Developmental Stability in Amphibians as a Biological Indicator of Chemical Contamination and Other Environmental Stressors

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Amphibians

Amphi- means **‘dual’** or **‘on both sides’**;

-bian is from bios, meaning **life**.

Amphibian thus refers to the dual life cycle of most amphibians, called a **complex life cycle**.

Why should we care about amphibians?

- Integral parts of many ecosystems
  - Cascading effects?
- Warning signals of environmental health
  - Complex life cycles = double jeopardy
  - Permeable membranes
- Moral/ethical arguments


Industrial Pollution

Agricultural Pollution

Amphibian Deformities

Pollutants, UV-B, or Parasites?

How can we assess threatened amphibian populations before declines or deformities take place?

Developmental Stability

Developmental Stability (DS)

- DS is one component of an organism's ability to withstand environmental and genetic disturbances during development.
- Previously used as a stress indicator in numerous species.
- Few studies have compared DS in amphibians, particularly in regard to stress.

Asymmetry in Bilateral Organisms

Population Asymmetry (PA) can be used to evaluate DS

- PA is population-level differences between the left and right sides of paired bilateral characters.
- Populations that are more developmentally stable have lower population asymmetry.
- Environmental stressors lead to decreased DS and thus greater PA.

Research Questions

- Is amphibian PA correlated with anthropogenic (contaminant levels, land use, water chemistry) or natural (density) stressors?
- Is PA applicable across amphibian species and life history stages?

Study Species

Species	Larval habitat	Adult habitat	Breeding habitat
Bullfrog	Aquatic	Semi-terrestrial	Aquatic
Leopard frog	Aquatic	Semi-terrestrial	Aquatic
Eastern newt	Aquatic	Aquatic	Aquatic
Spotted Salamander	Aquatic	Terrestrial	Aquatic
Slimy Salamander	Terrestrial	Terrestrial	Terrestrial

Study Organisms

Rana catesbeiana (bullfrog) tadpoles.

Notophthalmus viridescens

(Eastern newt) males.

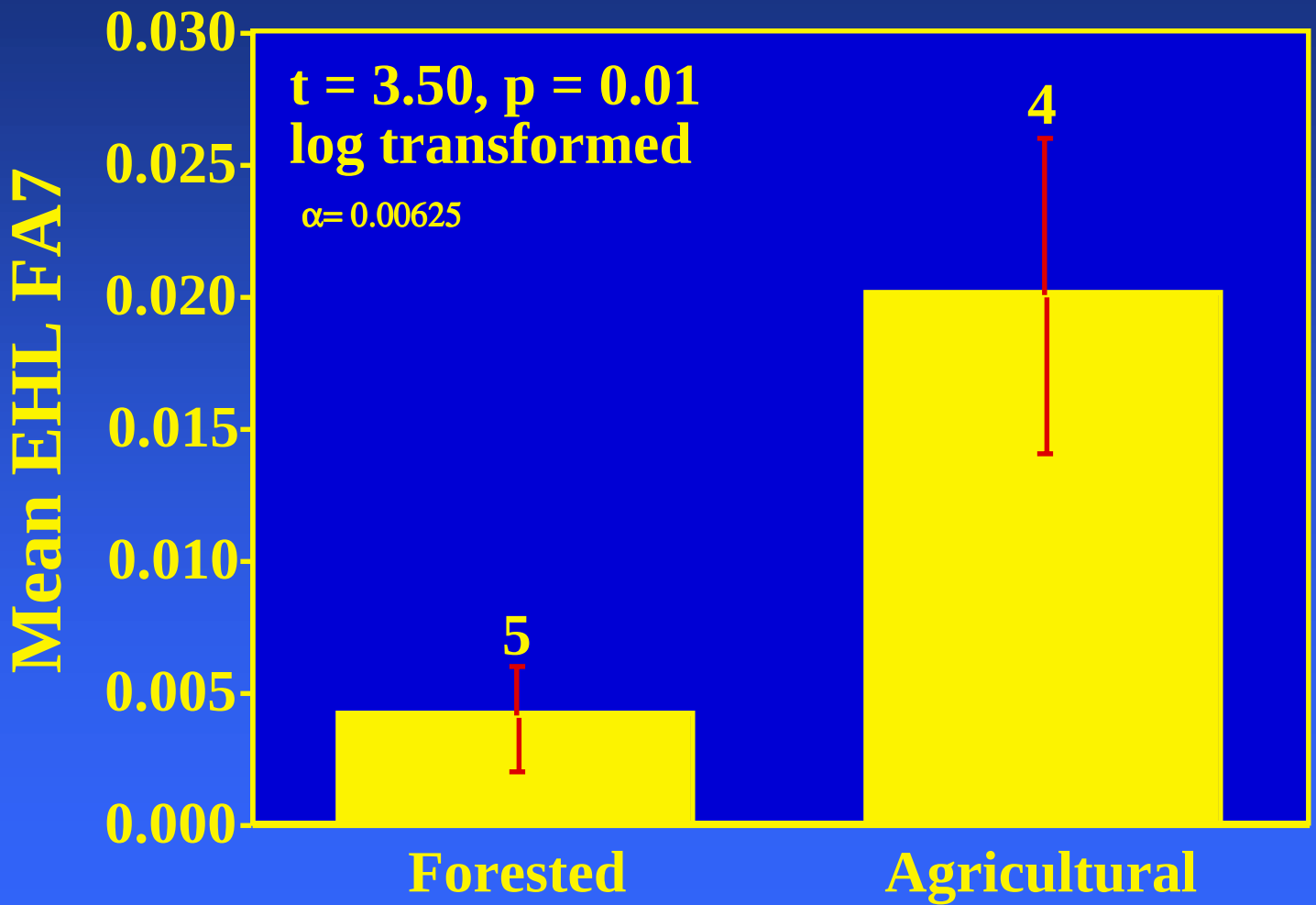
Ambystoma maculatum

(spotted salamander) males.

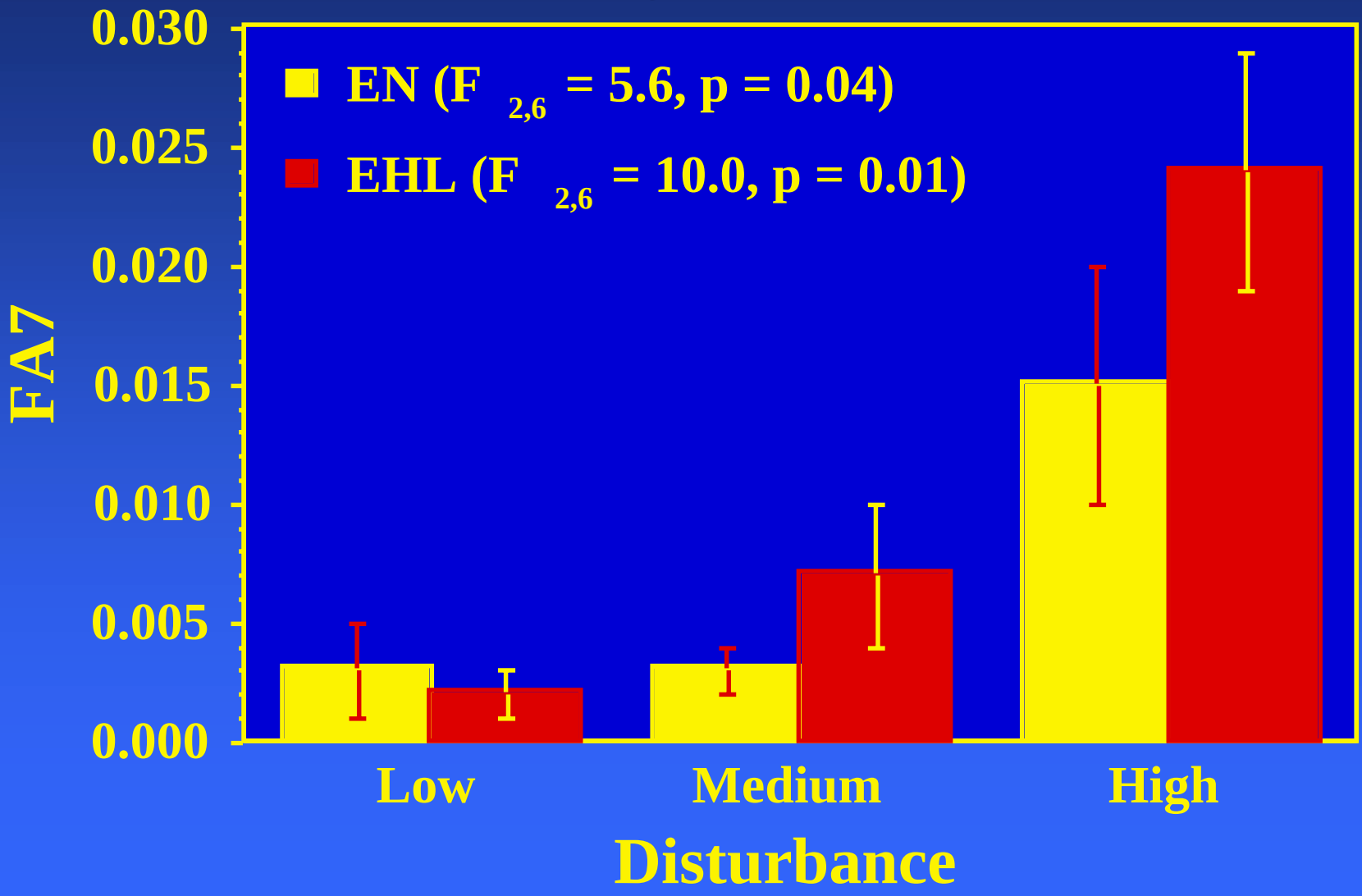

IN
ILLINOIS
MO
KENTUCKY
TENNESSEE
AK
Ohio River
Metropolis
Cumberland R.
Barkley Dam
Tennessee R.
Paducah
Cairo
Calvert City
Wickliffe
Kentucky Dam
Land Between The Lakes
KENTUCKY LAKE
BARKLEY LAKE
Mississippi River
10 0 10 20
Scale of km
Murray
Kentucky
Tennessee


THIS

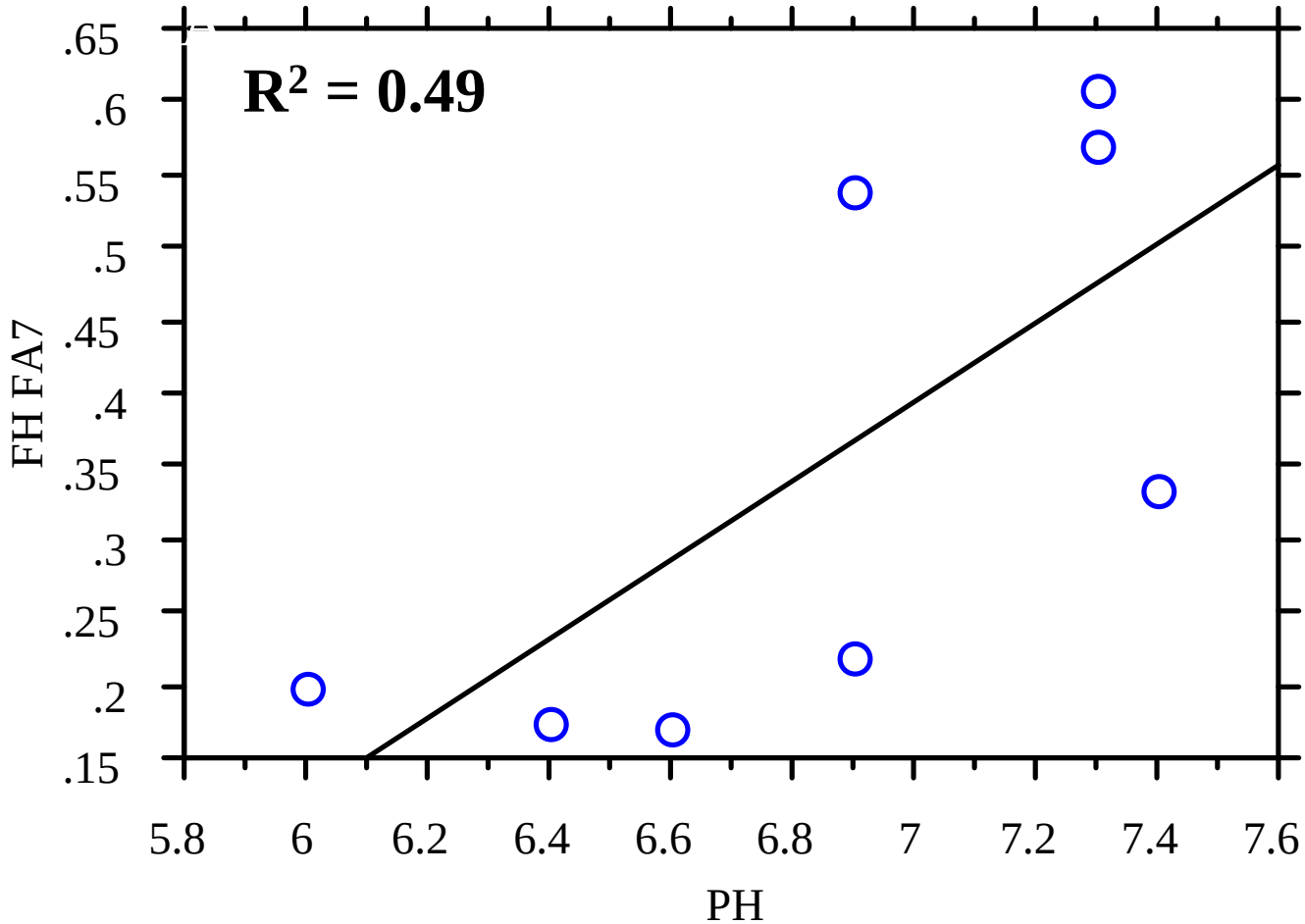
Tadpole asymmetry was greater in agricultural than forested sites.

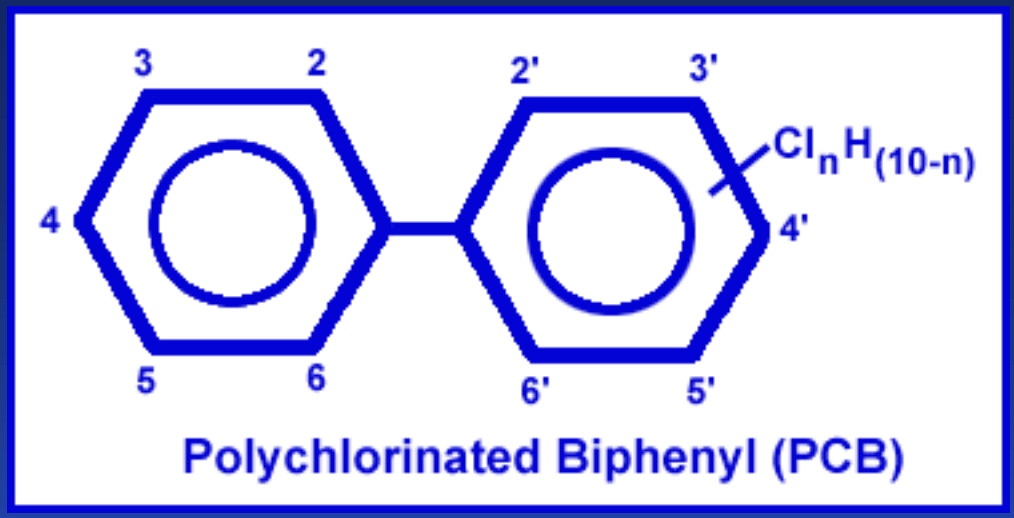


Tadpole asymmetry increased with anthropogenic disturbance.



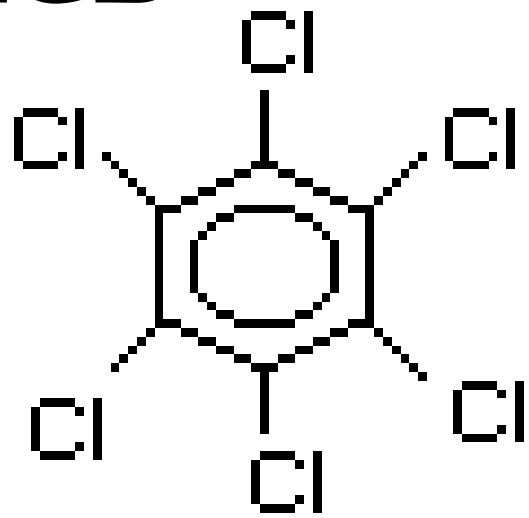
Male newt asymmetry increased with pH.

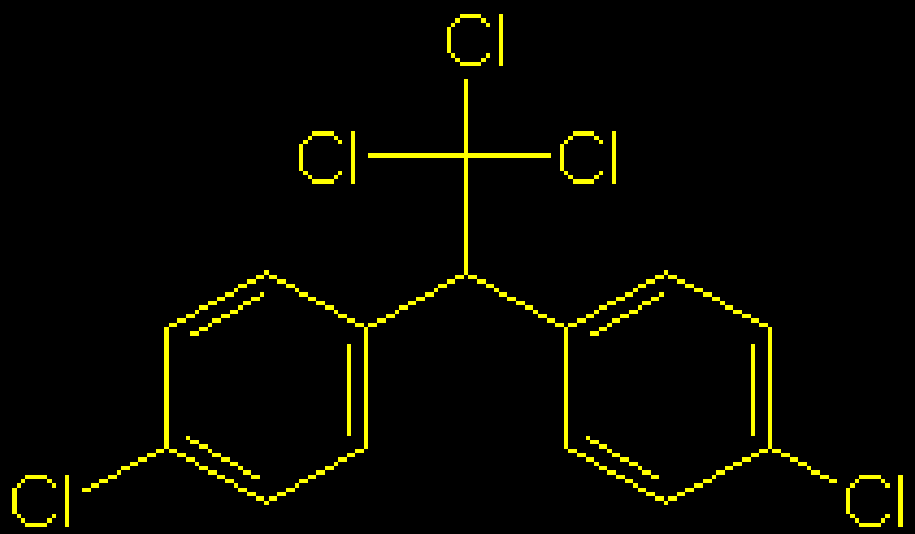




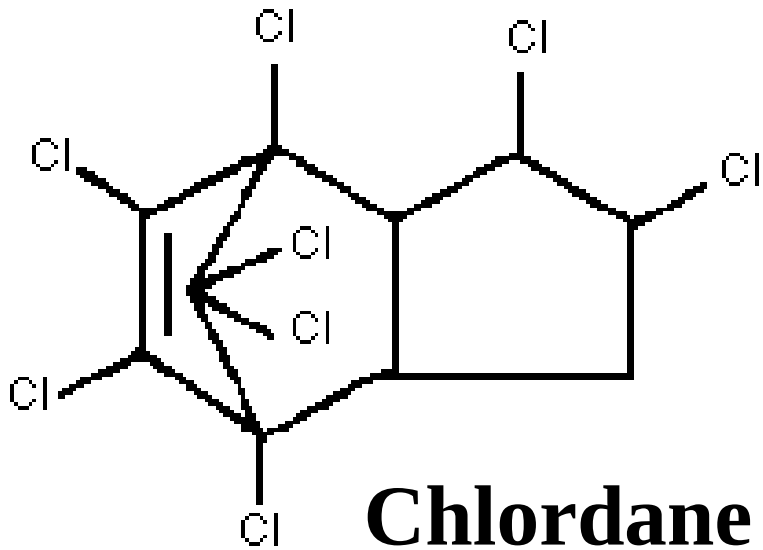
Polychlorinated Biphenyl (PCB)

HCB





DDT



Chlordane

MSU Chemical Services LaboratoryÕs Performance Evaluation Results of 2002 NIST Intercomparison Exercise Program

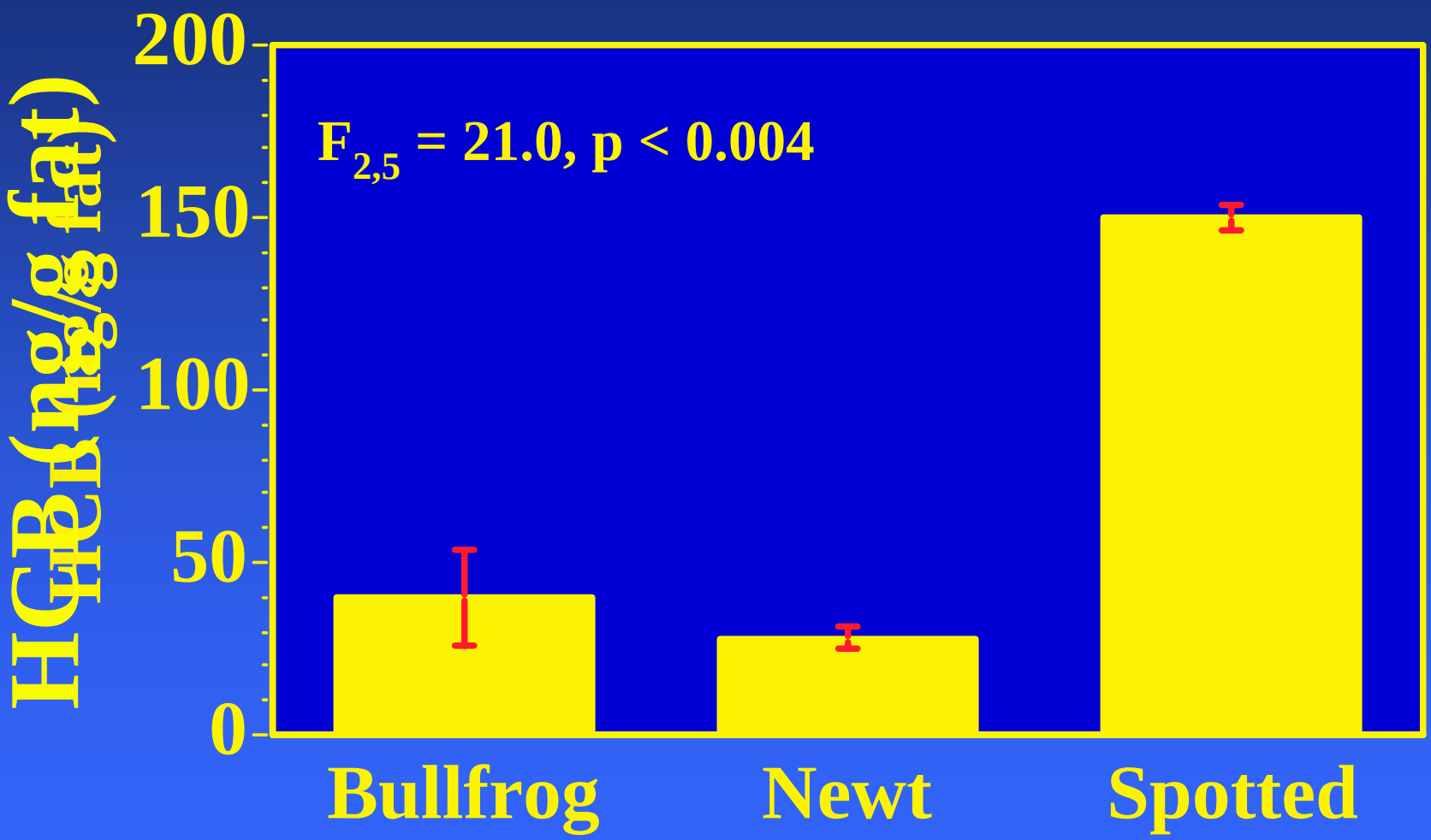
Sediment	Number of Analytes	Accuracy Assessment: Z-Scores
Pesticides	11	<2
	0	>3
PCB Congeners	20	<2
	1	>3
Fish		
Pesticides	19	<2
	1	>3
PCB Congeners	19	<2
	1	>3

Z-scores: <2= satisfactory; >3 = unsatisfactory.
(NISTÕs Accuracy Assessments are: Satisfactory, Questionable and Unsatisfactory).

Amphibian contamination varied by population and species.

Sampling Location	Species	Life Stage	Concentration (ng/g wet wt.) Total PCBs	Total DDTs	HCB	Chlordane
Shuman #2 (Def)	Bullfrog	Larva	22.43	3.36	0.11	2.20
Bishop #1	Bullfrog	Larva	10.36	1.98	0.75	2.21
M. Morgan #3	Bullfrog	Larva	8.70	5.05	0.77	2.28
Bishop #4	Bullfrog	Larva	9.99	4.02	1.40	2.53
Tower LBL (4)	Bullfrog	Larva	11.30	6.43	BDL	1.38
Elk & Bison (1M)	Spotted Salamander	Adult Male	24.56	6.88	3.98	*33.96*
Site 68/80	Spotted Salamander	Adult Male	13.61	9.70	3.47	1.13
Star Camp 2 (1M)	Spotted Salamander	Adult Male	18.72	BDL	1.80	1.21
LBL-142 (4M)	Eastern Newt	Adult Male	20.73	6.07	0.49	1.20
LBL-220 (6M)	Eastern Newt	Adult Male	33.40	6.80	0.78	3.14

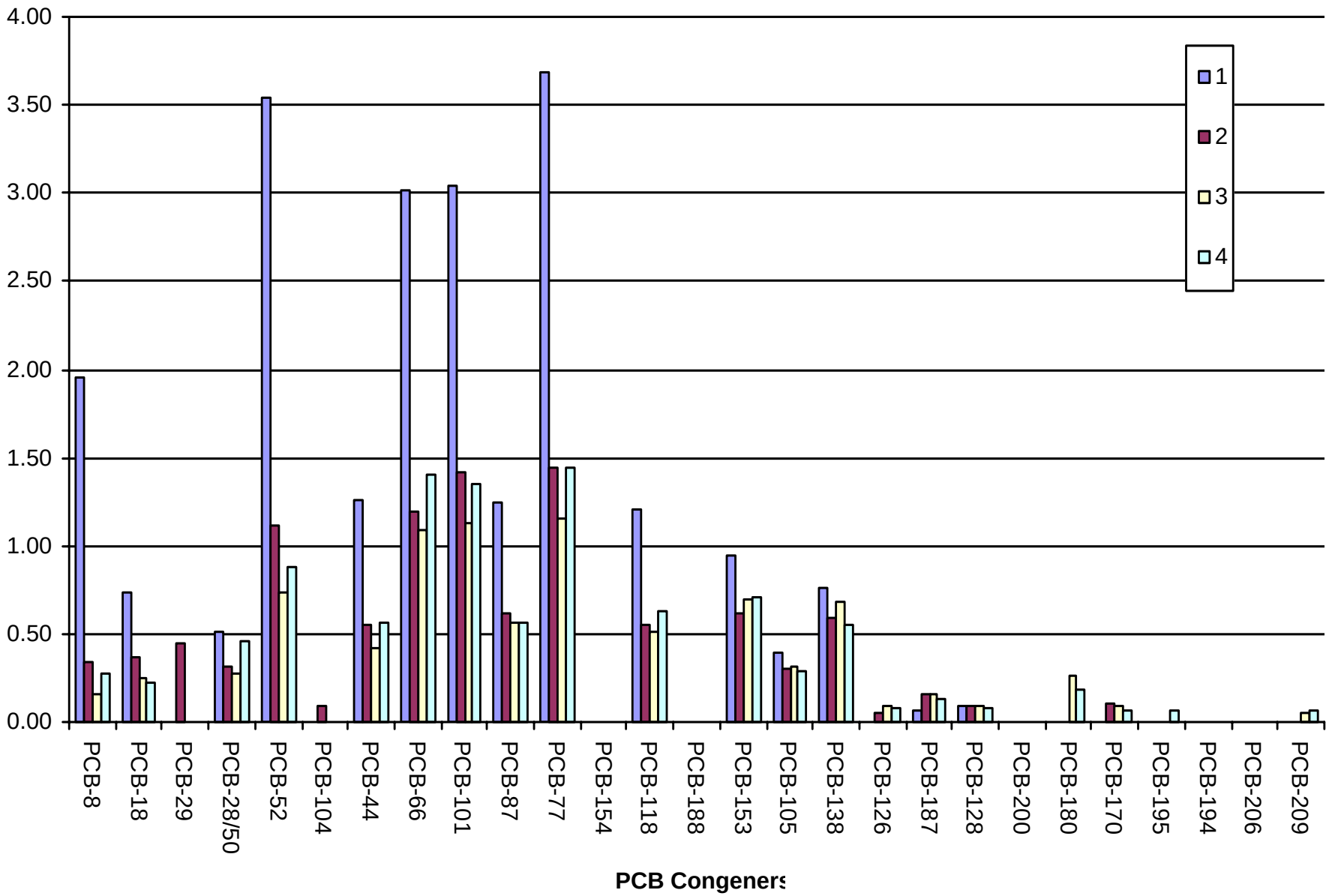
HCB levels varied significantly across species.



Is PA related to contaminant concentration in bullfrog tadpoles?

Population	Total PCBs (ng/g wet wt)	EHL FA 7 (mpu)
Morgan	8.70	0.020
Bishop	9.90-10.36	0.034
Shuman	22.43	???*

***major deformities**


PCB Congener Composition in Normal and Deformed Amph
(1-Deformed; 2,3,4-Normal)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1
2
3
4
PCB-8
PCB-18
PCB-29
PCB-28/50
PCB-52
PCB-104
PCB-44
PCB-66
PCB-101
PCB-87
PCB-77
PCB-154
PCB-118
PCB-188
PCB-153
PCB-105
PCB-138
PCB-126
PCB-187
PCB-128
PCB-200
PCB-180
PCB-170
PCB-195
PCB-194
PCB-206
PCB-209
PCB Congeners

Is PA related to contaminant concentration in eastern newts?

Population	Total PCBs (ng/g wet wt)	FA 11 (pixels)
LBL-142	20.73	39.4
LBL-220	33.40	41.1

***major deformities**

Conclusions

- Amphibian asymmetry was *correlated* with anthropogenic disturbance.

- Data suggest that contamination levels might also be related to asymmetry and phenodeviants.

Implications

- Developmental stability in amphibians may provide an early warning of environmental stressors affecting humans.

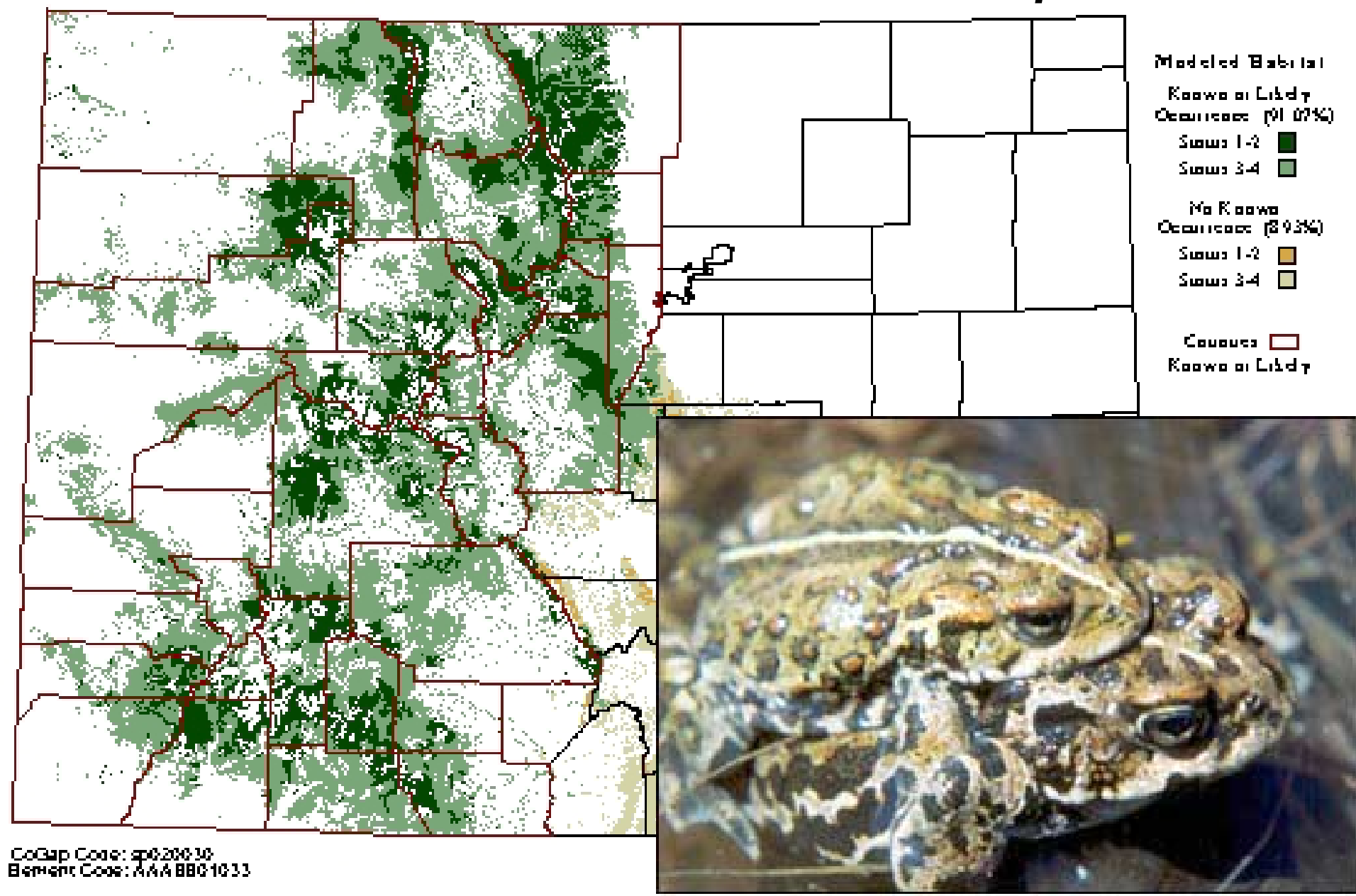
Consequences of Tissue Contamination in Humans

- Reproductive failure
- Developmental problems
- Hepatic damage
- Respiratory and cardiovascular problems
- Immune system suppression
- Cancer

Implications

- Developmental stability may act as a biological indicator for monitoring and restoring amphibian populations.

Bufo boreas



By Joseph Kiesecker / courtesy Penn State

Current and Future Research

- Other life stages and species
- Further contaminant analysis
- Age effects (B. Kobylarz MS)
- GIS/Remote Sensing (J. Boynton MS)
- Experiments
  - Causative factors
  - Effects of metamorphosis

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