant which has a similar AhR ligand binding domain, yet an interspecies uncertainty factor of 3 was applied [7].

Conclusions

KF nesting along the Tittabawassee River have a greater dietary and tissue-based exposure to DF-TEQs compared to those along the Saginaw River or in reference areas.

Tissue based HQs based on KF egg concentrations were all less than 0.2 suggesting that KF exposure is significantly less than effect concentrations.

HQs for mean dietary and tissue based exposure assessments were all less than 1.0 when compared to LOAECs.

Dietary HQs did exceed 1.0 but were less than 10 when dietary exposure based on geometric means of dietary items was compared to the conservative NOAEC. However exceeding a NOAEL does not indicate hazard and given the additional conservatism associated with the exposure calculation we would not expect to see population level effects.

Reproductive health parameters including hatching success and fledging success suggest that KF nesting downstream of Midland, MI are not likely to experience any adverse effects from their exposure to dioxin-like compounds.

Site-specific dietary- and tissue-based exposure assessments indicate that belted kingfisher nesting within the Tittabawassee River floodplain are not likely to experience population level adverse effects from PCDD/DFs. Direct site-specific measures of KF population condition support this conclusion.

Literature Cited

[1] Hilscherova, K., et al. (2003) *Environ Sci Technol* 37:468-474. [2] Van den Berg, M., et al. (1998) *Environ Health Perspect* 106:775-779. [3] Nosed, J.A. (1992) *J Toxicol and Environ Health* 35:187-198. [4] HITESA (2003) *Analysis of Laboratory and Field Studies of Reproductive Toxicity in Birds Exposed to Dioxin-Like Compounds for Use in Ecological Risk Assessments*. [5] USEPA (1993) *Wildlife Exposure Handbook*. [6] Hama, M.J. (1994) *Belted Kingfisher, Birds of North America*. AOU. [7] Kennedy S.W., et al. (2009) AhR ligand binding domain and its possible role in predicting avian species sensitivity to dioxin-like compounds. 30th Annual SETAC Meeting.

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Introduction

Around the turn of the century, dibenzofurans, dioxins and other byproducts were discharged into the Tittabawassee River near Midland, MI.

Mean PCDD/DF concentrations in soils and sediments downstream of Midland, MI were 10- to 20-fold greater than those collected from an upstream reference area [1].

The KF was selected as a receptor species due to its presence on site, high trophic status, territoriality, and site fidelity.

The KF is one of several receptor species included in a large scale ecological risk assessment of the Tittabawassee River basin.

Methods

Forage fish, crayfish, and frogs were collected from nine biological sampling areas (BSAs), two in reference areas (RA), five along the Tittabawassee River (TR) and two along the Saginaw River (SR) (Figure 1) during 2003 - 2006.

BSAs along the TR split into upper Tittabawassee River (UTR) and lower Tittabawassee River (LTR) based on contamination characteristics.

KF nests located within the TR study area and associated RA were accessed and monitored during 2005 - 2007.

Prey remains were collected from KF nests to determine a site-specific diet.

Eggs and nestlings were collected and analyzed for contaminant concentrations.

Analyses of the seventeen 2,3,7,8-substituted PCDD/DF congener concentrations were conducted at AsuruQuality Limited, Round Hutt, New Zealand.

TEQ values for PCDD/DFs (DF-TEQs) and PCBs (PCB-TEQs) are based on avian World Health Organization TCDD equivalency factors [2].

Site-specific diet-based DF-TEQ and total TEQ (DF-TEQ and PCB-TEQ) exposures were compared to toxicity reference values (TRVs) derived from Nosed 1992 [3] to evaluate potential hazard to resident KF in the TR floodplain (hazard quotients, HQs).

- Diet NOAEC: 14 ng TEQ/kg bw/day
- Diet LOAEC: 140 ng TEQ/kg bw/day

DF-TEQ and total TEQ concentrations in KF eggs were compared to TRVs derived from double-crested cormorants [4] (with an interspecies uncertainty factor of 3) to evaluate potential hazard to resident KF in the TR floodplain (HQs).

- Egg NOAEC: 3670/3 = 1300 ng TEQ/kg
- Egg LOAEC: 11090/3 = 3700 ng TEQ/kg