Avian Receptor Analysis

Estimating exposure of piscivorous birds to mercury in the South River

South River Science Team

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Purpose

- Using existing published information and exposure assessment protocols, estimate the potential exposure of piscivorous birds in the South River watershed to mercury.

Toxicology of Mercury in Avian Species

Table 1. Weights of adult mallards fed a control diet or a diet containing 10 ppm selenium as seleno-DL-methionine, 10 ppm mercury as methylmercury chloride, or 10 ppm selenium plus 10 ppm mercury (mean ± SE)

	Weight[a] (g)							
	Males				Females			
Diet	*n*	At onset of treatment	When birds were paired	At euthanasia or death	*n*	At onset of treatment	When birds were paired	At euthanasia or death
Control	12	1,218 ± 39.3 A	1,257 ± 26.6 A	1,174 ± 29.9 A	12	1,130 ± 27.3 A	1,173 ± 16.7 A	1,382 ± 51.3 A
10 ppm selenium	12	1,142 ± 24.7 A	1,208 ± 25.8 A	1,119 ± 27.2 A	12	1,143 ± 41.8 A	1,218 ± 46.2 A	1,394 ± 62.8 A
10 ppm mercury	12	1,169 ± 27.0 A	1,271 ± 38.1 A	1,072 ± 32.0 A	12	1,121 ± 45.4 A	1,198 ± 37.7 A	1,399 ± 52.7 A
10 ppm selenium + 10 ppm mercury	12	1,203 ± 19.7 A	1,295 ± 30.2 A	1,181 ± 26.5 A	11	1,168 ± 42.6 A	1,238 ± 50.1 A	1,423 ± 61.4 A

[a] Means in the same column that share a letter were not significantly different at $\alpha = 0.05$ using analysis of variance (ANOVA). The ANOVA for weights of adult males at euthanasia or death was significant ($p = 0.035$), but no significant differences were observed among means when a Student-Newman-Keuls test was used to separate means.

Table 2. Measurements of egg-laying and eggs for mallards fed a control diet or a diet containing 10 ppm selenium as seleno-DL-methionine, 10 ppm mercury as methylmercury chloride, or 10 ppm selenium plus 10 ppm mercury (mean ± SE)[a]

Diet	n[b]	No. of days between eggs	n	Percentage of eggs laid outside nestbox	n	Whole egg weight (g)	n	Egg-shell thickness (mm)
Control	12	1.24 ± 0.098 A	12	9.1 ± 3.38 A	12	61.9 ± 1.28 A	12	0.38 ± 0.010 A
10 ppm selenium	11	1.38 ± 0.266 A	11	11.5 ± 4.81 A	10	61.9 ± 2.06 A	10	0.38 ± 0.008 A
10 ppm mercury	10	1.24 ± 0.074 A	10	16.1 ± 5.57 A	9	59.9 ± 1.90 A	9	0.40 ± 0.013 A
10 ppm selenium + 10 ppm mercury	11	1.50 ± 0.234 A	11	10.3 ± 4.38 A	9	64.4 ± 2.90 A	9	0.39 ± 0.010 A

[a] Results are expressed as the arithmetic means. Percentage data were subjected to angular transformation before statistical analysis. Means in the same column that share a letter were not significantly different at $\alpha = 0.05$ using analysis of variance.

[b] n = number of females providing data on eggs.

Table 3. Reproductive success of mallards fed a control diet or a diet containing 10 ppm selenium as seleno-DL-methionine, 10 ppm mercury as methylmercury chloride, or 10 ppm selenium plus 10 ppm mercury (mean ± SE)[a]

Diet	*n*[b]	% Fertility of eggs	*n*	% Hatch of fertile eggs	*n*	% Survival to 7 d of age	*n*	No. of 7-d-old ducklings produced per hen
Control	12	96.0 ± 1.79 A	12	44.2 ± 10.06 A	10	96.2 ± 1.65 A	12	7.6 ± 1.80 A
10 ppm selenium	11	99.1 ± 0.61 A	11	24.0 ± 6.80 AB	10	66.0 ± 10.67 A	12	2.8 ± 0.97 B
10 ppm mercury	9	89.9 ± 4.44 A	9	11.3 ± 5.16 BC	4	70.8 ± 12.50 A	12	1.1 ± 0.56 B
10 ppm selenium + 10 ppm mercury	11	92.4 ± 5.60 A	11	1.4 ± 0.98 C	2	50.0 ± 50.00 A	11	0.2 ± 0.18 B

[a] Results are expressed as the arithmetic means. Percentage data were subjected to an angular transformation before statistical analysis. Means in the same column that do not share a letter were significantly different at $\alpha = 0.05$ by a Student-Newman-Keuls test after an analysis of variance was significant at $\alpha = 0.05$

[b] *n* = number of females providing data.

Table 4. Weights of mallard ducklings whose parents were fed a control diet or a diet containing 10 ppm selenium as seleno-DL-methionine, 10 ppm mercury as methylmercury chloride, or 10 ppm selenium plus 10 ppm mercury (mean ± SE)[a]

	Mean weight of ducklings (g)			
Diet	n[b]	At hatching	n	At 7 d of age
Control	10	42 ± 0.8 A	10	138 ± 5.9 A
10 ppm selenium	10	39 ± 1.5 A	9	114 ± 3.8 B
10 ppm mercury	4	40 ± 0.4 A	4	122 ± 7.6 AB
10 ppm selenium + 10 ppm mercury	2	39 ± 3.0 A	1	80 ± 0.0 B

[a] Means in the same column that do not share a letter were significantly different at $\alpha = 0.05$ by a Student-Newman-Keuls test after an analysis of variance was significant at $\alpha = 0.05$.

[b] n = number of females with ducklings at that age (a mean weight was calculated for all ducklings from the same female; these means were then averaged to produce the means in this table).

Table 5. Deformities exhibited by 1-week or older embryos from mallards fed a control diet or a diet containing 10 ppm selenium as seleno-DL-methionine, 10 ppm mercury as methylmercury chloride, or 10 ppm selenium plus 10 ppm mercury

	No. of embryos exhibiting deformity[a]			
Deformity	Controls	10 ppm selenium	10 ppm mercury	10 ppm selenium + 10 ppm mercury
Gastroschisis	1			
Hydrocephaly	4	16	11	5
Conjoined embryos	1			
Misshapen face		1		3
Missing or malformed bill		16	4	84
Missing, small, or bulging eyes	2	24	9	25
Small or malformed wings		2		23
Missing or malformed feet or legs	1	32		105
Small or missing toes		35		29
Scoliosis or lordosis				11
Malformed tail				11
Dicephaly with exencephaly				1
Spina bifida				40

[a] Some embryos exhibited more than one deformity.

Field Studies in Avian Species

Table 2. Western grebe productivity (young to adult ratios) for Clear, Eagle, and Tule lakes, California, USA, 1992–1994[a]

	Clear Lake	Eagle Lake	Tule Lake
1992	0.001 (1)	No data	0.16 (1)
1993	0.16 (3)	0.74 (2)	0.48 (3)
1994	0.06 (2)	0.47 (4)	0.34 (3)
Summer population	3,500	2,500	1,000

[a] Productivity given as young per adult. A higher number indicates better productivity. Numbers in parentheses indicate the number of breeding surveys at each site that were used to calculate the total young to adult ratios.

Clear Lake = Hg, DDD, boating

Eagle Lake = boating

Tule Lake = no chems, no boating

Productivity

Although the productivity of western grebes at Clear Lake in all years of this study was lower than the productivity of the grebes at the other two lakes, it is not clear why they are exhibiting lower productivity. It is unlikely that only the Hg levels are causing lowered reproductive output. Bioaccumulation of a variety of different compounds, including Hg, could be contributing to the lowered reproductive output for wildlife at Clear Lake [5,14–16]. Clear Lake grebes also have to deal with disturbance. Large numbers of boaters and skiers use the lake during the summer. Anglers often move along the coast looking for bass. The colonial-nesting grebes could be easily disturbed if a boat moved into their colony. Eagle Lake also has moderate boat use, but boats there are less likely to disturb colonies, as most activity is near the center of the lake. Tule Lake NWR has no boat traffic.

The grebes at Eagle Lake and Tule Lake are reproducing at a rate comparable to that reported elsewhere [12–14] Clear Lake, however, is clearly exhibiting low reproductive success. The yearly breeding population may still remain stable due to input from other populations. Clear Lake, in this way, would become a sink population, whereas the other lakes would be sources [17]. Why the grebes of Clear Lake are reproducing poorly is unclear. This study is an example of the difficulties involved in performing field studies. The existence of a variety of confounding factors makes it difficult to link reproductive performance to the existence of pollutants in the environment. More controlled studies may be needed to produce more substantial cause–effect linkages.

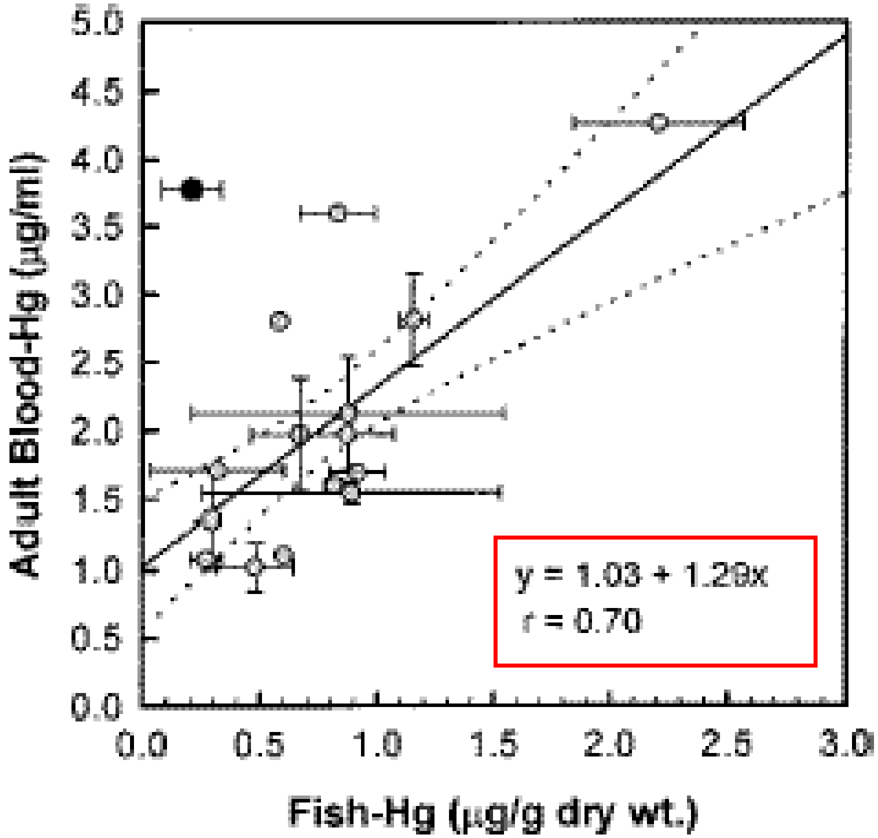


Fig. 5. Relationship between Hg in 20- to 50-g perch and sunfish and Hg in blood of adult loons ($p < 0.01$). The solid data point indicates a single individual with an anomalously high blood-Hg concentration not included in the regression.

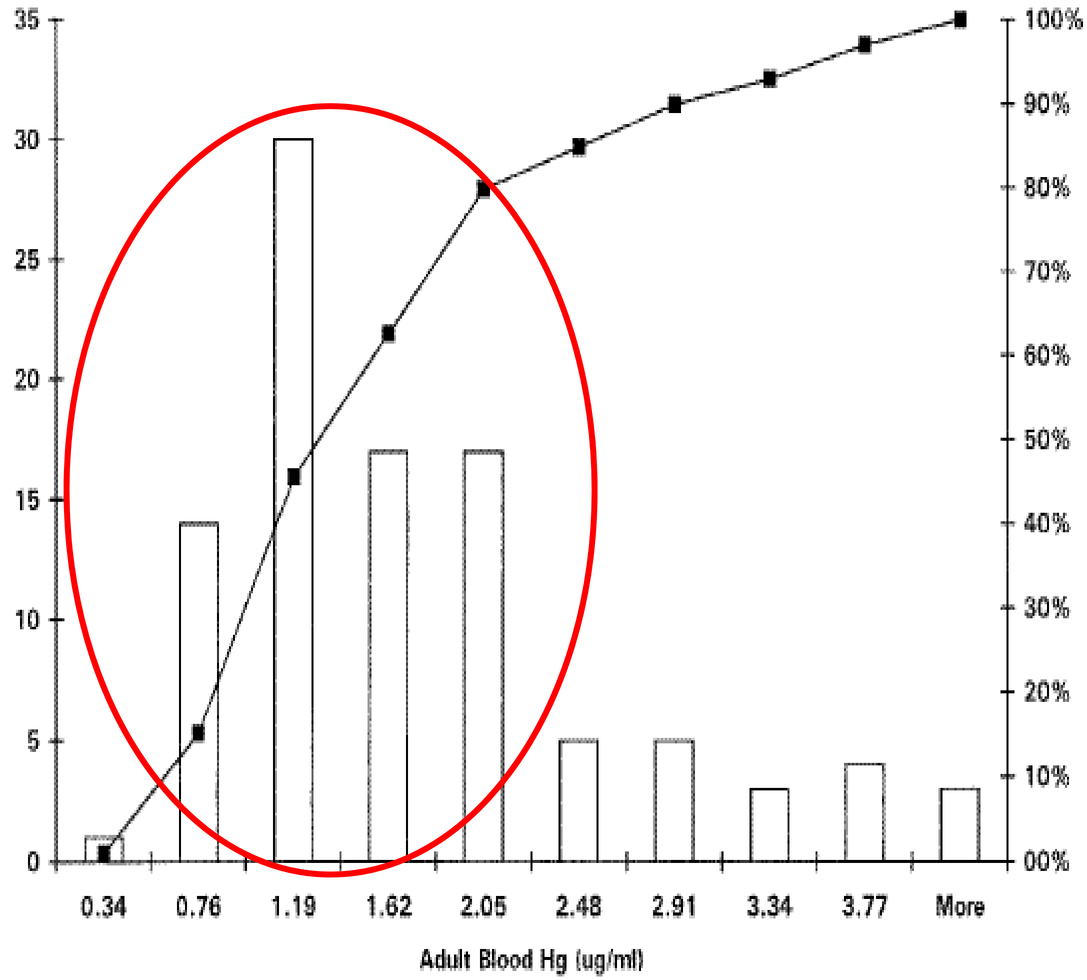


Fig. 3. Frequency distribution and cumulative frequency polygon of adult blood Hg concentrations (μg/ml) on 45 study lakes in northern Wisconsin. Bars indicate frequency; filled squares give cumulative percentage.

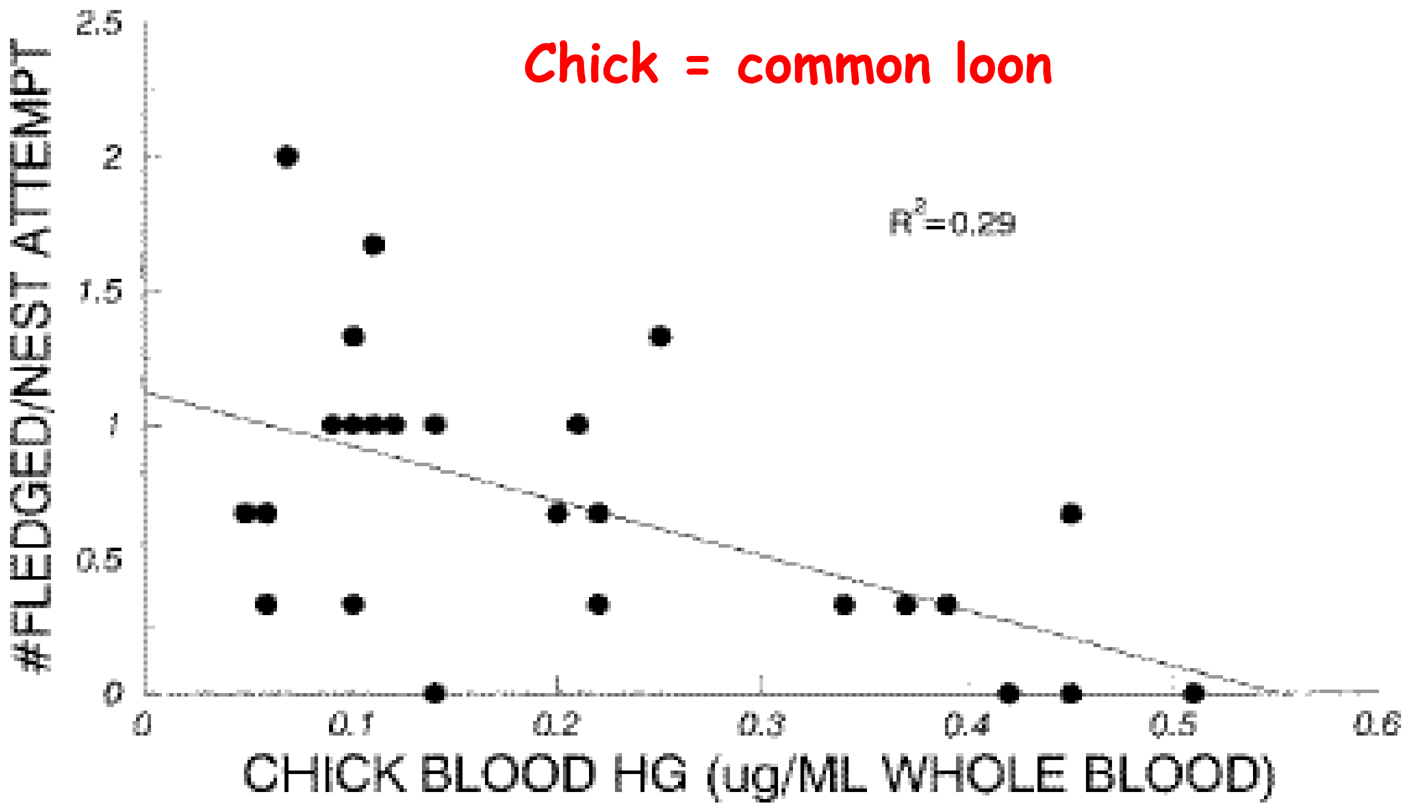


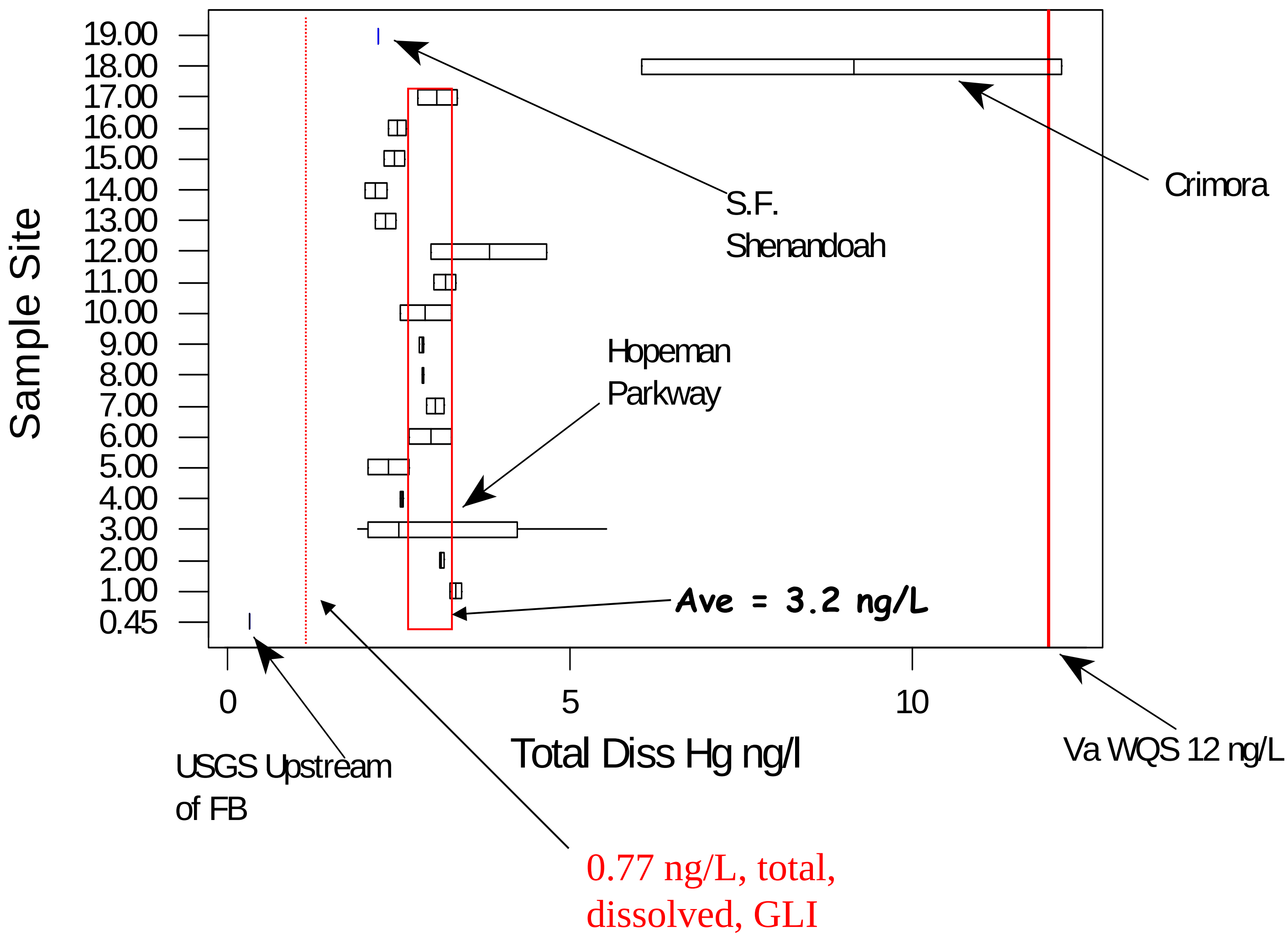
Fig. 5. Linear relationship between chick blood Hg concentrations (µg/ml) and chick production (3-year total) on 26 study lakes in northern Wisconsin.

Regulatory Criteria

Hg “Water Criteria”

- 0.91 ng/L total, unfiltered (for the GLI)
- 0.77 ng/L total, dissolved (for the GLI)
- 0.53 ng/L total, dissolved (2003 proposed in NJ)
- 1400 – 2400 ng/L, total, dissolved, acute value (NOAA)
- 12 – 770 ng/L, total, dissolved, chronic value (NOAA)

Total Dissolved Hg in South River and S.F. Shenandoah River Compared to Virginia WQS of 12 ng/L.



Hg in Surface Water

Descriptive Statistics: Total Diss Hg ng/l

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Total Di	42	3.232	2.825	2.952	1.946	0.300

Variable	Minimum	Maximum	Q1	Q3
Total Di	0.310	12.200	2.435	3.253

Estimating Exposure

Two Piscivorous Birds: Estimates for South River

- Belted Kingfisher
  - Consume 0.075 kg / d
  - TRV (mallard)
    - 0.078 mg/kg/day
  - Bw = 0.15 kg
  - Prey = TL3, TL4 fish

Microsoft Excel Worksheet

- Osprey
  - Consume 0.3 kg / d
  - TRV (mallard)
    - 0.078 mg/kg/day
  - Bw = 1.5 kg
  - Prey = TL3, TL4 fish

Uncertainties

- **No formal lab study of Hg toxicity conducted except in mallard ducks.**
  - **Piscivorous birds have greater tolerance for Hg than do mallards.**
- **Current water quality standards for Hg are based on studies in mallards.**
  - **Average dissolved Hg concentrations in South River are below current AWQC.**
- **Field studies have difficulty accounting for other stressors and their effects on reproduction.**
  - **Field surveys indicate good populations of passerines and other species in the watershed.**
- **Gray areas: consumption habits; concentration of Hg in TL3 forage fish; potential influence of non chemical stressors; population survey data from South River watershed.**

What Does This Mean ?

- The published toxicology of Hg in birds is primarily a result of studies in mallards - mallards appear to be more sensitive to Hg exposure than piscivorous birds.
- Field studies in loons, grebes, great egrets and Canada geese do not provide a clear cause - effect relationship between exposure to Hg and population-level impacts.
- Survey data suggest the South River watershed supports abundant species of passerines and others.
- Large uncertainties exist with South River exposure estimations for piscivorous birds.
- The diet appears to be the primary source of exposure in piscivorous birds, and fish tend to be the primary element of the diet.
- Addressing the fish tissue mercury is the key to addressing potential exposures in birds.