

The Tree Swallow (*Tachycineta bicolor*) as a Sentinel Species for Sediment Contaminant Bioavailability and Effects in the Chesapeake Bay Watershed



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Abstract

The tree swallow has proven to be a useful sentinel species for studying the bioavailability and effects of sediment contaminants. Sediment contaminants are taken up by developing insects which are then consumed by the tree swallows attracted to and using nest boxes that have been placed in the area of interest. Egg contaminants are measured for the baseline and nestling contaminants are measured to determine the amounts that have been taken up by the growing hatchling at the study site. In addition to reproductive success, biochemical biomarkers such as EROD, a biomarker for the contaminant classes PCBs, TCDD, and PAHs, are assayed. Because of concern about sediment contaminants in the Chesapeake Bay watershed the tree swallow has been utilized in a number of locations of interest. These locations include the Pocomoke River which has been the focus of significant USGS activities, and reconstructed tidal wetlands on NPS lands along the Anacostia River (Kingman Lake and Kenilworth Lake).

Pocomoke River

USGS studies on the Pocomoke River have shown a variety of contaminants to be present. In order to assess the bioavailability and impact of such contaminants to a terrestrial species the Tree swallow was utilized as a sentinel species. Thirty-nine nest boxes were placed on the edge of a marsh on the Maryland shore just upriver from Millersville, MD launch site. 8 complete clutches of eggs were laid and 1 egg was collected from each. 6 clutches were successfully hatched. Data presented is for metals in the egg shell eggs and monooxygenase activities (ethoxyresorufin-O-deethylase (EROD) and benzyloxy-ROD (BROD)) in one nestling from each of the 6 successful clutches.

Discussion of Pocomoke River results

Monooxygenase activities in Pocomoke River tree swallow nestling livers were intermediate between those from clean sites and those from contaminated sites. This suggests that there are elevated levels of contaminants such as PAHs or PCBs present in the study area.

We do not know the exact reasons why the clutches of eggs in 2 of the nest boxes failed to produce nestlings that lived to 13 days post-hatch. In one case the nest was abandoned, but we don't know whether this was caused or effect and in another nest the young disappeared. Although the tissue metal levels were in general unremarkable, it is interesting that the eggshells from the 2 failed nests were the only ones that had Pb levels above detection limits. The values are not high enough, however that one would expect harm.

Anacostia River reconstructed tidal wetlands (NPS-NRPP)

The Chesapeake Bay watershed has experienced a substantial loss of tidal and nontidal wetlands. The National Park Service has laid along the Anacostia River, a River that had lost most of its tidal wetlands. Two tidal wetlands, at Kenilworth Marsh and at Kingman Lake, have been reconstructed using dredged sediment. Because the sediments used for the reconstruction were known to be contaminated there was concern about possible harm to aquatic and terrestrial species using the reconstructed wetlands. In order to assess the bioavailability and impact of such contaminants to a terrestrial species the Tree Swallow was utilized as a sentinel species. Nest boxes were placed at Kenilworth Marsh, Kingman Lake, Duelling Creek, Colmar Manor, and Knowles Marshes (USFWS Patuxent Research Refuge). Eggs and nestlings were collected and a variety of biomarkers and contaminants were measured

Table 3 - Sediment contaminants pertinent to the reconstruction of the Anacostia River tidal wetlands. Data presented as range (frequency of occurrence).

	Washington Sailing Marina 1996	Anacostia River 1996	Anacostia River 1998	Kenilworth Marsh 1997
Metal	mg/kg	mg/kg	mg/kg	mg/kg
As	5.3-8.3 (12/12)	1.5-8.7 (12/12)	3.3-6.5 (11/11)	
Be	1.0-1.8 (10/12)	0.5-1.7 (10/12)	1.5-3.3 (11/11)	
Cd	<DL	0.5-2.2 (1.0)(2/2)	0.42-2.2 (11/11)	
Cr	22-58 (12/12)	8.9-75 (6.6-114)(12/12)	27-100 (11/11)	
Cu	26-52 (12/12)	7.8-53 (5.6-74)(12/12)	25-64 (11/11)	
Hg	16-63 (12/12)	0.2 (1/9)	0.12-0.20 (11/11)	
Mn	623-913 (12/12)	89-348 (12/12)	311-850 (11/11)	
Pb	32-116 (12/12)	16-224 (12/12)	33-180 (11/11)	
Se	<DL	1.1 (1/12)	<DL	
Zn	121-357 (12/12)	61-324 (20-359)(12/12)	141-413 (11/11)	
Chlordane	50-380	80-240		
Aroclor 1254	80-300			
Aroclor 1260	21-44			
PNAs	3.3-17.0			

Overview of status of activities

After the spring 2002 field season it was necessary to plan for three field seasons rather than two and to replace Duelling Creek as a sampling site with Colmar Manor. Sediments were collected from all sites and the chemical analysis data currently available is presented in tables 4, 5 and 6. Organochlorine and metals data for tree swallow samples from 2002 are presented in tables 7 and 8. EROD results for tree swallow nestlings from both 2002 and 2003 are presented in Figure 1. Chemical analysis of 2003 samples has not yet occurred and other biomarker results from 2002 and 2003 have not yet been compiled. Investigation of possible use of nonlethal sampling for cytochrome P450 induction in emerging feathers in tree swallows is underway using samples collected in 2002 and 2003 (at PWRW in black ducks) and demonstrated that this approach works in mallard ducks and in hawks.

B and Be were <DL for all samples at all locations

Table 4 - Current (2001) organochlorine sediment contaminants in Anacostia River reconstructed tidal wetlands (Kenilworth Marsh and Kingman Lake), Duelling Creek, and Knowles Marshes (USFWS Patuxent Research Refuge). Data presented as PPR - dry weight (frequency).

Contaminant	Kingman Lake 5 samples	Kenilworth Marsh 2 samples	Duelling Creek 3 samples	Knowles Marshes 2 samples
Aldrin	0.66 (1/5)	0.50 (1/2)	0.35 (1/3)	0/2
Dieldrin	1.39 (5/5)	1.93 (2/2)	5.3 (3/3)	0/2
BHC (total)	0.92 (5/5)	0.77 (2/2)	0.81 (2/3)	4.4 (2/2)
Chlordane (total)	97 (5/5)	100 (2/2)	173 (3/3)	3.8 (2/2)
DDT (total)	47 (5/5)	51 (2/2)	175 (3/3)	11 (2/2)
Endosulfan II	1.65 (4/5)	2.16 (2/2)	1.79 (2/3)	0/2
Endrin	2.25 (4/5)	2.32 (2/2)	0.94 (2/3)	1.63 (2/2)
HCB	0.62 (4/5)	1.99 (1/2)	1.48 (3/3)	0/2
Mirex	0/5	0/2	0/3	0/2
PCA	0/5	0/2	0.48 (1/3)	0/2
Tosaphene	0/5	0/2	0/3	0/2
PCBs	370 (5/5)	461 (2/2)	430 (3/3)	0/3

Table 5 - Current (2001) Polycyclic Aromatic Hydrocarbon (PAH) Sediment Contaminants in Anacostia River reconstructed tidal wetlands (Kenilworth Marsh and Kingman Lake), Duelling Creek, and Knowles Marshes (USFWS Patuxent Research Refuge). Data presented as ppm - dry weight. Every sample at each site contained the listed PAHs at above the detection limit.

Contaminant	Kingman Lake	Kenilworth Marsh	Duelling Creek	Knowles Marshes (PRR)
B[a]P	1.25	0.80	0.50	0.06
B[fl]P	0.82	0.57	0.33	0.03
Pyrene	1.60	1.11	0.93	0.08
Benzo (h) fluoranthene	1.73	1.19	0.63	0.07
All naphthalenes	0.43	0.51	0.85	0.07
All phenanthrenes & anthracenes	2.56	1.90	1.75	0.14
All chrysenes	2.05	1.57	1.00	0.12
Total PAHs	16.6	12.1	9.7	1.1

Table 6 - Current (2001) Inorganic Sediment Contaminants in Anacostia River reconstructed tidal wetlands (Kenilworth Marsh and Kingman Lake), Duelling Creek, and Knowles Marshes (USFWS Patuxent Research Refuge). Data presented as average ppm - dry weight. Every sample at each site contained the listed metals at above the detection limit.

Metal	Kingman Lake	Kenilworth Marsh	Duelling Creek	Knowles Marshes (PRR)
As	2.9	3.6	5.1	3.5
Be	1.4	1.5	1.5	1.5
Cd	1.0	1.2	1.2	0.6
Cr	61.5	56.5	84.5	37.8
Cu	51.1	53.9	49.4	29.5
Hg	0.20	0.15	0.16	0.10
Mn	416	336	373	341
Pb	72	97	66	54
Se	0.42	0.52	0.49	0.96
Sr	18	19	17	15
Ti	415	55	310	54
Zn	253	325	278	169

Table 7 - Organochlorine contaminants present in Tree swallow eggs and nestlings collected in 2002. Data presented as average concentration - ppb - dry weight (frequency of occurrence)

Contaminant	Egg			Carcass		
	Kingman Lake 4 samples	Kenilworth Marsh 4 samples	Knowles Marsh 5 samples	Kingman Lake 2 samples	Kenilworth Marsh 1 sample	Knowles Marshes 5 samples
Oxychlorodane	(0/4)	(0/4)	(0/5)	(0/2)	0.10 (1/1)	(0/5)
PCBs (total)	7.9 (1/4)	35.4 (4/4)	4.3 (1/5)	0.38 (2/2)	6.36 (1/1)	2.25 (4/5)
p,p'-DDD	(0/4)	(0/4)	(0/5)	(0/2)	0.04 (1/1)	0.03 (1/5)
p,p'-DDE	0.95 (4/4)	1.14 (4/4)	0.81 (5/5)	0.08 (2/2)	0.19 (1/1)	0.09 (4/5)
trans-nonachlor	(0/4)	(0/4)	(0/5)	(0/2)	0.12 (1/1)	(0/5)

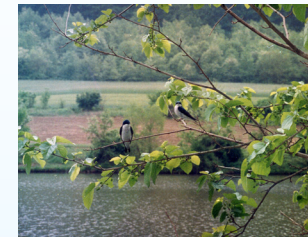
The following were < Detection Limit for all samples from all locations:

cis-nonachlor	heptachlor epoxide	alpha chlordane	gamma chlordane
op'-DDD	op'-DDE	op'-DDT	Dieldrin
toxaphene	Endrin	pp'-DDT	HCB
			BHC (total)
			Mirex

Table 8 - Metal concentrations in Tree Swallow eggs and nestlings collected in 2002. Data presented as average ppm - dry weight (frequency of occurrence).

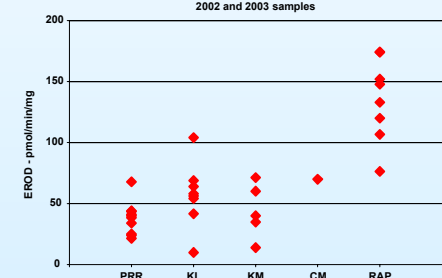
Metal	Eggs/shells			Feather		
	Kingman Lake	Kenilworth Marsh	Knowles Marshes	Kingman Lake	Kenilworth Marsh	Knowles Marshes
Al	20.2(4/4)	18.8(4/4)	15.6(5/5)	13.6(2/2)	7.3	7.8(5/5)
B	1.7(4/4)	1.6(4/4)	2.1(5/5)	1.4(2/2)	1.5	1.6(5/5)
Ba	21.9(4/4)	23.0(4/4)	30(5/5)	0.22(2/2)	0.26	0.56(5/5)
Cd	<DL	<DL	(1/5)	<DL	0.04	<DL
Cr	0.10(2/4)	0.11(2/4)	0.19(4/5)	0.34(2/2)	0.47	0.36(5/5)
Cu	3.2(4/4)	3.0(4/4)	3.5(5/5)	6.1(2/2)	6.2	7.0(5/5)
Fe	24.2(4/4)	23.0(4/4)	22.2(5/5)	50.0(2/2)	52.1	43.2(5/5)
Hg	(1/4)	0.07(2/4)	0.06(3/5)	0.49(2/2)	0.64	0.71(5/5)
Mg	151.8(4/4)	149.5(4/4)	155.7(5/5)	60.9(2/2)	61.9	59.0(5/5)
Mn	2.4(4/4)	2.7(4/4)	3.0(5/5)	1.0(2/2)	1.9	1.0(5/5)
Ni	7.4(4/4)	8.1(4/4)	7.6(5/5)	0.28(2/2)	0.22	0.56(4/5)
Pb	0.05(4/4)	0.29(4/4)	0.44(5/5)	0.06(2/2)	0.07	0.09(5/5)
Se	(1/4)	0.30(3/4)	0.35(5/5)	0.98(2/2)	2.46	2.31(5/5)
Sr	6.96(4/4)	4.42(4/4)	3.74(5/5)	1.09(2/2)	1.14	1.11(5/5)
Zn	13.1(4/4)	23.9(4/4)	16.9(5/5)	19.2(2/2)	18.9	18.2(5/5)

The following metals were below detection limits in all samples from all locations: As, Be, Mo, V.



Tree Swallow sitting on tree branch

Figure 1 - EROD by Location 2002 and 2003 samples



Discussion of Anacostia River / reconstructed tidal wetland data and results

Table 3 shows older data on some metals and organic contaminants in sediments that were used to reconstruct the Anacostia River tidal wetlands and metals in sediments soon after the reconstruction of the Kenilworth Marsh tidal wetlands. Table 4 shows that a variety of organochlorine contaminants (OCs) including PCBs and pesticides are still present in the Anacostia River reconstructed tidal wetlands and the nearby Duelling Creek, but these are generally not present in the sediments of the relatively "clean" Knowles Marshes on the USFWS Patuxent Research Refuge located in Laurel, MD. A similar pattern holds true for PAHs at these locations where the concentrations of PAHs at the three Anacostia River sites are generally 10-fold or more greater than at Knowles Marshes. The situation with metals (Table 6) is different because many of the metals are normally present in sediments. Some of the metals which would have been used in various government and commercial activities on the Anacostia River such as Cd, Cr, Hg, Pb, and Zn are present at higher levels than at the Knowles Marshes, but generally at a factor of 2-fold or less. The exception is Ti which is present at two of the Anacostia River sites at 6- to 8-fold the level at the Knowles Marshes.

Table 7 shows that five OCs including PCBs are present in eggs or carcasses from the reconstructed tidal wetlands while many more were below detection limits. The main difference between the Anacostia River sites and Knowles Marsh is the greater amounts of PCBs in eggs from the Anacostia River sites. At this point we have results from only three Anacostia River nestling samples; too few to draw any conclusions. Table 8 shows metals present in eggshells and feathers collected at the study sites. There are few differences in eggshell metals between the sites, and the number of feather samples analyzed is too small to draw any conclusions.

The results of EROD assay for Tree Swallow liver samples from both field seasons (2002 & 2003) are presented in Figure 1. The sites codes are PRR (Knowles Marshes, Patuxent Research Refuge), KL (Kingman Lake), KM (Kenilworth Marsh), CM (Colmar Manor) and RAP (a highly contaminated site in Rhode Island - positive control). Note that at Knowles Marshes only 1 of 10 EROD activities is >50 pmol/min/mg microsomal protein while at Kingman Lake 6 of 8 are elevated, at Kenilworth Marsh 2 of 5 are elevated, at Colmar Manor the only one is elevated, and at the Rhode Island site all 8 are elevated. This suggests that contaminants such as PCBs and PAHs that are inducers of the cytochrome 450A1A family are present.

Overall conclusions

The EROD results from both the Pocomoke River at Shelltown, MD and the Anacostia River reconstructed tidal wetlands indicate the presence of organic contaminants that are inducing agents of the cytochrome P450A1A family. The induction appears to be moderate as compared to clean and highly contaminated sites. Awaiting chemical analysis results should help to determine the class(es) of chemicals responsible for the induction.

Reproductive results plus metal levels on the Pocomoke are interesting, but too limited to draw any conclusions.