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**The Influence of Ecological Contaminants on State Endangered Common
(*Sterna hirundo*) and Forster's (*Sterna forsteri*) Terns in Illinois**

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Introduction

Both the Forster's (*Sterna forsterii*) and Common tern (*S. hirundo*) currently are listed as state-endangered in Illinois (Illinois Endangered Species Protection Board, 2004). The Common tern also is listed as a species of special concern throughout its range by the U.S. Fish and Wildlife Service (2002). In addition, the Illinois Department of Natural Resources has recognized both populations of terns as critical; species exhibiting the greatest need of conservation in the state (IDNR, 2005).

In 1998 the only remaining nesting site for Forster's terns was abandoned due to loss of available nesting habitat. By the following season, the Forster's tern had been extirpated as a breeding species in Illinois (Table 1). In 2003, using conspecific attraction and habitat creation, we were able to successfully re-establish a nesting colony of Forster's terns at Grass Lake within the Chain O' Lakes State Park (COLSP), Lake County, IL. In 2005 we expanded this effort to include Fourth Lake where we were successful in establishing a second Illinois breeding colony (Jablonski et. al, 2005).

Common terns have consistently nested in Illinois, but often only with limited success (Table 2). The sole remaining active nesting colony in Illinois is located at the Naval Station Great Lakes (NSGL) in Lake County. To enhance reproduction and to protect nests from mammalian predators and human interference, intensive colony management was initiated in 2001. Due to our activities, the 2002 through 2004 nesting seasons at NSGL produced nearly as many young (n=101) as the previous 25 years combined (Jablonski et. al, 2004).

Despite our aggressive management efforts, the remaining active tern colonies in Illinois remain vulnerable to a number of significant environmental threats. Among the most potentially serious, and as yet unstudied, remains the impact of environmental contaminants. Anecdotal evidence (e.g., crossed-bills, foot lesions, eye and feather deformities) gathered during the initial three years of work with the Illinois tern populations suggests that the birds may be susceptible to organochlorides and/or heavy metal pollutants. Toxicology screening was needed to determine the source and extent of environmental contamination. In addition to the observed deformities in hatchlings, reduced hatching success, lethargic behavior, or as yet described physiological influences, may negatively impact reproductive success and population viability of these endangered species in Illinois.

Recent toxicology studies suggested we investigate the possibility that contaminants were being concentrated by Zebra Mussels and subsequently made available to the forage prey base of terns. Contaminants such as lipophilic PCBs accumulate up the aquatic food chain, with the highest concentrations found in apex predators. However, it is possible for populations of smaller fish to have higher levels of PCBs than the top predatory fish. This apparent contradiction may be linked to concentrated levels of toxins in zebra mussels' "pseudo feces" (mucus wrapped, undigested food particles) upon which sediment dwelling invertebrates feed (Ng as quoted by Pelley, 2005). Consumption of contaminated invertebrates by small fish concentrated near mussel beds may then be passed directly to birds that feed upon the contaminated fish. Given this recent information, Zebra Mussel tissue and sediment samples were included to investigate the possible impact to forage fish due to the

efficient filtering capacity and subsequent concentration of contaminants by Zebra Mussels within the harbor at NSGL. Preliminary tests were done on eggs, young, forage fish, Zebra Mussel tissue, and sediment to examine this possible transfer of contaminants.

Preliminary toxicological screening on failed eggs and morbid young collected from NSGL and Chain o' Lakes State Park (COLSP) indicated relatively high levels of polychlorinated biphenyls (PCBs) and, in some cases, relatively high levels of selenium in the eggs and young (Table 3). Three of the four fish composites tested also had high levels of PCBs (Table 4) and one sample had a relatively high level of selenium. The Zebra Mussel tissue composite and the sediment directly beneath the Zebra Mussel colony, in 2006, showed high levels of PCBs (Table 5). However, the sediment sample taken approximately 30 feet from the colony had no detectable concentration of PCBs. Given this new information, further tests were run on the same type of samples: forage fish, failed eggs, morbid young, Zebra Mussel tissue, sediment samples, and invertebrates that collect near mussel beds; the tests were narrowed down to PCB congeners and detectable levels of selenium.

Methods

We contracted Carbon Dynamics Institute, LLC, located in Springfield, Illinois, to do toxicological screening on representative biological samples taken from the Common Tern colony, the Forster's Tern colony and the harbor at NSGL. The sampling protocol included: failed eggs, morbid young, forage fish, zebra mussels, and sediment samples. Eggs and morbid young from each colony were tested, along with forage fish that were found discarded within the nesting colony at NSGL during the breeding season. Zebra mussel tissue and sediment samples were also included. Concentrations of the following chemicals will be determined:

PCBs

Aroclor-1016	3,3',4,4'-TetraCB	2,3,3',4,4',5-HexaCB
Aroclor-1221	3,4,4',5-TetraCB	2,3,3',4,4',5'-HexaCB
Aroclor-1232	2',3,4,4',5-PentaCB	2,3',4,4',5,5'-HexaCB
Aroclor-1242	2,3,3',4,4'-PentaCB	3,3',4,4',5,5'-HexaCB
Aroclor-1248	2,3,4,4',5-PentaCB	2,3,3',4,4',5,5'-HeptaCB
Aroclor-1254	2,3',4,4'5-PentaCB	
Aroclor-1260	3,3',4,4'5-PentaCB	

Heavy Metals

Selenium (Se)

Results

The eggs from the 2007 breeding season had very high levels of PCBs, especially Aroclor-1254, and some of the eggs, had detectable levels of selenium (Table 6). The morbid young and adult also had high levels of PCBs, especially Aroclor-1254, and all had detectable levels of selenium (Table7). Table 8 shows the

toxicology results for zebra mussels from NSGL and North Point Marina. All the mussels from NSGL had concentrations of PCBs and some detectable levels of selenium. The three samples of zebra mussels taken from North Point Marina had no detectable levels of PCBs and only one had detectable levels of selenium. The fish samples from NSGL all had detectable concentrations of PCBs and one of the spot-tailed shiner samples had detectable levels of selenium (Table 9). In all cases where detectable levels of PCBs were found, the congener Aroclor-1254 made up the majority of the composition. The Forster's Tern colony at COLSP failed to produce young in 2006 and 2007. We were unable to obtain any morbid young or failed eggs for toxicological screening.

Conclusions

The high concentration of PCBs in the failed eggs and young suggests a local source of contamination. The presence of organochlorides (i.e. PCBs) may help explain the demise of over two thirds of the 2006 brood, when 27 of the nearly fledged young perished, presumably from hypothermia after an unseasonably heavy rain. Evidence of organochlorine-associated suppression of T-cell-mediated immunity in nestling water birds has been documented in the Great Lakes (Grasman et al. 1996). Immunosuppression by organochloride contaminants appears to weaken the immune system and increase susceptibility to bacteria, viruses, and protozoan parasites.

Also, the high percentage of Aroclor-1254 in the samples provides some clues as to the low reproductive success of the Common Terns at the Naval Station in 2007 when the majority of the young failed to hatch, died while pipping, or died very shortly after hatching. Aroclor 1254 is one of several commercial PCB mixtures that were marketed between the 1930's and 1970's. It is a highly chlorinated PCB mixture which, by definition contains 54% chlorine by weight. Aroclor-1254 is a known carcinogenic according to ¹California Proposition 65, a neurotoxin (Branchi et al, 2005), and an endocrine disrupter at the hypothalamic level (Gore et al. 2002),

Contaminant mediated disruption of the endocrine system may also lead to reduced parental attentiveness and abnormal reproductive behavior (Stapleton et al. 2001). Impaired parental behavior as a result of PCB induced endocrine disruption may cause preternatural incubation leading to lower reproductive success (Grasman et al. 1996). The incubation period was found to be significantly longer for a similar species, Forster's Terns (*Sterna forsteri*), on organochlorine contaminated Green Bay, Lake Michigan compared to a relatively uncontaminated inland location. Also, nest abandonment and egg disappearance were found to be higher at the contaminated site; this study by Kubiak et al. (1989) strongly suggested that PCBs were a causal factor.

The presence of contaminants in the zebra mussels at NSGL indicates the ability of Zebra Mussels to concentrate contaminants; however, conclusive evidence as to the pathway of contamination to the terns is not available at this time. The possible impact

¹ A list of chemicals known to cause cancer is maintained by the State of California under the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). Unlike rating systems, California does not rank chemicals for their carcinogenicity, but simply designates a chemical as a "known" carcinogen.

to forage fish due to the efficient filtering capacity and subsequent concentration of contaminants by Zebra Mussels within the harbor needs to be further investigated.

In conclusion, although Common Terns are annually present at NSGL, the site may be an ecological trap due to the presence of environmental contaminants. This new information provides vital insight into the full scope of conservation issues facing Terns in Illinois. Common terns have lost most of their breeding habitat in the Great Lakes region. Conservation of the remaining colony should be a high priority. Due to the toxicology issues at the Naval Station, finding alternate nesting sites should be a priority. The absence of PCBs in the Zebra Mussel samples from North Point Marina suggests that foraging sites associated with Lake Michigan may be available that do not expose the population to ecological contaminants and yet provide viable breeding site alternatives.

The continued absence of a successful breeding season for Forster's Terns demonstrates that tern colonies in Illinois face a multitude of environmental constraints that impact viability of local populations. Therefore, combined behavioral and ecological studies are necessary to document which factors continue to impede population stability and alternative strategies will be necessary to manage this species.

This grant helped provide the funds necessary to obtain preliminary toxicological data and thus the basis to secure matching grants to further pursue this aspect of tern conservation. Further testing will enable us to compare inland nesting terns with species dependent upon Lake Michigan.

Table 1. Nesting records and survey of Forster's terns (*Sterna forsteri*) during the breeding season in Illinois.

Year	Grass Lake			Fourth Lake			Lake Elizabeth			Statewide		
	Adults	Nests	Yg	Adults	Nests	Yg	Adults	Nests	Yg	Adults	Nests	Yg
1876	14	7										
1983	28	16	19							28	16	19
1986	0			0			0			0	0	
1987	0			0			0			0	0	
1988	0			0			0			0	0	
1989	7	3	-	0			0			7	3	-
1990	-			0			0					
1991	35	39	-	0			0			35	39	-
1992	76	49	-	0			0			76	49	-
1993	90	46	-	0			0			90	46	-
1994	60	10	-	0			0			60	10	-
1995	162	92	67	0			0			162	92	67
1996	3	0	0	5	4	4	16	7	5	24	11	9
1997	57	27 ^a	0	2	0	0	14	5	2	73	32	2
1998	2	0	0	0			11	4	2	13	4	2
1999	0			0			0			0		
2000	5			0			0			5		
2001	2			0			0			2		
2002	2			0			0			2		
2003	65	57	149	0			0			65	57	149
2004	67	131	0	0			5	4	0	72	135	0
2005	35	17	12	20	10	14	2	0	0	57	27	26
2006	60	41	0	20	7	0	0	0	0	80	49	0
2007	36	19	0	0	0	0	0	0	0	36	19	0

Table 2. Common Tern (*Sterna hirundo*) nesting summaries for Illinois

Year	Site	Maximum Tern Number	Maximum Nesting Attempts	Maximum Eggs Laid	Total Young Fledged
1948	Midwest Generation		4		0
	Johns-Mansville	30		36	33
1975	Unknown				
1976	Johns-Mansville		2		0
	Midwest Generation		8		0
1977	Waukegan Harbor	16	9		0
	Waukegan Island		12		9
1978	Waukegan Harbor		16		0
1979	Midwest Generation	43	15		35
1980	Midwest Generation	60	29	52	0
1981	Midwest Generation	70	33	98	0
1982	Midwest Generation	50	25	70	16
1983	Midwest Generation	64	32	87	21 ³
1984	Midwest Generation	22	17	41	0
1997	Midwest Generation	26	10		0
	Johns-Mansville	6	3	9	0
1998	Midwest Generation	17	9		7
1999	Midwest Generation	35	8		0
2000	Midwest Generation	17	1	1	0
	Naval Station	42	12	27	0
2001	Naval Station	49	54	109	0
2002	Naval Station	49	18	44	26
2003	Naval Station	49	46	129	43
2004	Naval Station	66	26	67	32
2005	Naval Station	96	23	67	6
2006	Naval Station	63	38	99	2
2007	Naval Station	120	49	136	5

Table 3. Toxicology results for morbid young and failed eggs.

Site	date collected	Source	Total PCBs (μ /kg)	⁷⁸ Se (mg/kg)
NSGL	6-Jul-04	young	204.0	n/a
NSGL	6-Jul-04	young	24.1	n/a
COLSP	13-Jul-04	egg	113.0	n/a
COLSP	2-Aug-05	egg	818.0	n/a
NSGL	15-Jul-05	egg	4.1	n/a
NSGL	29-Jun-05	young	1187.0	n/a
NSGL	6-Jul-05	young	1391.0	n/a
COLSP	13-Jul-04	young	658.0	n/a
NSGL	6-Jul-05	young	149.0	n/a
NSGL	6-Jul-05	young	n/a	2.90
NSGL	15-Jul-05	egg	n/a	1.50
COLSP	25-May-04	egg	n/a	0.70
NSGL	13-Jul-05	egg	n/a	0.62

These samples were tested in 2006.

Table 4. Toxicology results for fish samples.

Site	date collected	Source	total PCBs (μ /kg)	⁷⁸ Se (mg/kg)
NSGL	6-Jul-05	fish composite	69.8	n/a
NSGL	7-Jul-05	fish composite	15.8	n/a
NSGL	4-Jul-04	fish composite	n/a	1.00
NSGL	2006	Fish composite	69.8	

These samples were tested in 2006.

Table 5. toxicology results for zebra mussels and sediment in the harbor

Site	Source	total PCBs (μ /kg)
NSGL - under dock	Zebra mussel composite	4.69
under z. mussel colony	Sediment	4.93
near mussel colony (control)	sediment	undetected

These samples were collected and tested in 2006.

Table 6. toxicology results for COTE young and egg from NSGL, tested in 2007.

source	date collected	Aroclor 1254(μ /kg)	total PCBs (μ /kg)	Se (mg/kg)
egg	15-May-07	7,456.00	7,634.518	1.3
egg	11-Jun-07	13,599.00	13,812.914	1.0
egg	16-May-07	8,456.00	8,642.030	0.9
egg	17-May-07	14,998.00	15,279.285	0.7
egg	18-May-07	7,459.00	7,590.864	U
egg	18-May-07	37,235.00	37,479.630	U
egg	18-May-07	16,921.00	17,002.866	U
egg	25-May-07	8,541.00	8,649.612	1.3
egg	7-Jun-07	11,695.00	11,870.638	U
egg	8-Jun-07	12,962.00	13,144.740	1.8
egg	11-Jun-07	15,871.00	16,068.140	U
egg	25-Jul-07	22,344.00	22,741.206	U
egg	25-Jul-07	16,235.00	16,339.926	U
egg composite	25-Jul-07	10,789.00	10,899.714	1.3
egg composite	25-Jul-07	24,213.00	24,586.234	U
egg composite	25-Jul-07	16,847.00	17,010.689	U

Table 7. Toxicology results for young and one adult from NSGL, tested in 2007.

source	date collected	Aroclor 1254(μ /kg)	total PCBs (μ /kg)	Se (mg/kg)
Young	26-Jun-06	8,647.00	8,685.143	1.7
Young	26-Jun-06	4,967.00	4,975.213	2.8
Young	26-Jun-06	1,822.00	1,830.405	3.3
Young	26-Jun-06	10,736.00	10,770.228	2.7
Young	26-Jun-06	141.00	142.575	3.2
Young	26-Jun-06	1.38	1.387	2.5
Young	26-Jun-06	3,701.00	3,712.616	2.3
Young	26-Jun-06	4,554.00	4,574.320	3.1
small young	6-Jun-07	7,485.00	7,528.112	1.0
small young	11-Jun-07	238.00	240.195	0.8
small young	25-Jun-07	16.07	26.500	1.3
small young	13-Jul-07	5,092.00	5,173.671	1.9
small young	14-Jul-07	2,393.00	2,417.923	1.6
adult	13-Jul-07	2,497.00	2,530.467	2.4
small young	25-Jun-07	2,645.00	2,670.209	1.3

Table 8 Toxicology results for zebra mussels from NSGL and North Point Marina, tested in 2007.

Site	Aroclor 1254(μ /kg)	total PCBs (μ /kg)	Se (mg/kg)
NSGL	118.00	126.478	0.80
NSGL	66.80	72.937	U
NSGL	159.00	169.116	U
NSGL	605.00	621.17	1.00
NSGL	391.00	404.893	0.90
NSGL	170.00	180.369	1.00
NSGL	115.00	119.607	U
NSGL	108.00	114.071	U
NSGL	214.00	217.727	U
N.Point	U	U	1.00
N.Point	U	U	U
N.Point	U	U	U

U indicates undetected levels; detection limit for selenium was 0.20 mg/kg, detection limit for PCBs was 0.10 μ /kg or 0.20 μ /kg, depending on the congener.

Table 9. Toxicology results for fish from NSGL harbor and from forage fish found in the colony, tested in 2007.

Source	Aroclor 1254(μ /kg)	total PCBs (μ /kg)	Se (mg/kg)
Alewife from harbor	234	236.494	U
Alewife from harbor	1449	1451.367	U
Alewife from harbor	1177	1179.452	ND
Spot-tailed shiners	71.4	88.158	0.50
Spot-tailed shiners	29.5	60.652	U
Spot-tailed shiners	144	159.587	ND

U indicates undetected levels; detection limit for selenium was 0.20 mg/kg, detection limit for PCBs was 0.10 μ /kg or 0.20 μ /kg, depending on the congener. ND indicates the presence of selenium was not determined.

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