Mercury Bioaccumulation and Toxicity to Birds in San Francisco Bay Estuary


Photo by Ken Phenicie


Photo by Michael Kern

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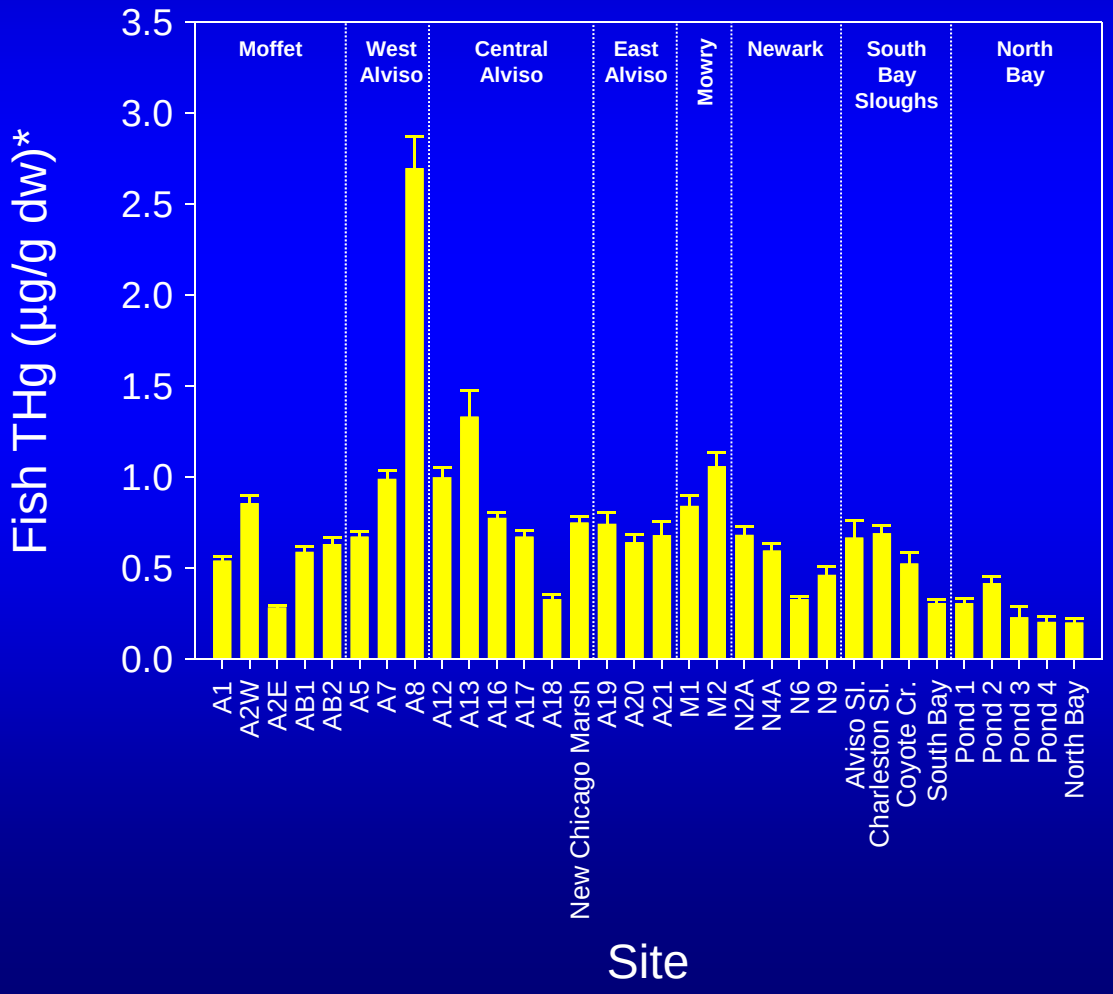
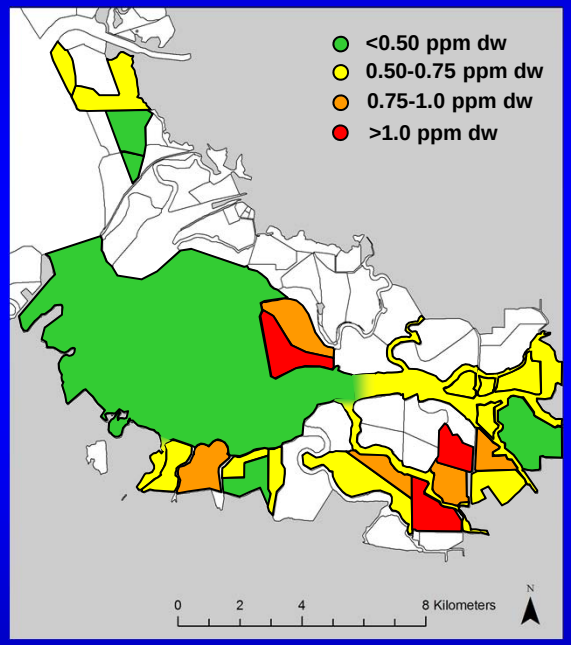
Talk Outline

1) Hg bioaccumulation in fish and birds
2) Differences in Hg among wetland types
3) Maternal transfer of MeHg to eggs
4) Hg effects on nesting success
5) Hg effects on chick survival
6) Hg variability among years

Fish Mercury Among Wetlands

N = 3,033 fish
10 species
32 wetlands





*least-square means controlling for species, year, date, site, length, & body condition

*0.8=fish effects;
1.2=bird effects

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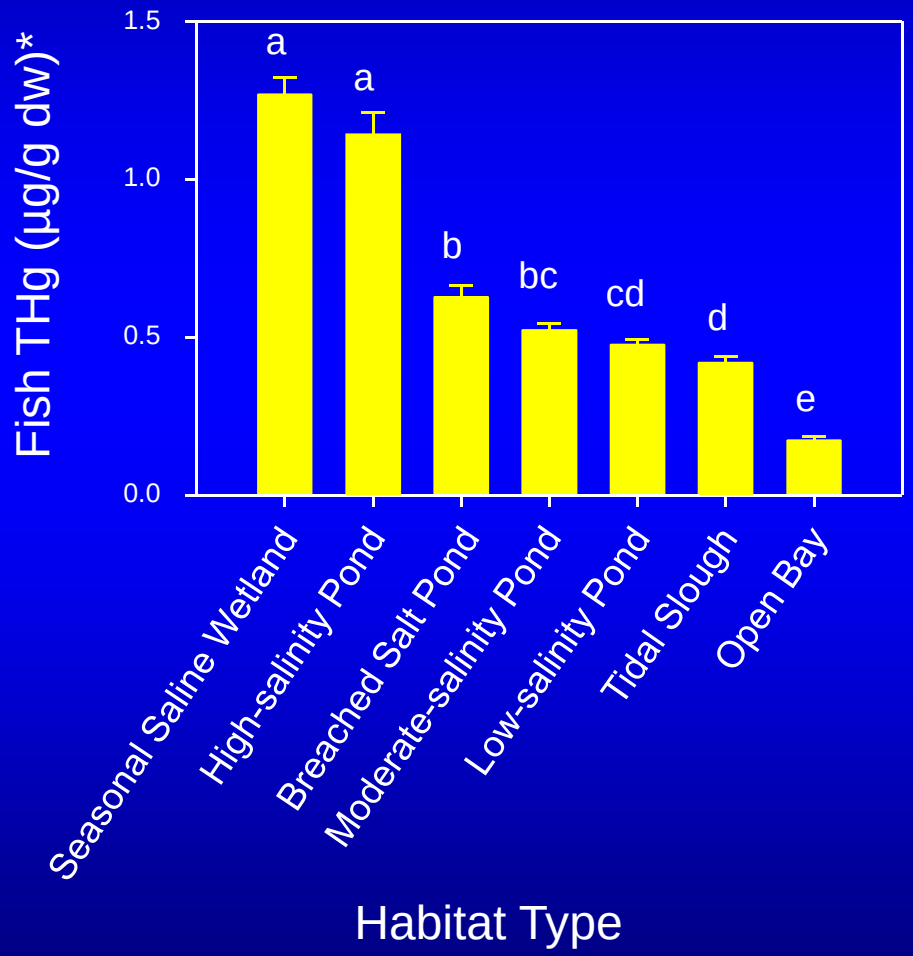
Fish Mercury Among Wetland Habitats



*least-square means controlling for region, wetland [region], date^2, and year.

*Concentrations are normalized to species-specific mean length.

*0.8=fish effects; 1.2=bird effects

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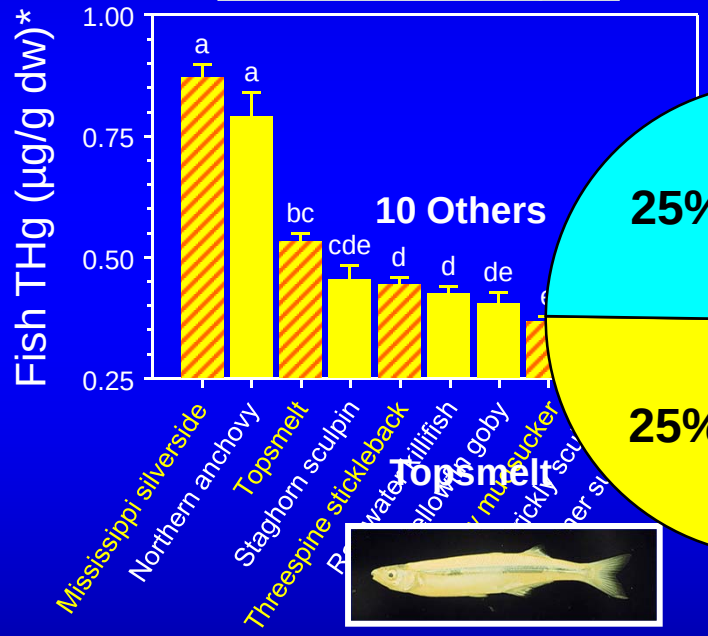
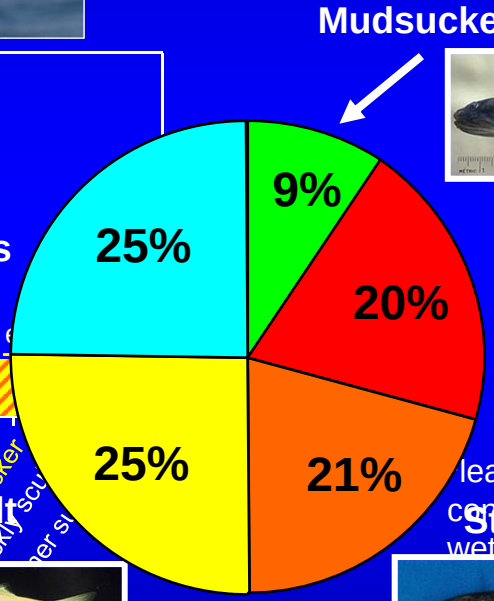
Fish Mercury Among Species

Tern Diet

***N*=2880**



Topsmelt



Mudsucker

Silverside

Stickleback

least-square means controlling for region, wetland [region], date^2,

re normalized to species-specific mean length.

*0.8=fish effects; 1.2=bird effects

§ excluded from model, found mainly in Bay

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Mercury in Prey Fish Highest During Bird Reproduction

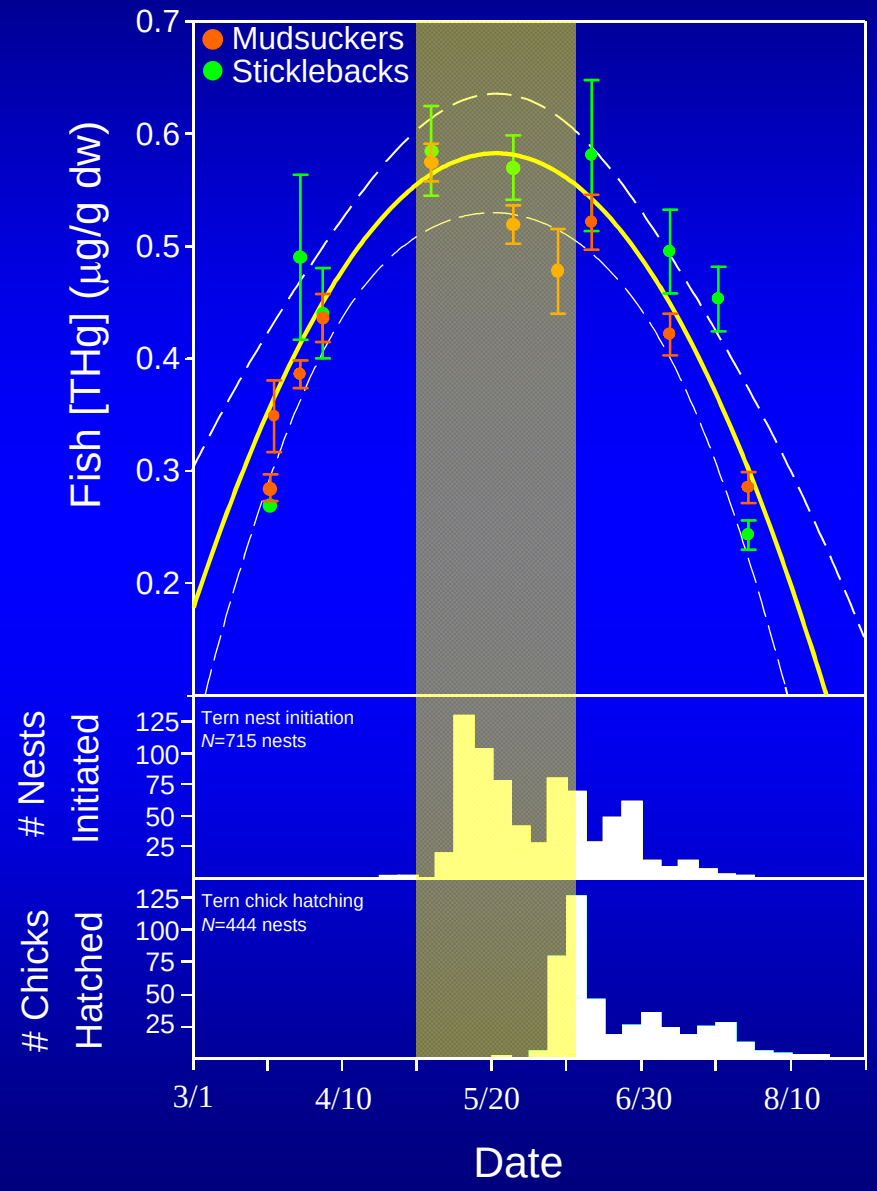

Photo by Ken Phenicie

% at peak prey Hg

68% nests initiated

31% chicks hatch

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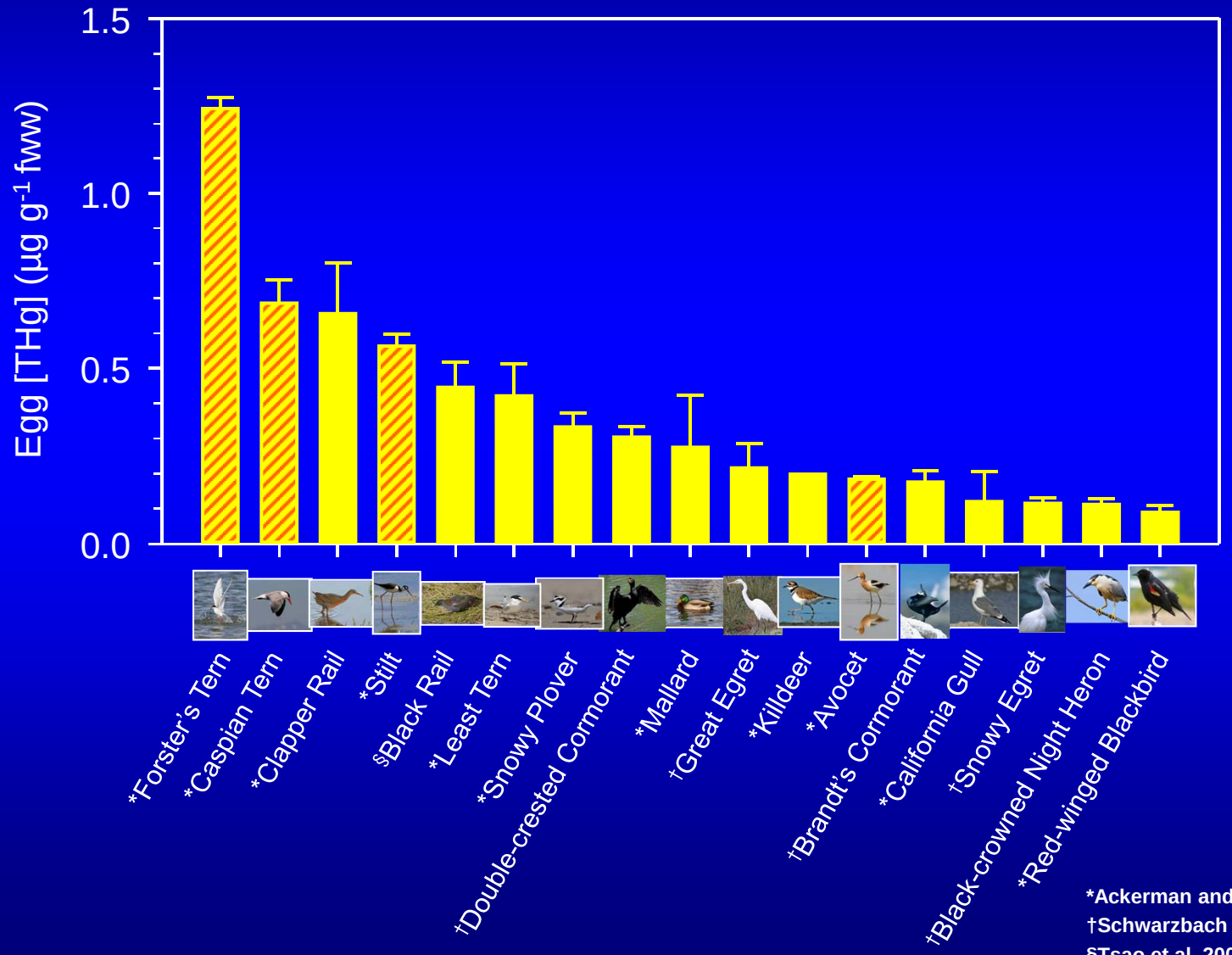
Eagles-Smith & Ackerman, Environmental Science & Technology, 2009

Avian Mercury Exposure in San Francisco Bay

17 species



*Ackerman and Eagles-Smith 2008
†Schwarzbach and Adelsbach 2003
§Tsao et al. 2008

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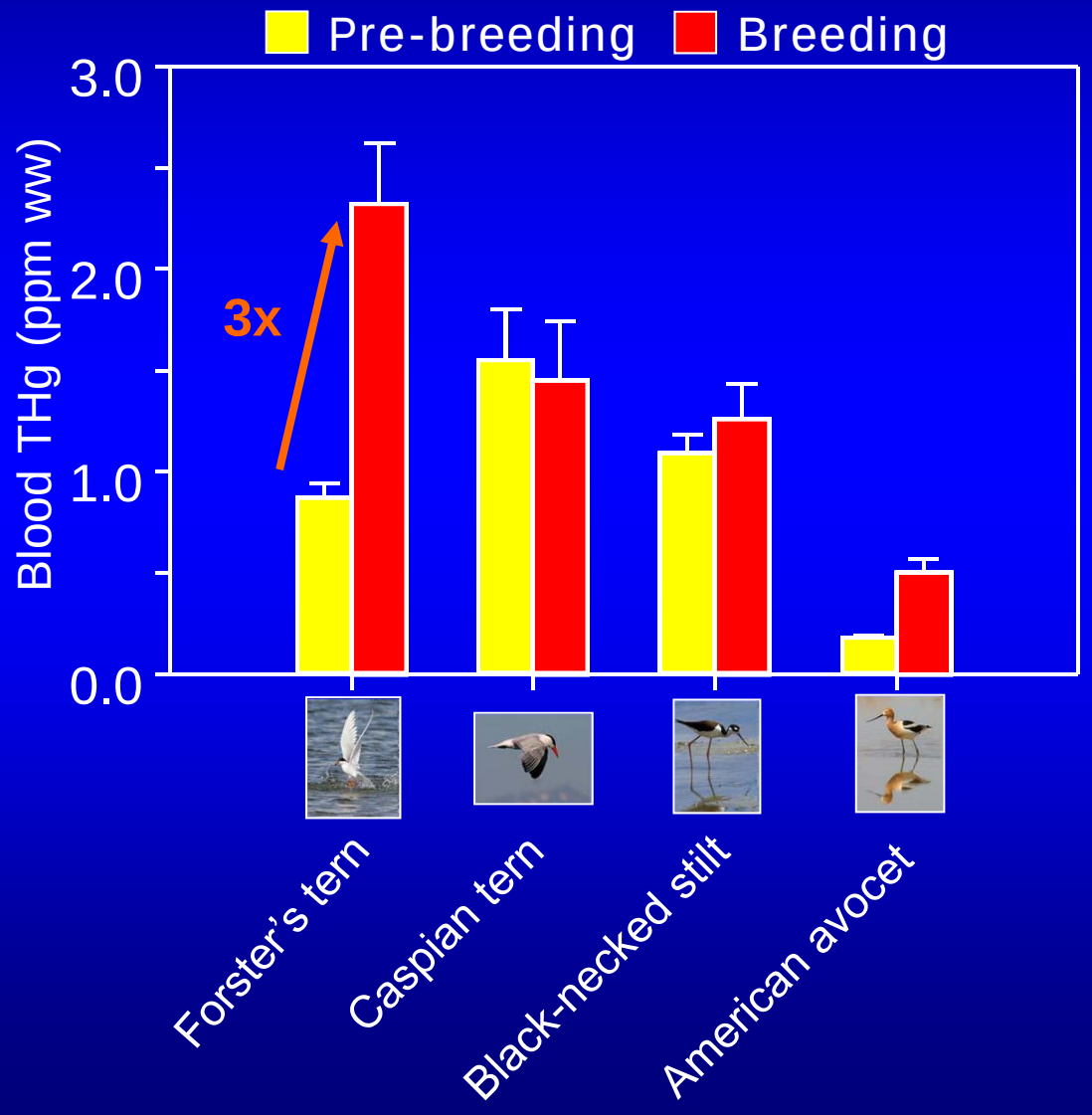
Waterbird Mercury Exposure



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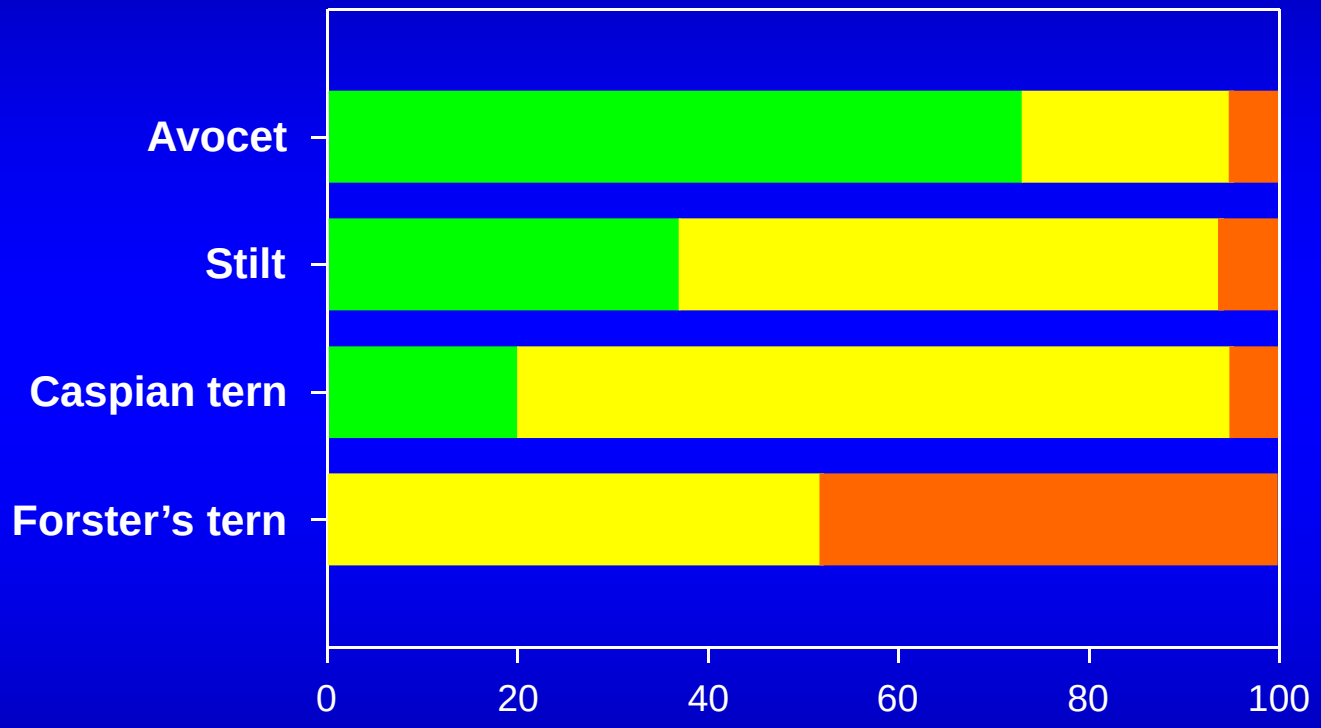
Environmental Pollution 2009

Percent of Breeding Population at Risk to Mercury Toxicity



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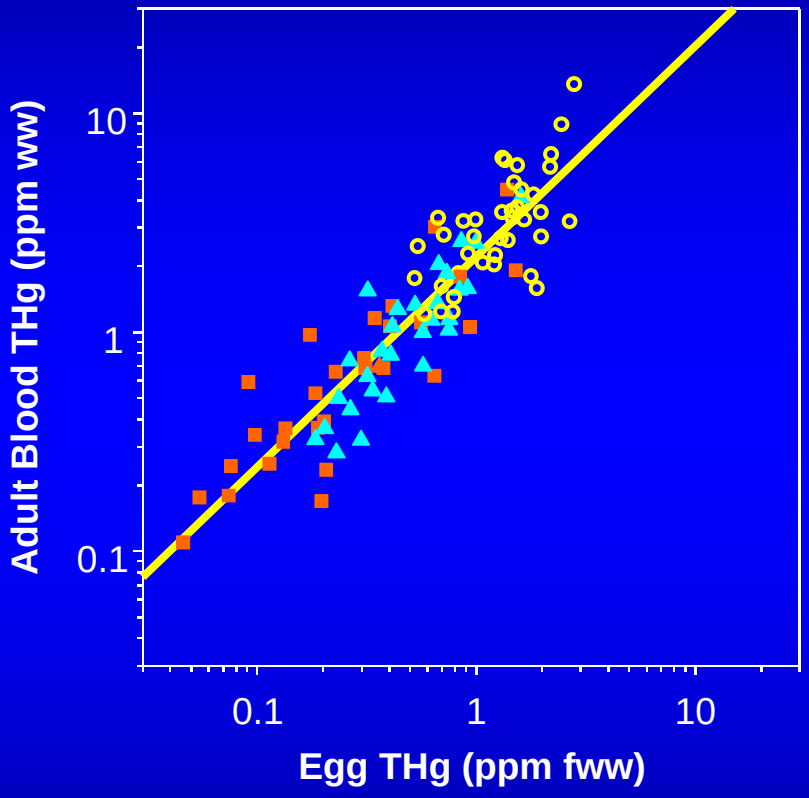
Maternal Transfer of Mercury



P<0.0001
R^2=0.83
N=99 clutches & parents

- Terns
- Stilts
- Avocets

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Effects of Mercury on Reproductive Success

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Is Mercury Impairing Egg Hatchability?
A Multi-Phased Approach

1. Dead vs Alive Eggs
   - Hg in failed-to-hatch eggs vs random viable eggs

2. Surrogate Egg Technique
   - Hg in surrogate egg vs survival of remaining clutch

3. Microsampling Technique
   - Hg in individual egg vs hatchability of same egg

4. Embryo Malposition
   - Hg in individual egg vs embryo position for hatching

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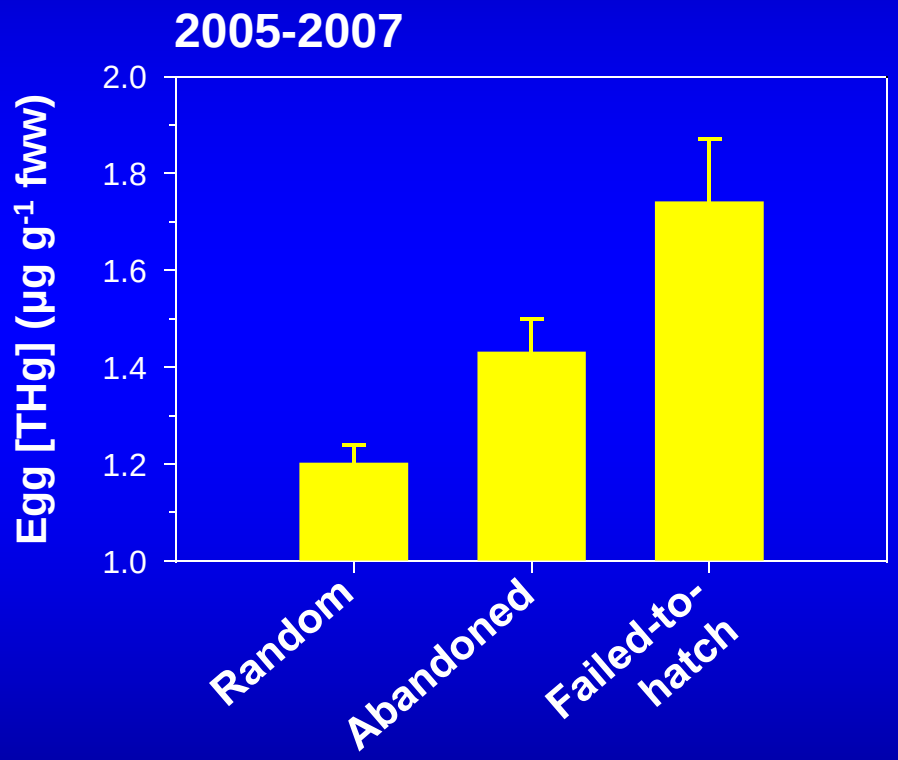
Mercury Highest in Failed-to-Hatch Tern Eggs



P*<0.001

$F_{2,341}$=13.58

N=52 failed eggs in successful nests

*Statistically controlled for effects of colony site and year

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Is Mercury Impairing Egg Hatchability?
A Multi-Phased Approach

1. Dead vs Alive Eggs
   - Hg in failed-to-hatch eggs vs random viable eggs
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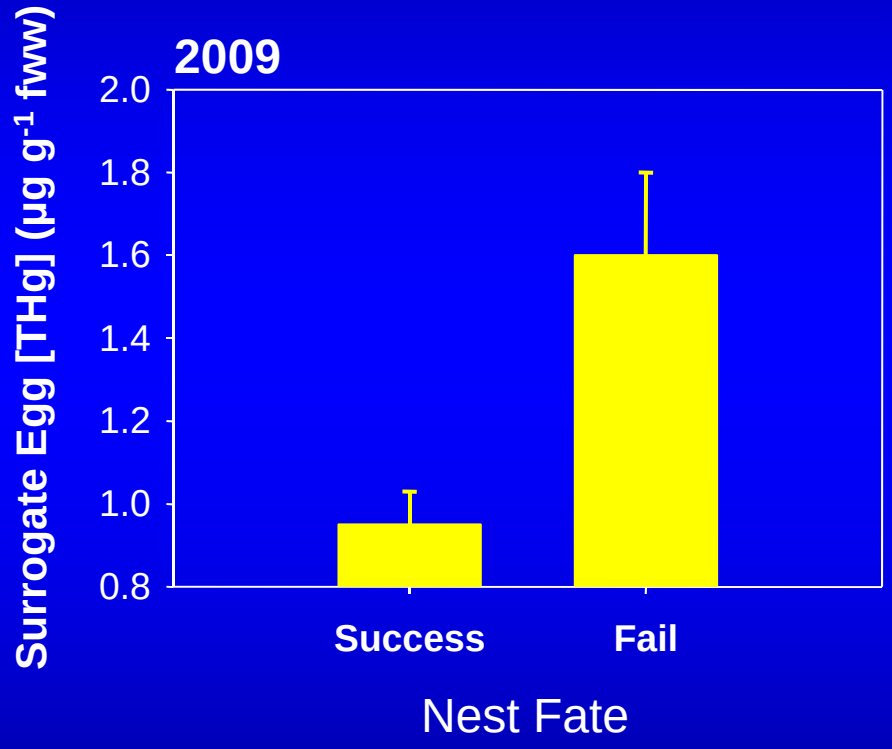
Mercury Highest in Random Eggs Collected from Nests that Subsequently Failed



P*<0.0004

$F_{1,81}$=13.79

N=24 failed eggs in successful nests

*Statistically controlled for effects of colony site

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Is Mercury Impairing Egg Hatchability?
A Multi-Phased Approach

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Egg Microsampling Technique

Individually-Based Index of Egg Mortality

1. Egg drilling

2. Albumen microsampling

3. Egg sealing

4. Egg replacement and monitoring

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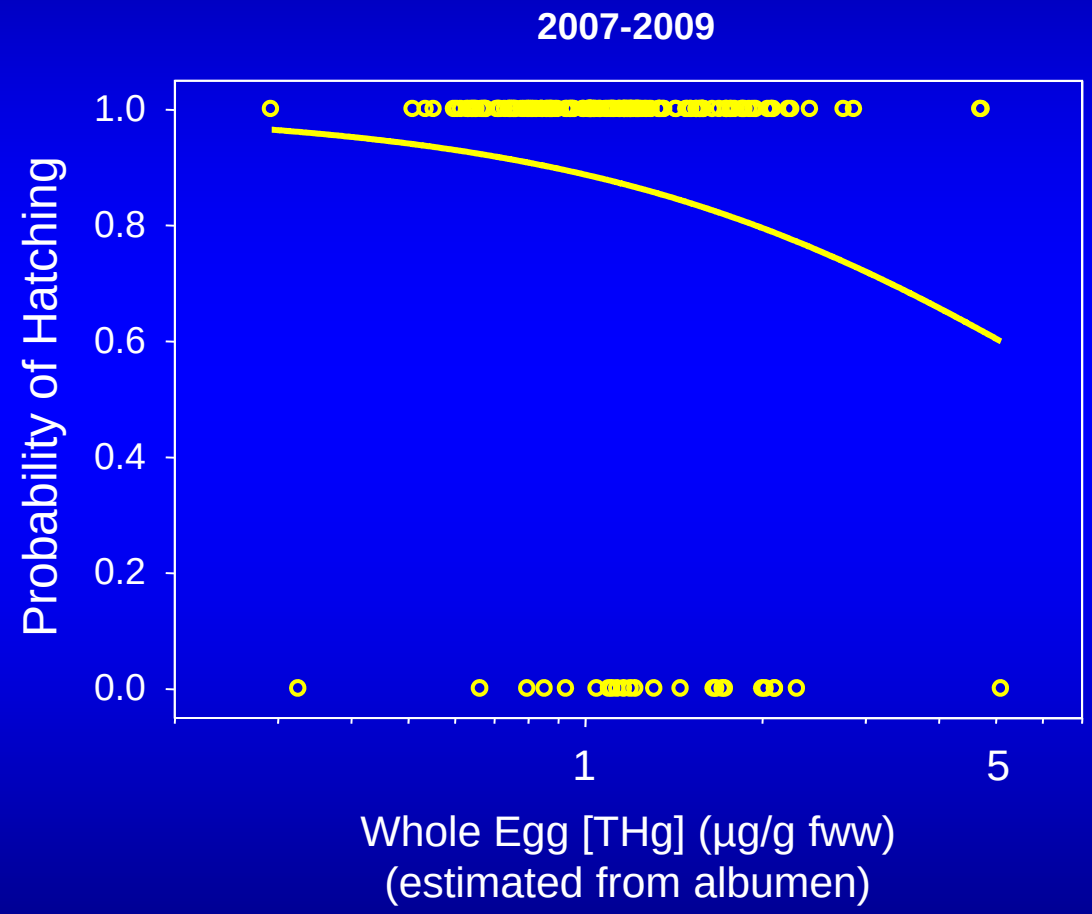
Environmental Toxicology and Chemistry 2009
Environmental Science and Technology 2009

Mercury Reduces Tern Egg Hatchability

(Egg Microsampling Technique – Extract Albumen and Follow Fate of Microsampled Egg)



Egg Hatches
N=157

P=0.04

Wald χ^2=4.23

Odds Ratio 2.30

(2.3 times more likely to fail with each log unit increase in Hg [0.1 to 1])

Egg Fails
N = 24

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Is Mercury Impairing Egg Hatchability?
A Multi-Phased Approach

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   - Hg in surrogate egg vs survival of remaining clutch
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   - Hg in individual egg vs embryo position for hatching

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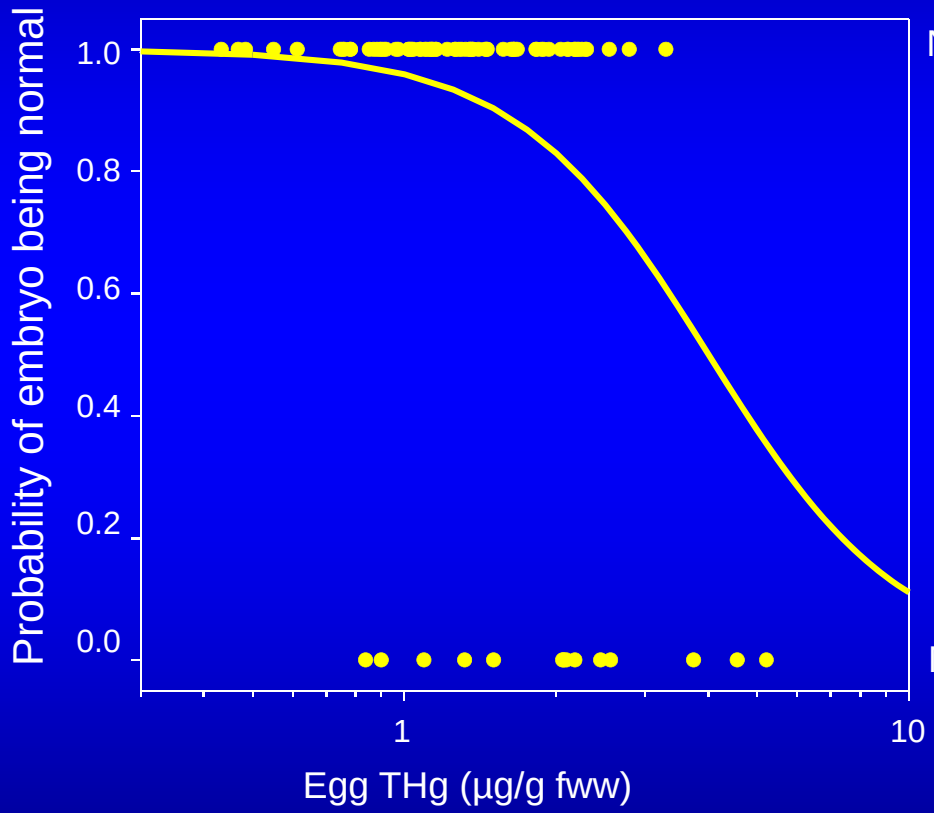
Mercury Increases Likelihood of Embryo Malposition in Tern Eggs

2% of Random Eggs are Malpositioned
27% of Failed-to-Hatch Eggs are Malpositioned



Normal embryo

Malpositioned embryo

P = 0.001
X^2_1 = 10.75
N = 81

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Environmental Toxicology and Chemistry 2010

Mercury Impairs Egg Hatchability in the Wild

1. Dead vs Alive Eggs
   - Failed-to-hatch and abandon eggs had higher Hg than random eggs
2. Surrogate Egg Technique
   - Probability of a nest surviving decreased with egg Hg
3. Microsampling Technique
   - Probability of an egg hatching decreased with egg Hg
4. Embryo Malposition
   - Probability of an embryo being positioned correctly for hatching decreased with egg Hg

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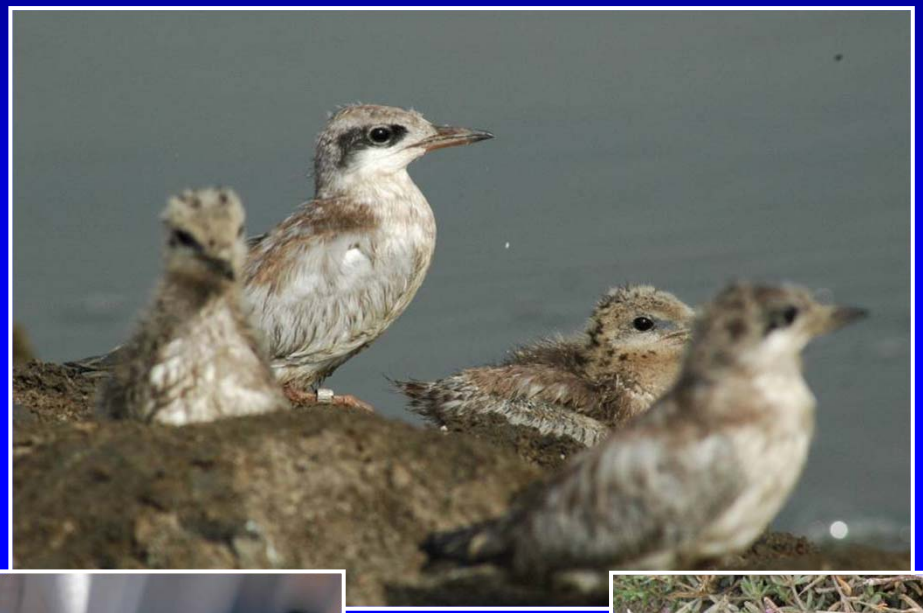
Effects of Mercury on Chick Survival



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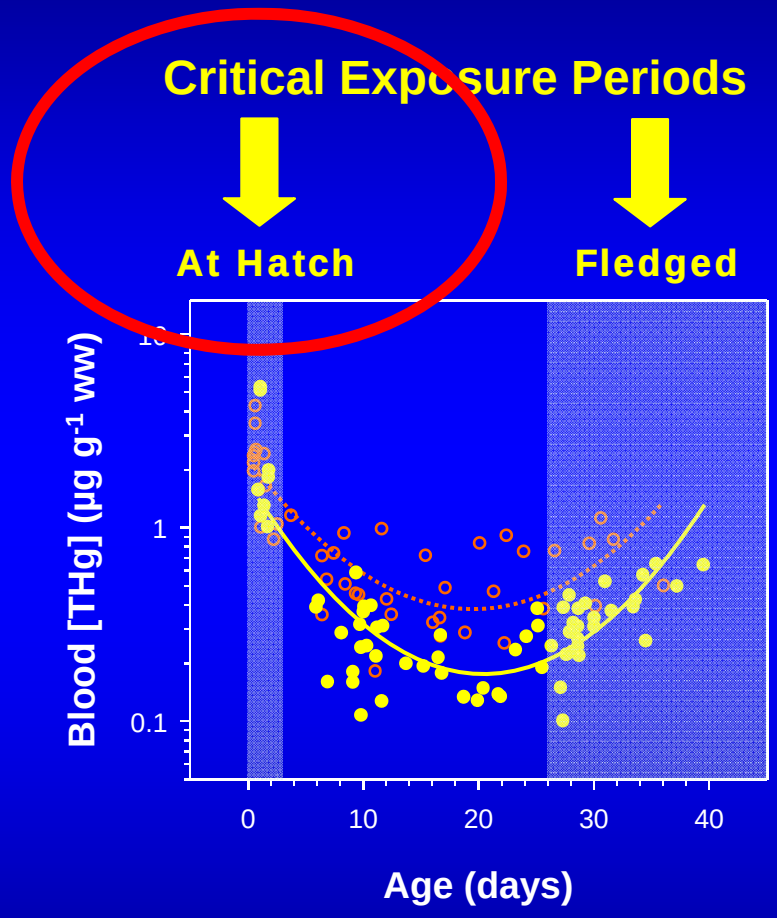
Mercury as Tern Chicks Age



Low Hg site N7

High Hg site A16

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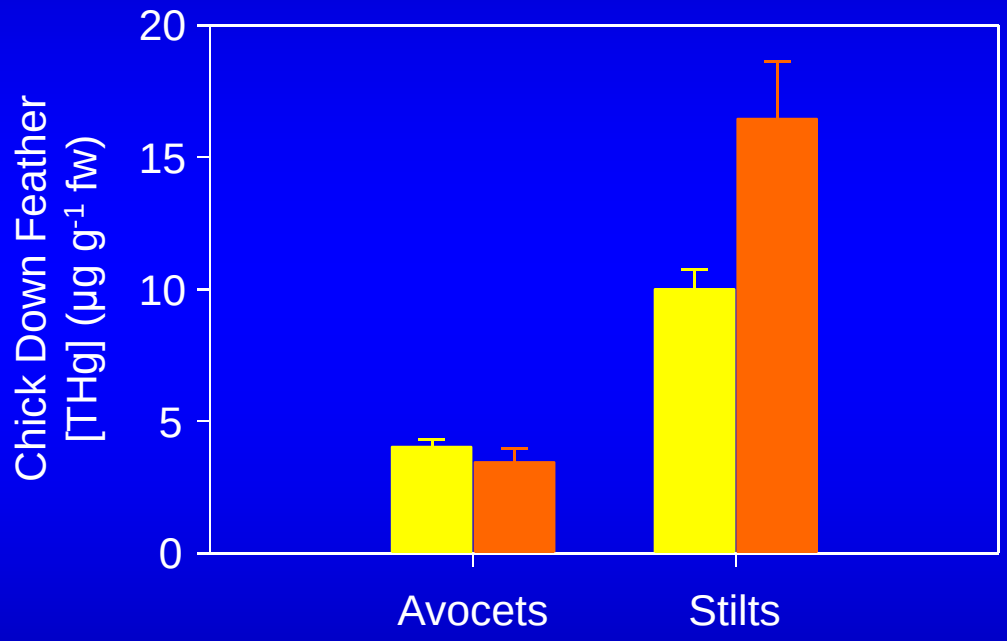
Effects of Mercury on Chick Mortality at Hatching



Newly Hatched

- Live chicks
- Dead chicks

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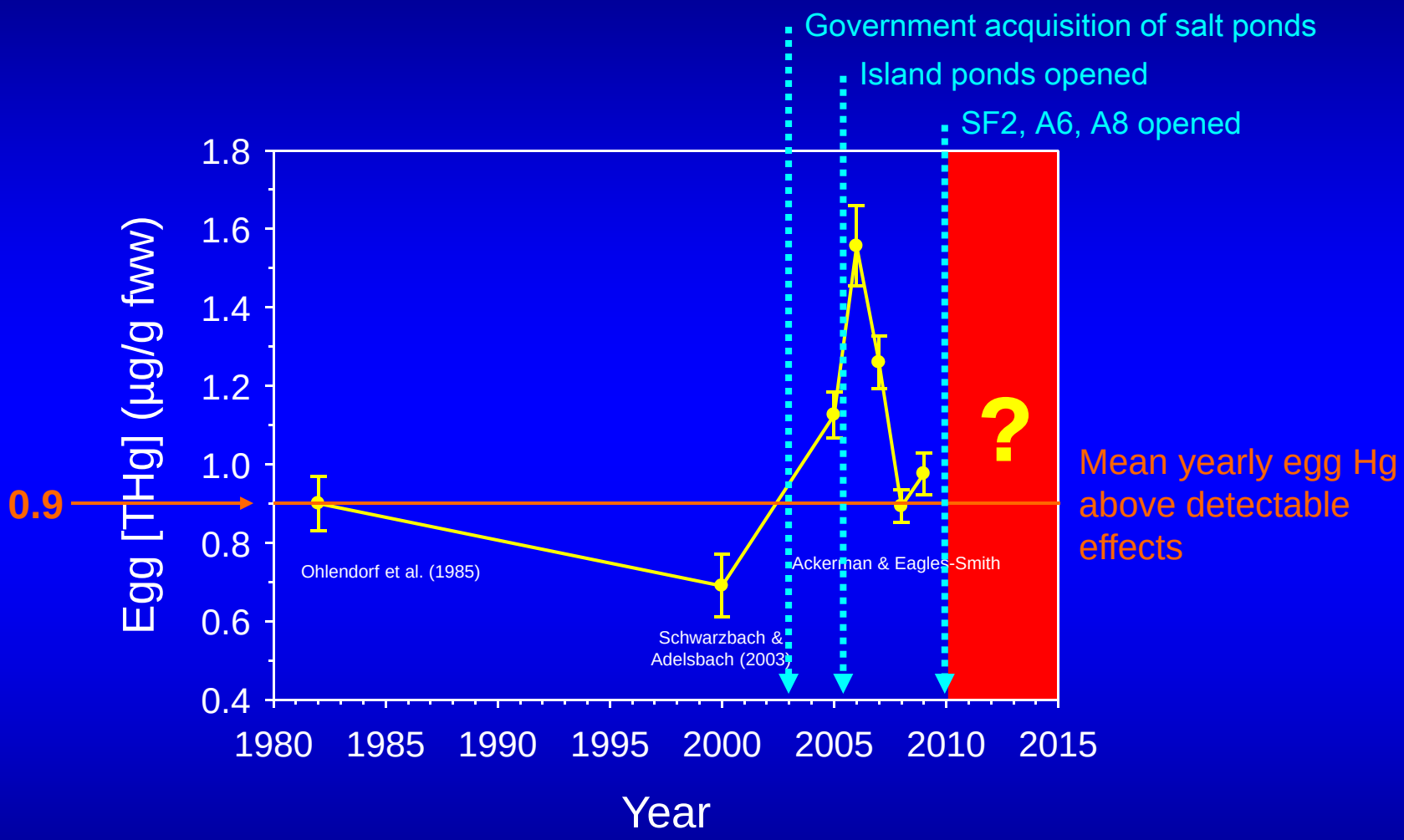
Ackerman et al., Ecotoxicology, 2008

Tern Egg Hg Over Time



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Conclusions

- SF Bay birds are at high risk to Hg
- Hg reduced hatching success, nest survival, and chick survival
- Seasonal wetlands and high salinity ponds have highest Hg in biota
- Recent egg Hg concentrations above toxicity threshold – natural variation or restoration induced?
- Continued monitoring of waterbird eggs warranted as Restoration Projects are implemented

Photo by Ken Phenicie

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Funding

- CALFED Ecosystem Restoration Program
- Regional Monitoring Program, Exposure & Effects Workgroup
- US Geological Survey

Support

- Don Edwards San Francisco Bay National Wildlife Refuge, Eden Landing Ecological Reserve, Napa-Sonoma Marshes Wildlife Area, USFWS, CDF&G, San Francisco Bay Bird Observatory, PRBO Conservation Sciences

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