Are environmental contaminant concentrations in U.S. waters harmful to fish-eating wildlife?

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Contaminant exposure pathways to consider for risk modeling

Media	Herbivore	Invertivore	Omnivore	Carnivore	Piscivore
Water	X	X	X	X	X
Sediment					X
Soil	X	X	X	X	
Plants	X		X		
Invertebrates		X	X		
Mammals			X	X	
Fish			X		X
Air	X	X	X	X	X

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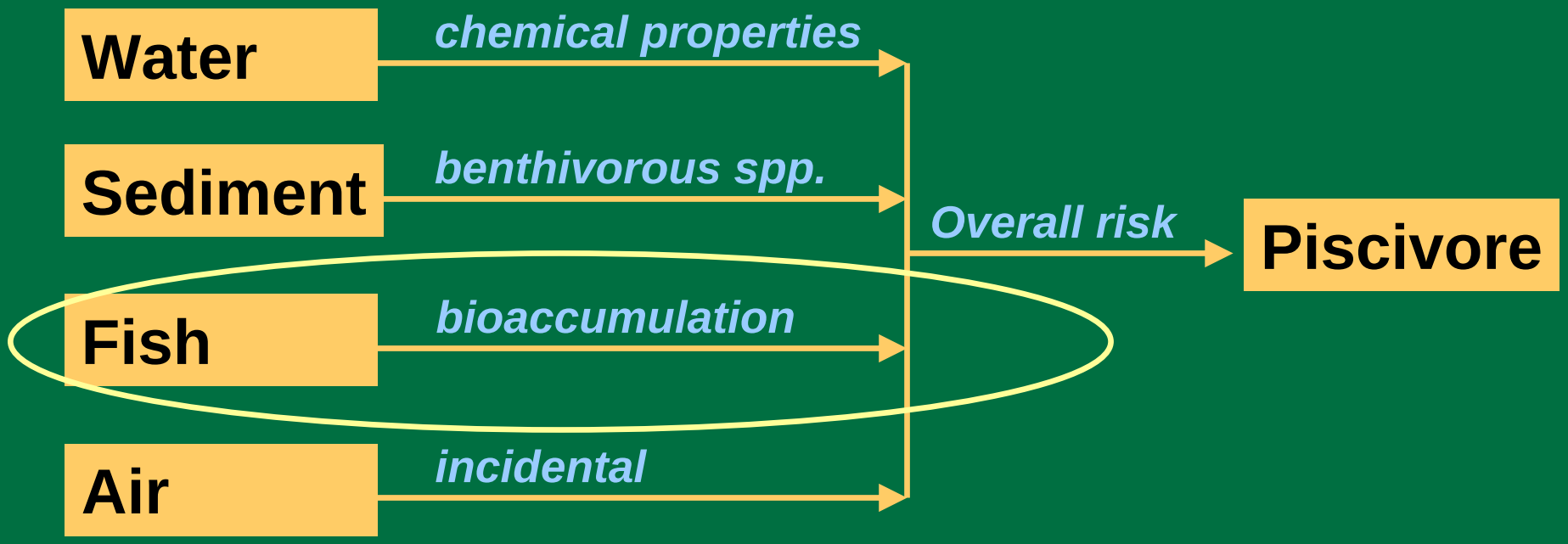
Risk model for piscivorous wildlife



Many studies have only water and sediment data and must calculate contaminant concentrations in fish using bioaccumulation factors

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Large River Monitoring Network (LRMN) of the Biomonitoring of Environmental Status and Trends (BEST) Program

Contaminants: Organochlorine pesticides, PCBs, metals

Fish Health Indicators: Somatic indices, necropsy, general histopathology

Reproductive Biomarkers: Gonad histopathology, vitellogenin, steroid hormones

Carnivore: Largemouth Bass

Benthivore: Common carp

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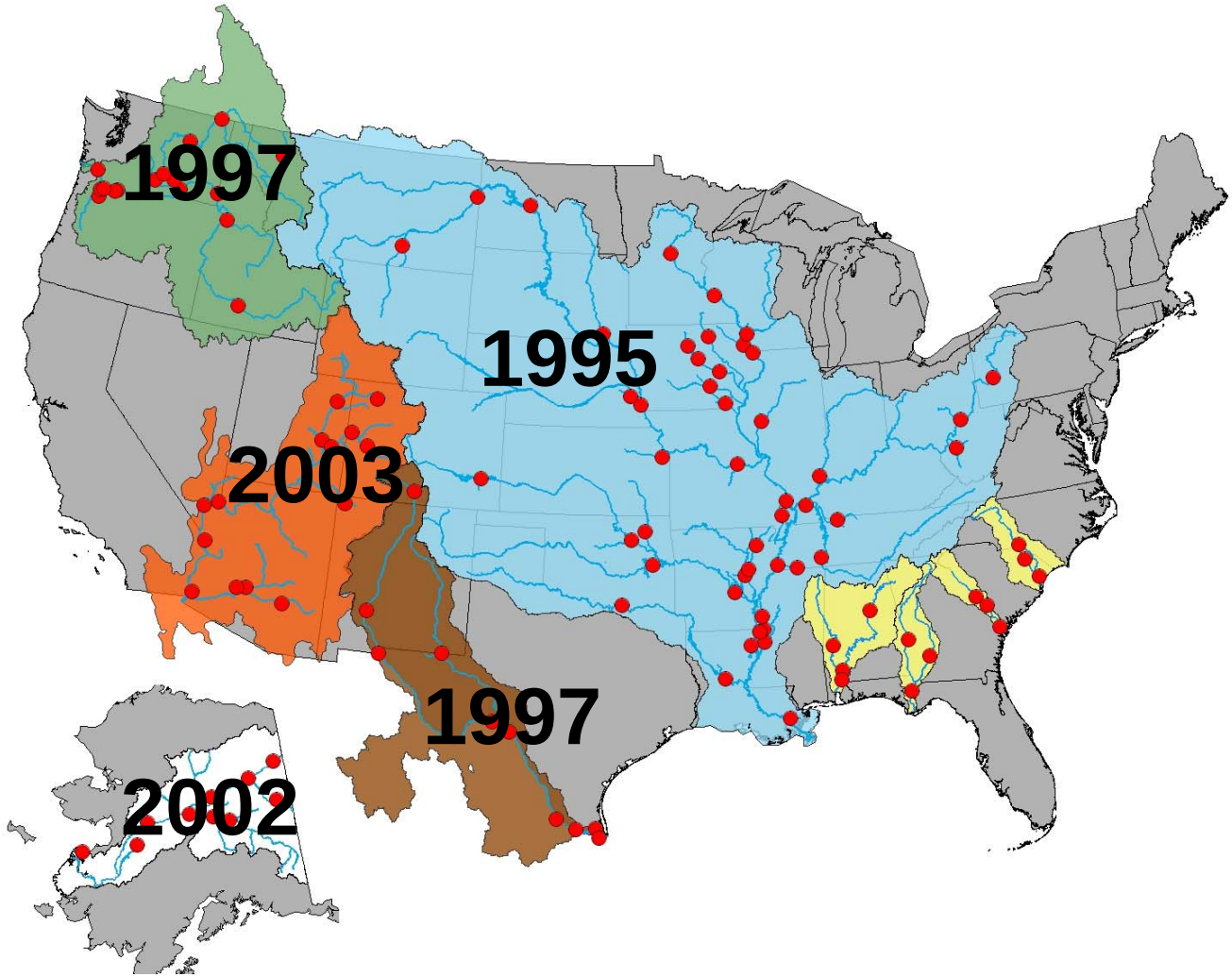
LRMN Dataset

Basins: 5
Sites: 97
Individual fish: 3040
Whole body composite samples: 357



Could chemical contaminants in U.S. waters be harmful to fish-eating wildlife?

Measured contaminant concentrations from LRMN

Toxicity reference values

Piscivorous species of varying sizes

Screen for risk to piscivorous wildlife

Identify areas with high risk

Site-specific studies

Confirm with wildlife studies

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Piscivorous wildlife models

Birds

Belted kingfisher

Osprey

Bald eagle

Mammals

Mink

River otter

Represent various size classes of wildlife
Diet considered the only route of exposure
Assume 100% of diet is fish

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Screening for Risk

$$\frac{\text{No adverse effects level (mg/kg/d)} \times \text{Body weight (kg)}}{\text{Food ingestion rate (kg/kg/d)}} = \text{No effects hazard concentration } (\mu g/g)$$

- The NOAEL for individual contaminants are from Sample et al. 1996
- Body weight and food ingestion rate for each wildlife model (e.g. osprey) are from USEPA Wildlife Exposure Handbook (1993)

If measured concentration is greater than the no effects hazard concentration (NEHC), then piscivorous wildlife may be at risk

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Percent of samples (*n* = 357) exceeding NEHC

Elemental contaminant	Birds			Mammals	
	BK	O	BE	M	RO
Aluminum	30	0	0	68	24
Arsenic	0.6	0	0	0.6	0
Barium	7	0	0	0.6	0
Beryllium	NA	NA	NA	0	0
Cadmium	0.8	0	0	0	0
Chromium	91	6	0.8	2	0.6
Copper	0	0	0	0	0
Iron	62	0	0	3	0
Mercury	100	90	12	20	0
Magnesium	NA	NA	NA	NA	NA
Manganese	0	0	0	0	0
Molybdenum	NA	NA	NA	NA	NA
Nickel	0	0	0	0	0
Lead	4	0	0	0	0
Selenium	98	1.1	0	13	0.6
Strontium	NA	NA	NA	NA	NA
Vanadium	0	0	0	0	0
Zinc	100	1.1	0	0	0

Organochlorine contaminant	Birds			Mammals	
	BK	O	BE	M	RO
p,p'-DDD	87	11	3	0	0
p,p'-DDE	92	43	14	0.8	0
p,p'-DDT	82	2	0	0	0
o,p'-DDD	80	2	0	0	0
o,p'-DDE	79	0	0	0	0
o,p'-DDT	80	2	0	0	0
BHC (α, β, γ, δ)	0	0	0	0	0
cis-chlordane	0	0	0	0	0
trans-chlordane	0	0	0	0	0
cis-nonachlor	NA	NA	NA	NA	NA
trans-nonachlor	NA	NA	NA	NA	NA
Oxychlordane	NA	NA	NA	NA	NA
Heptachlor epoxide	NA	NA	NA	NA	NA
Dieldrin	14	0	0	1.1	0
Endrin	82	2	0.6	0.3	0
Mirex	NA	NA	NA	NA	NA
HCB	NA	NA	NA	NA	NA
Toxaphene	NA	NA	NA	0	0
Total PCBs*	46	3	0	16	3

NA = no NOAEL available
* NOAEL for total PCBs unavailable; computed using NOAEL for Aroclor 1260

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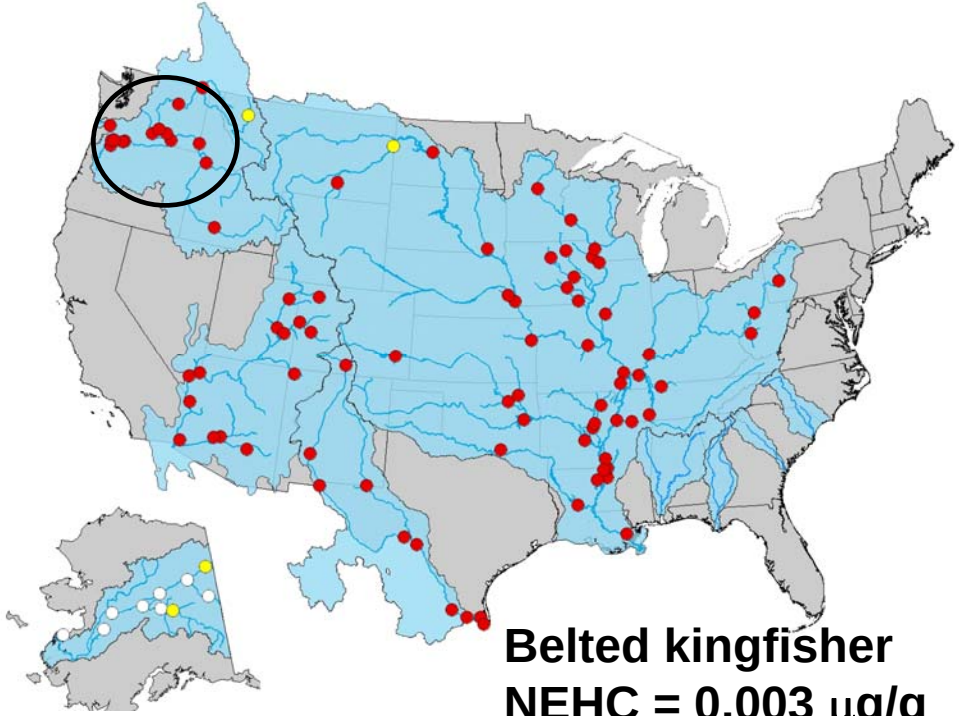
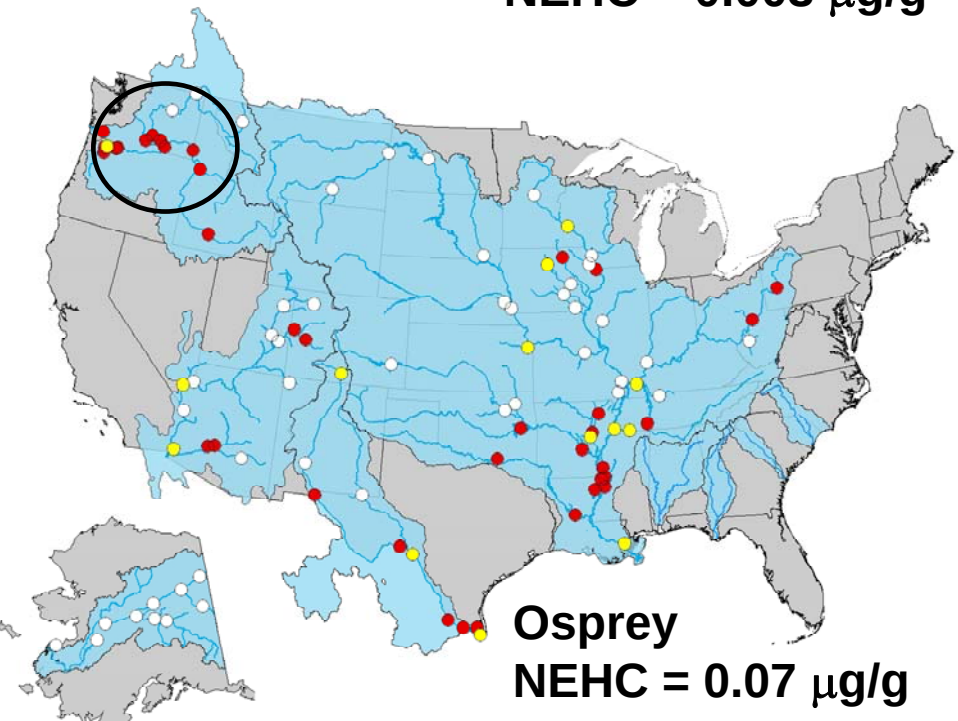
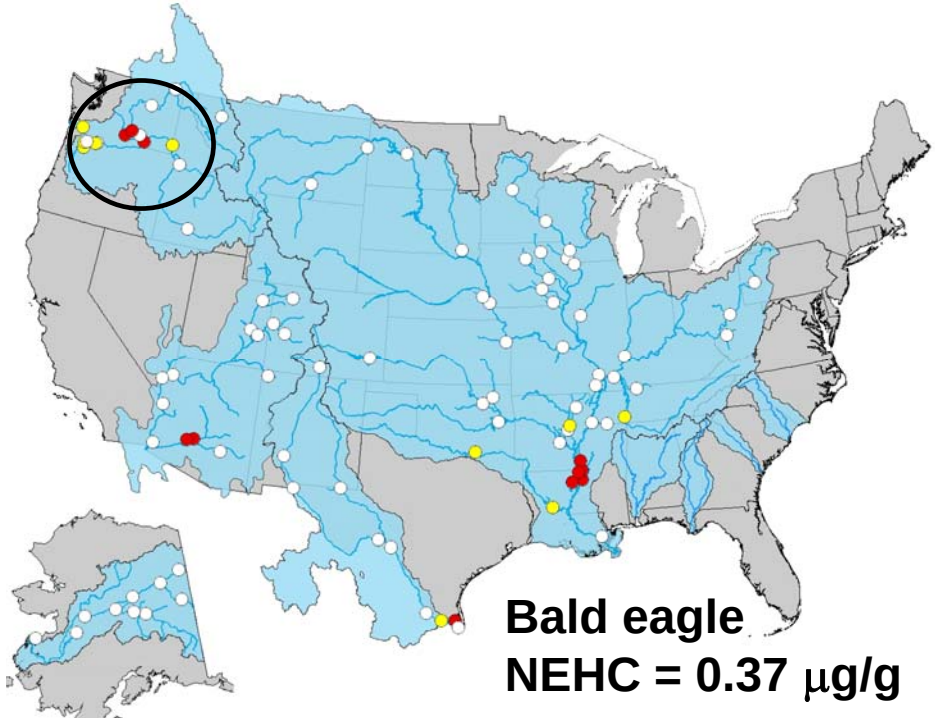
p,p'-DDE concentrations potentially hazardous to fish-eating birds



- <NEHC
- 1-2x NEHC
- >2x NEHC





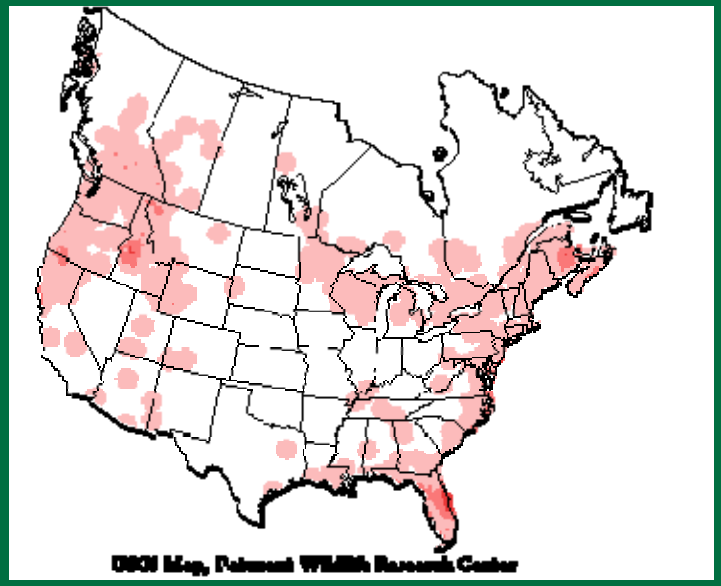
p,p'-DDE in the Lower Columbia River: Effects in osprey

Photo from www.fredmiranda.com

- Historically high concentrations in this region (e.g. orchards)
- Osprey studied since the 1970s; diet of largescale sucker
- Successful hatching decreased as concentrations increased
- >18% eggshell thinning can cause decrease in raptor populations

DDE in osprey eggs	Shell thinning (%)
<4.2 μg/g	3.4%
4.2-8.0 μg/g	12.7%
>8.0 μg/g	>17%

From Henny et al. 2004



Map of osprey breeding range in US

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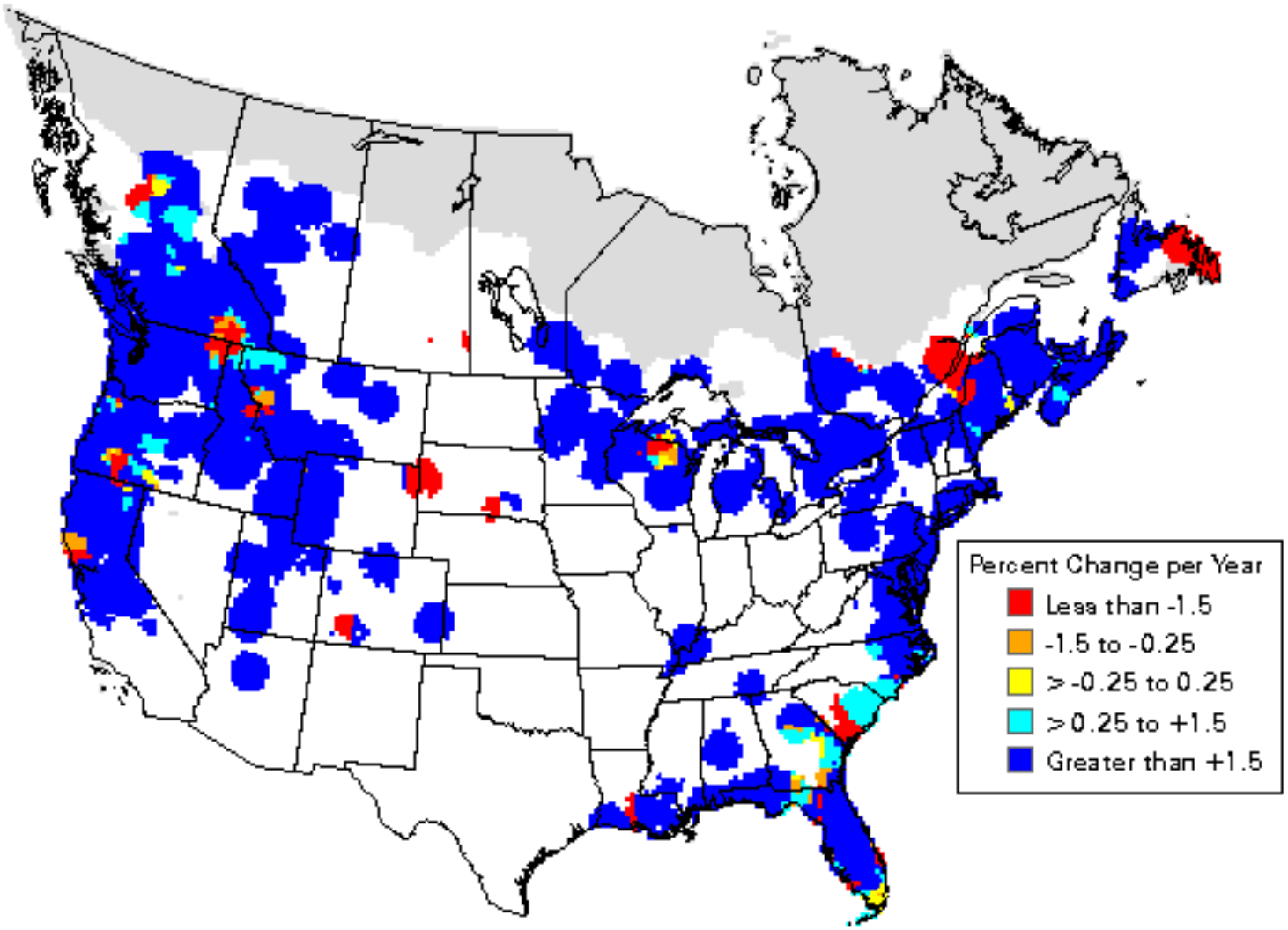
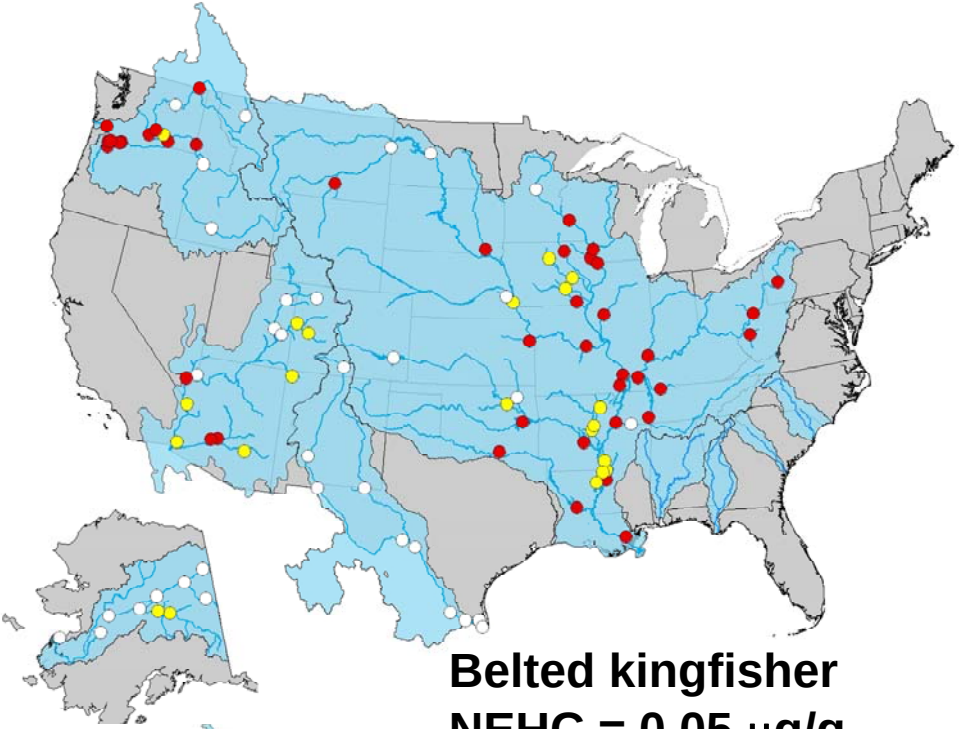
Osprey populations in the Columbia River Basin are not declining



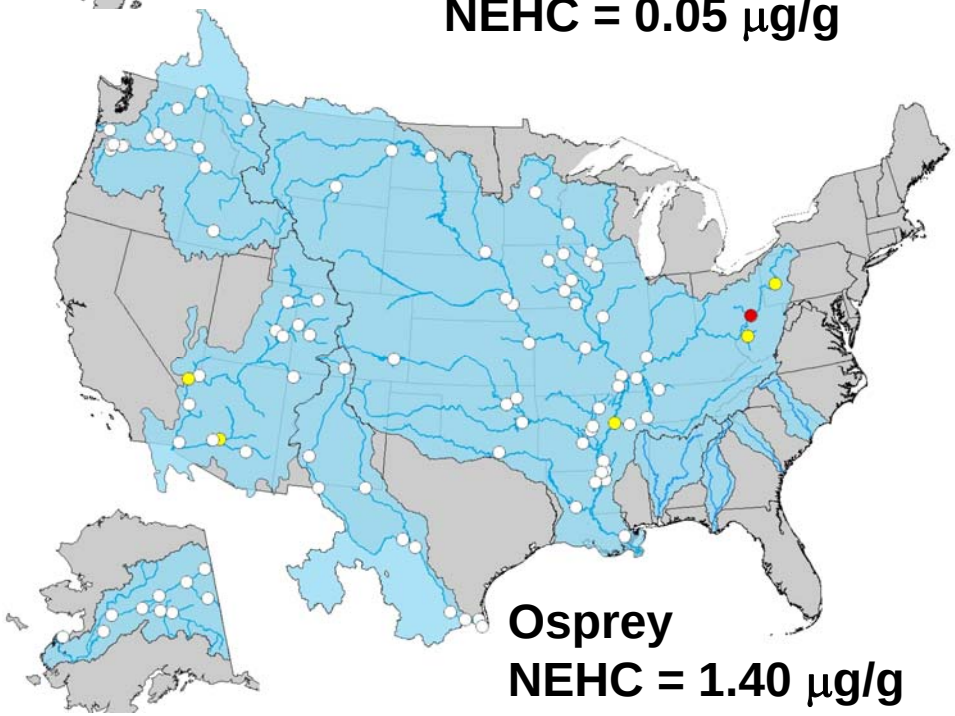
Osprey distribution map from the Breeding Bird Survey (1966-2003)

Total PCB concentrations potentially hazardous to fish-eating birds

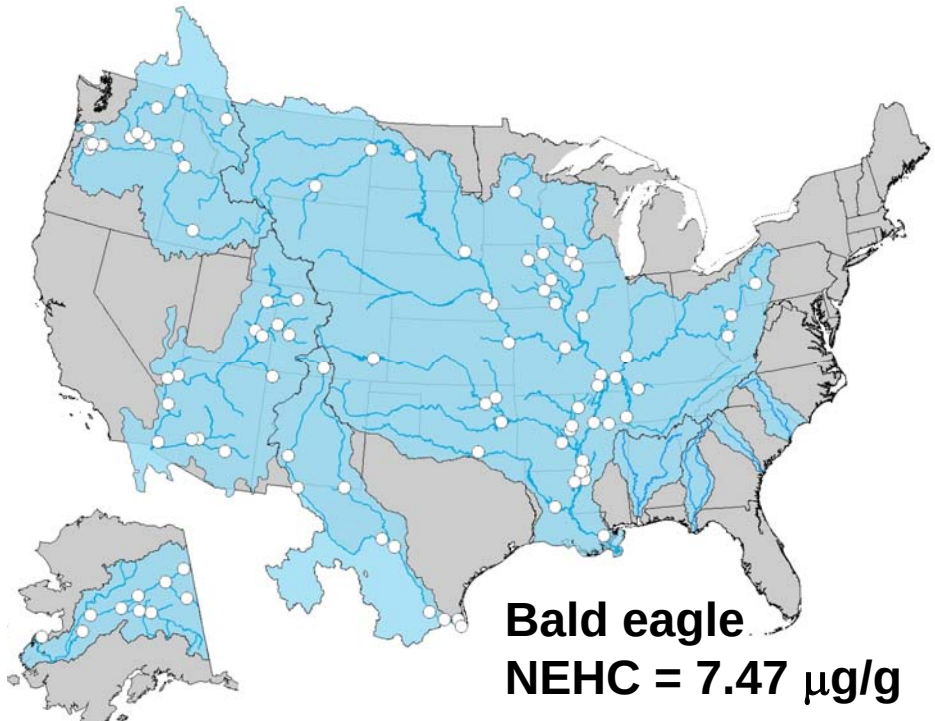


Belted kingfisher
NEHC = 0.05 μg/g

- <NEHC
- 1-2x NEHC
- >2x NEHC

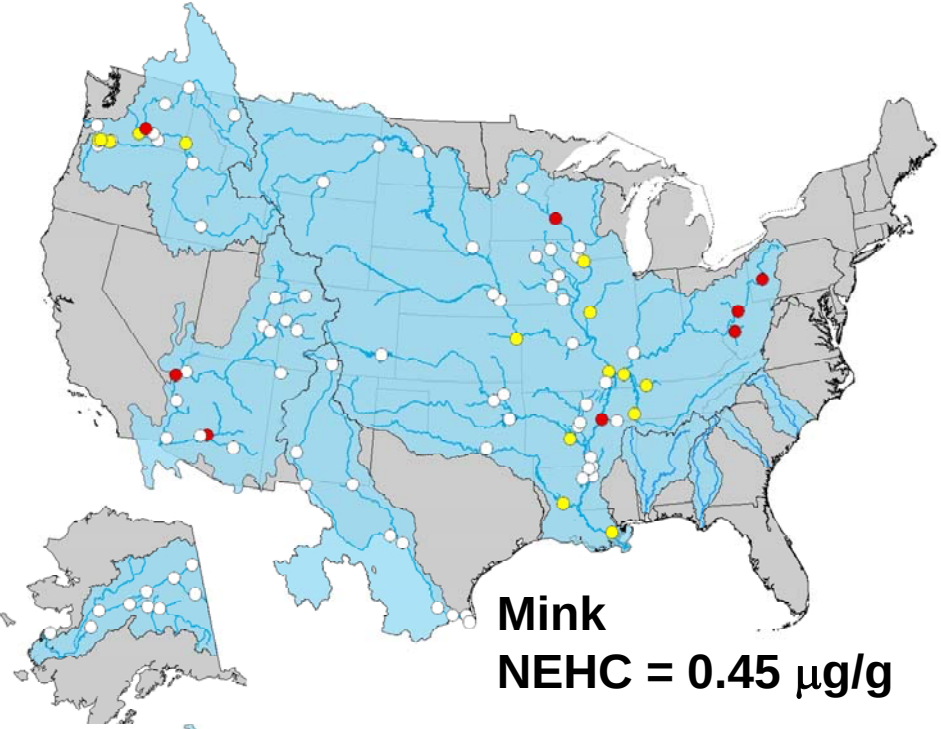


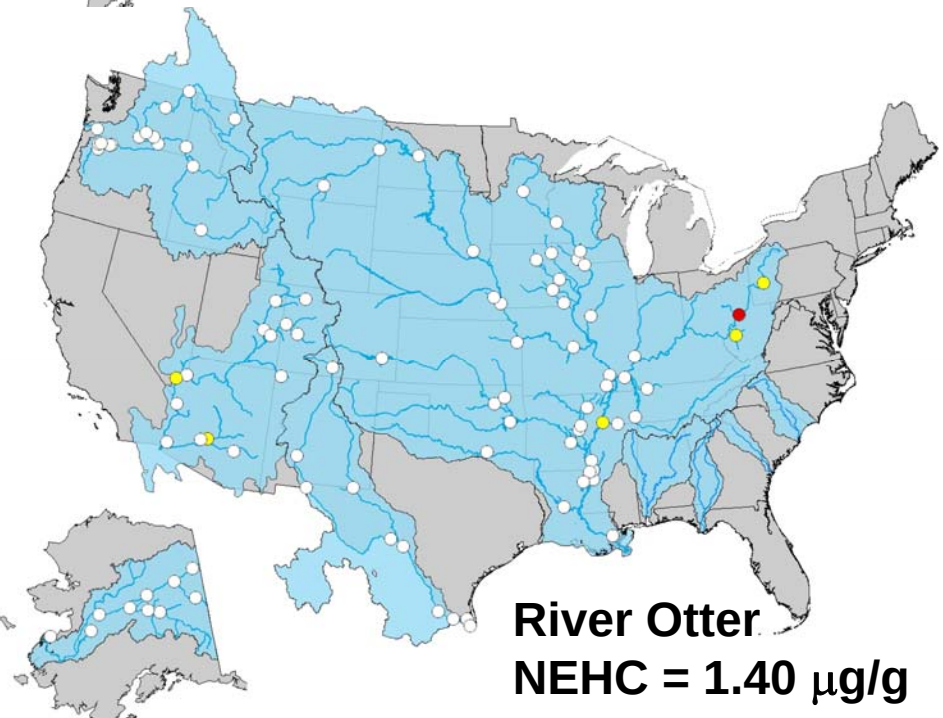
Osprey
NEHC = 1.40 μg/g



Bald eagle
NEHC = 7.47 μg/g

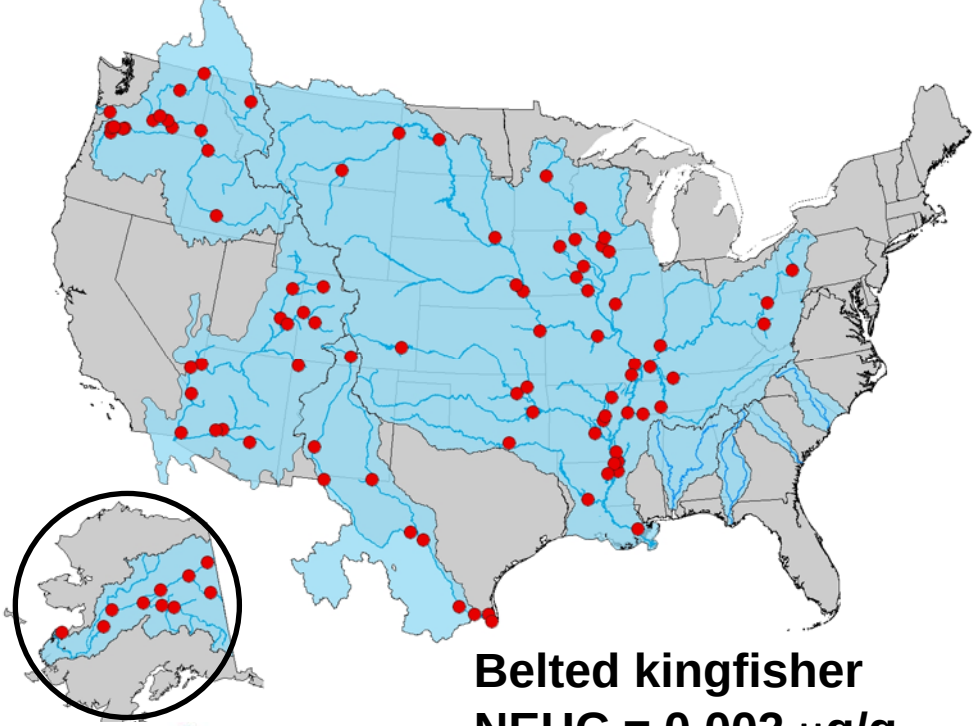
Total PCB concentrations potentially hazardous to fish-eating mammals





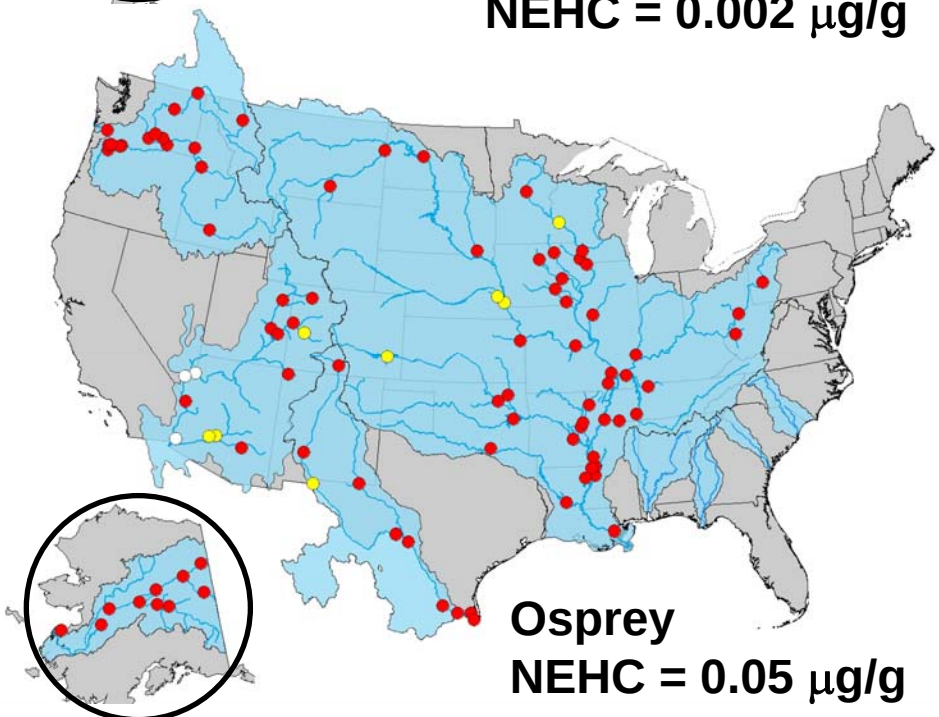
- <NEHC
- 1-2x NEHC
- >2x NEHC

Mercury concentrations potentially hazardous to fish-eating birds

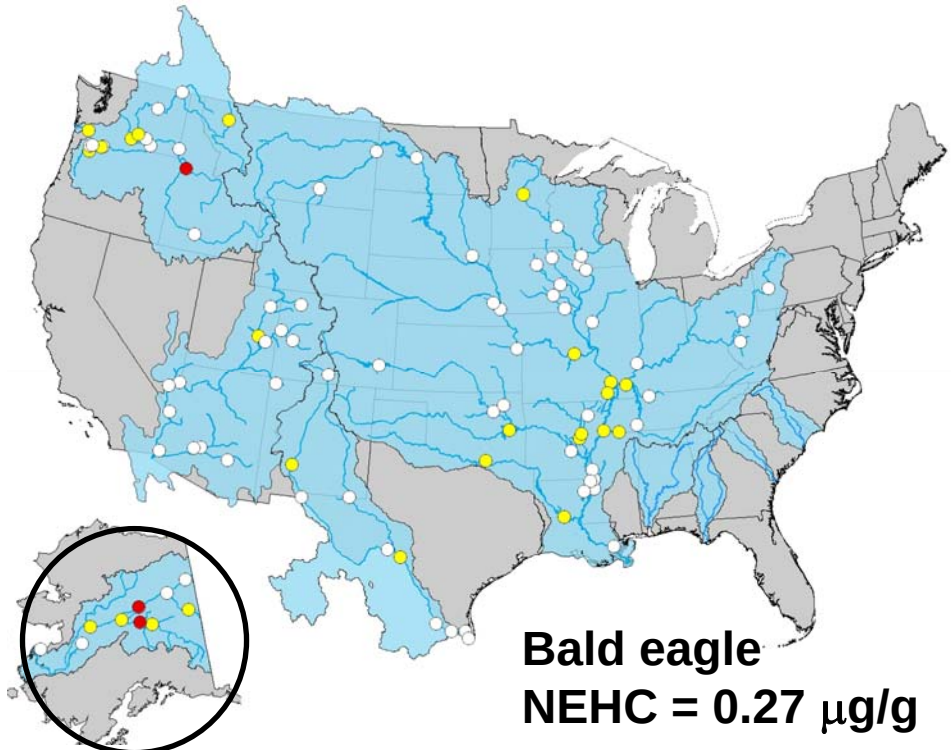


Belted kingfisher
NEHC = 0.002 μg/g

- <NEHC
- 1-2x NEHC
- >2x NEHC



Osprey
NEHC = 0.05 μg/g



Bald eagle
NEHC = 0.27 μg/g

Are top predators at risk from Hg in Alaska?

Photo by T. Swem/USFWS

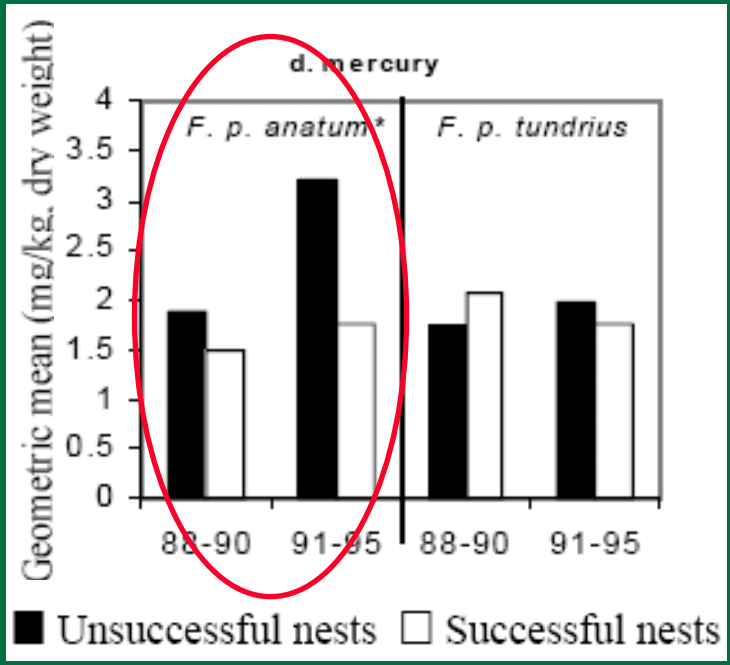
American Peregrine falcon eggs in Alaska

Year	Mean Hg concentration (mg/kg ww)	# (%) exceeding effects threshold (0.5 mg/kg)*
1988-1990	0.328	3/22 (13%)
1991-1995	0.526	10/33 (30%)

From Ambrose et al. 2002

* Peakall et al. 1990

- Yukon basin is an important breeding area for the American peregrine falcon
- Eggs from unsuccessful nests have > Hg conc.
- Concentrations increased in the 1990s and > in Yukon basin than other Alaskan basins
- Hg cycle poorly understood in the arctic and subarctic



From Ambrose et al. 2002

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Conclusion of Screening Risk Analysis

Belted kingfishers would not be found in the US due to risk from contaminants

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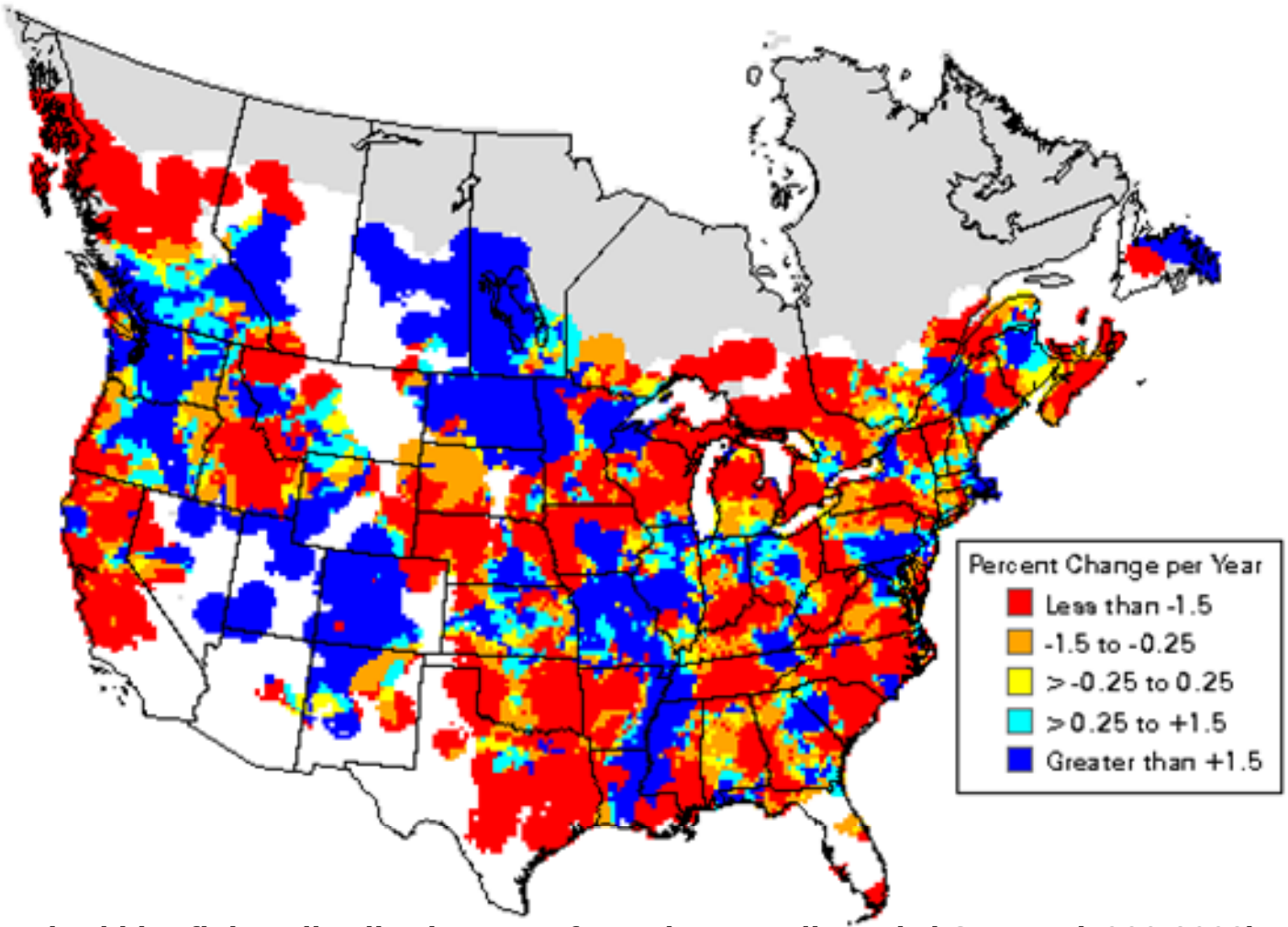
Belted kingfisher populations have decreased in some regions



Belted kingfisher distribution map from the Breeding Bird Survey (1966-2003)

Conclusion of Screening Risk Analysis

Belted kingfishers represent a size class of birds that may be at greater risk from contaminants

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Risk to nestlings of large birds

Nestling eagles rely on parents to provide food

- **fish comprise 85% of nestling diet in some areas**
- **eat up to 2 pounds of fish per day**

Eagles are opportunistic and scavenge on dead or dying prey such as:

- **dead salmon from migratory spawning**
- **fish kills from summer oxygen depletion, toxic spills**

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Examples of other tools to refine our risk model

Breeding Bird Survey:
http://www.mbr-pwrc.usgs.gov/bbs/bbs.html

Birds in Agricultural Areas:
www.abcbirds.org/biaa/

Avian Incident Monitoring System:
www.abcbirds.org/aims/index.cfm

Environmental Mercury Mapping, Modeling, & Analysis:
http://emmma.usgs.gov/default.aspx

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Summary

- Risk from contaminants to piscivorous wildlife can be screened by calculating hazard concentrations
- Increases the utility of monitoring data (including water and sediment data)
- Highlight high risk areas to direct further investigations
- Refine models to more precisely assess risk at specific locations or to piscivorous wildlife
- Must consider risk to young of larger piscivorous wildlife

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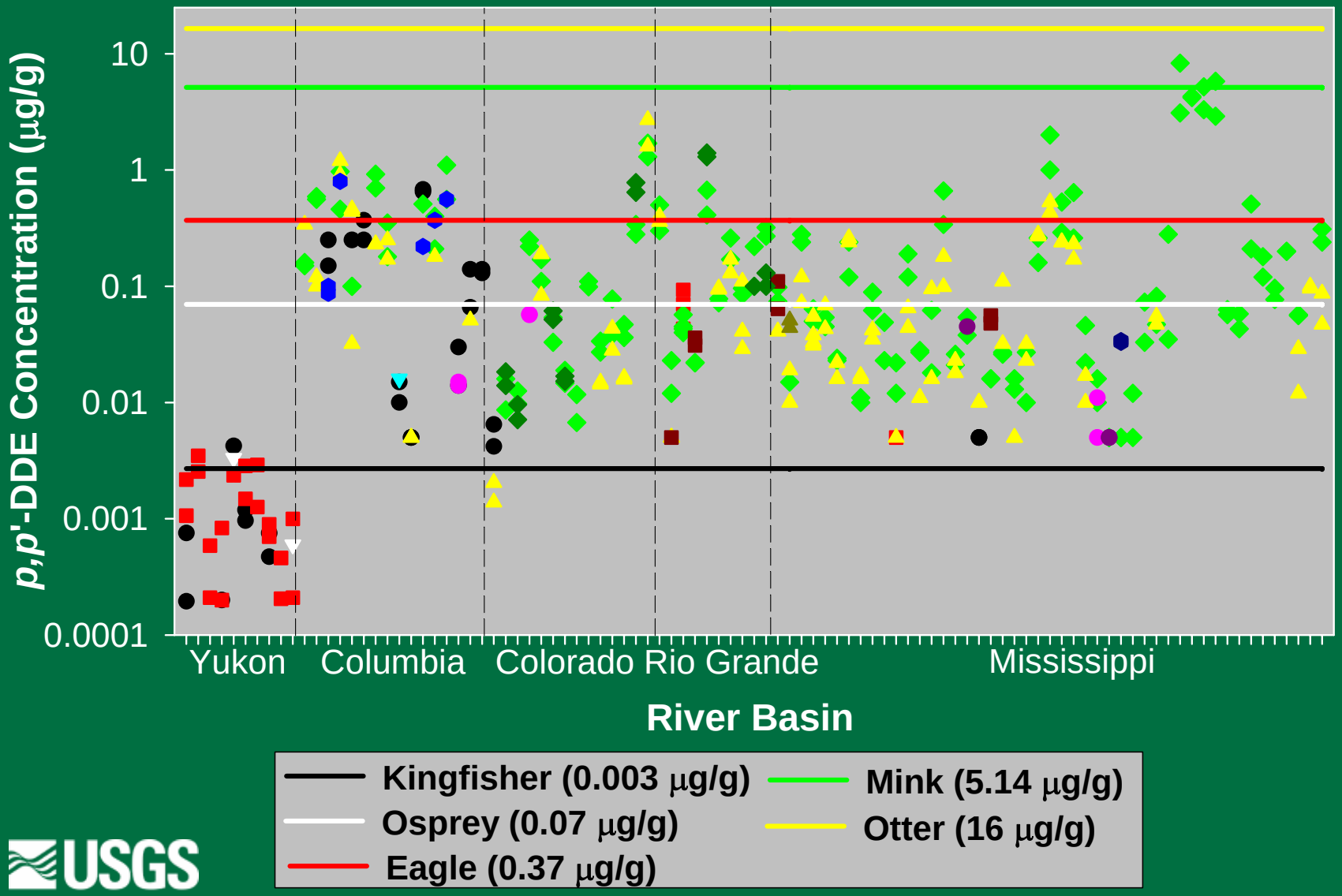
p,p'-DDE concentrations exceeding NEHC for piscivorous wildlife



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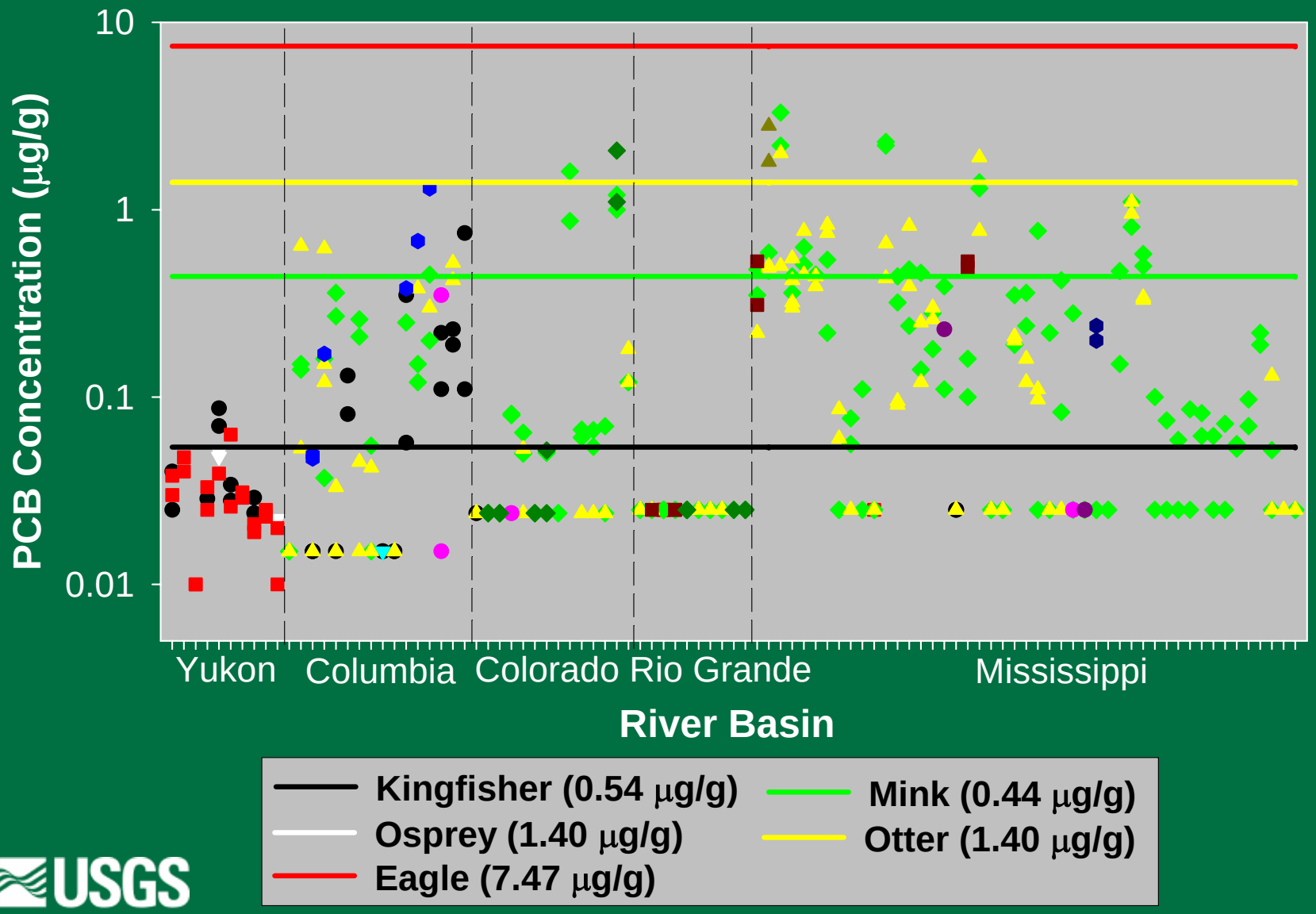
Total PCB concentrations exceeding NEHC for piscivorous wildlife



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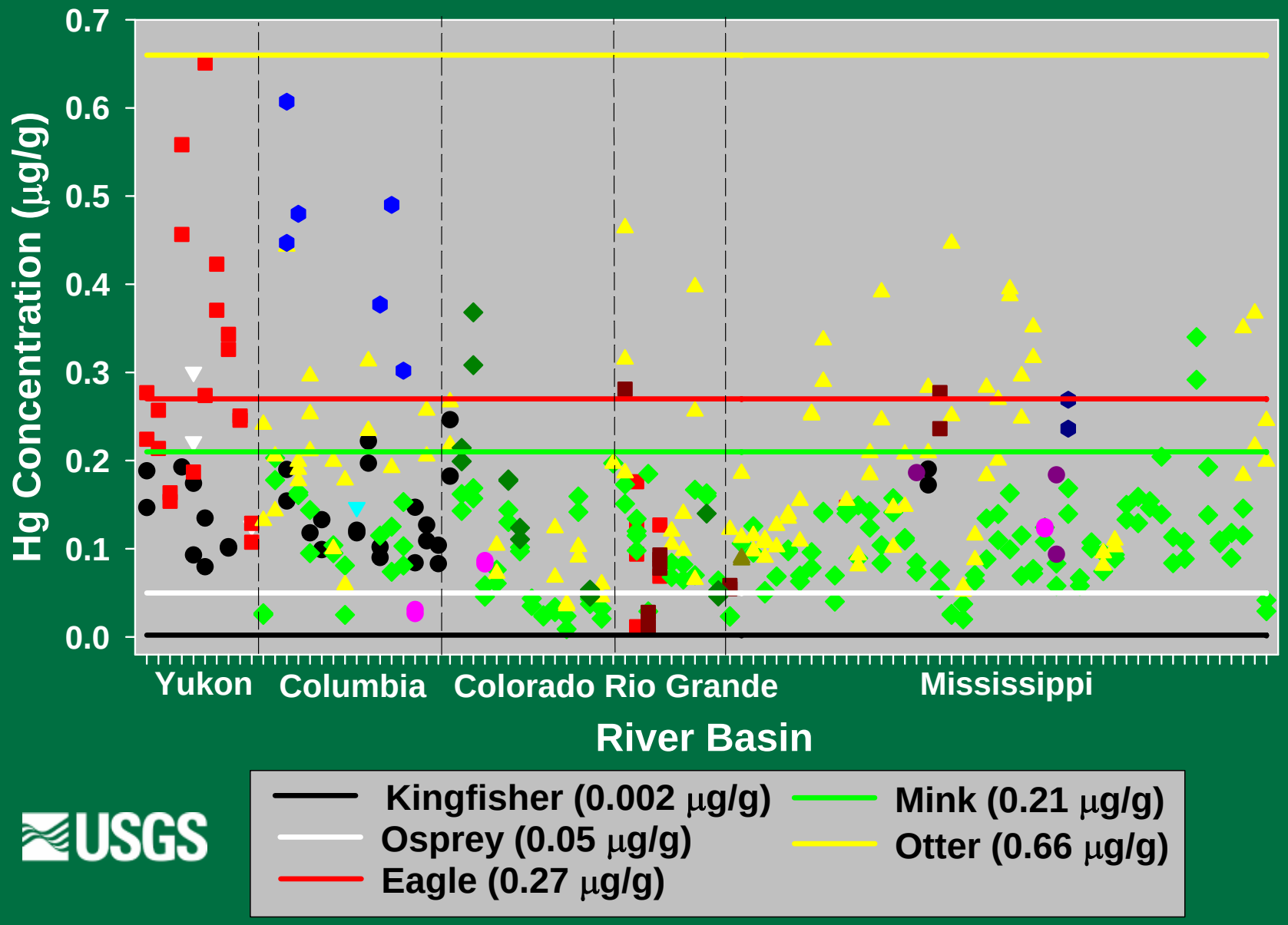
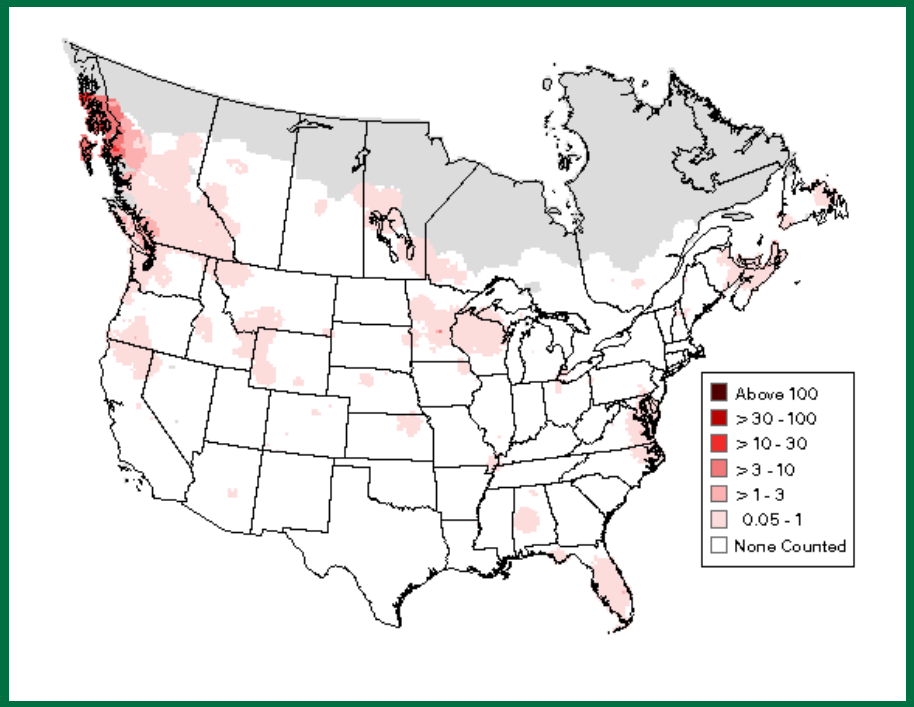
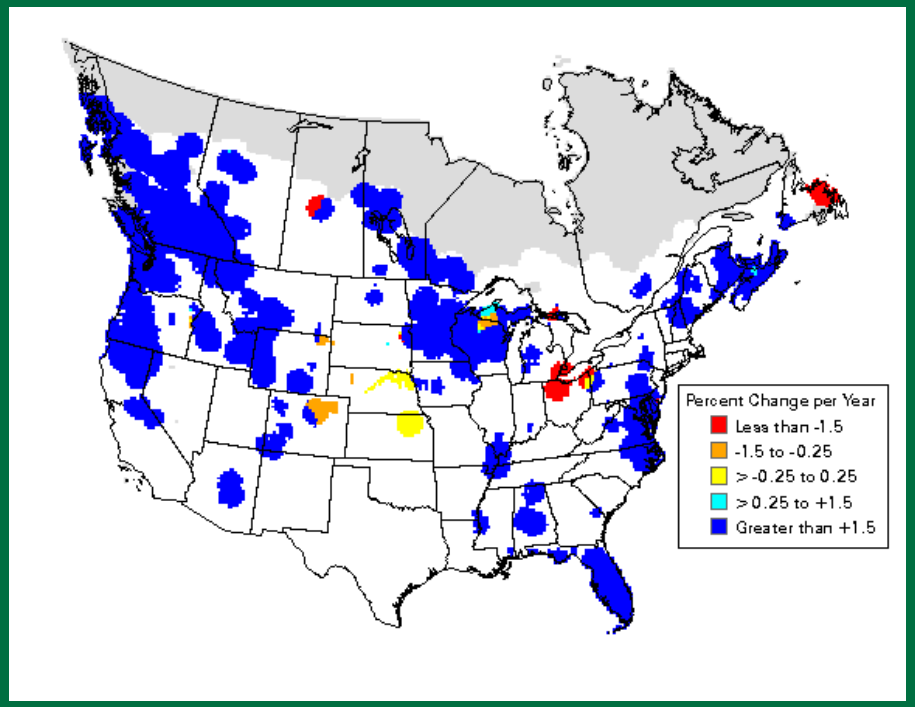
Mercury concentrations exceeding NEHC for piscivorous wildlife



Bald eagle summer distribution (1994-2003) and trend (1966-2003)





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