Contaminants of Emerging Concern in the North American Great Lakes: Evidence of Reproductive Disruption from Field and Laboratory Studies

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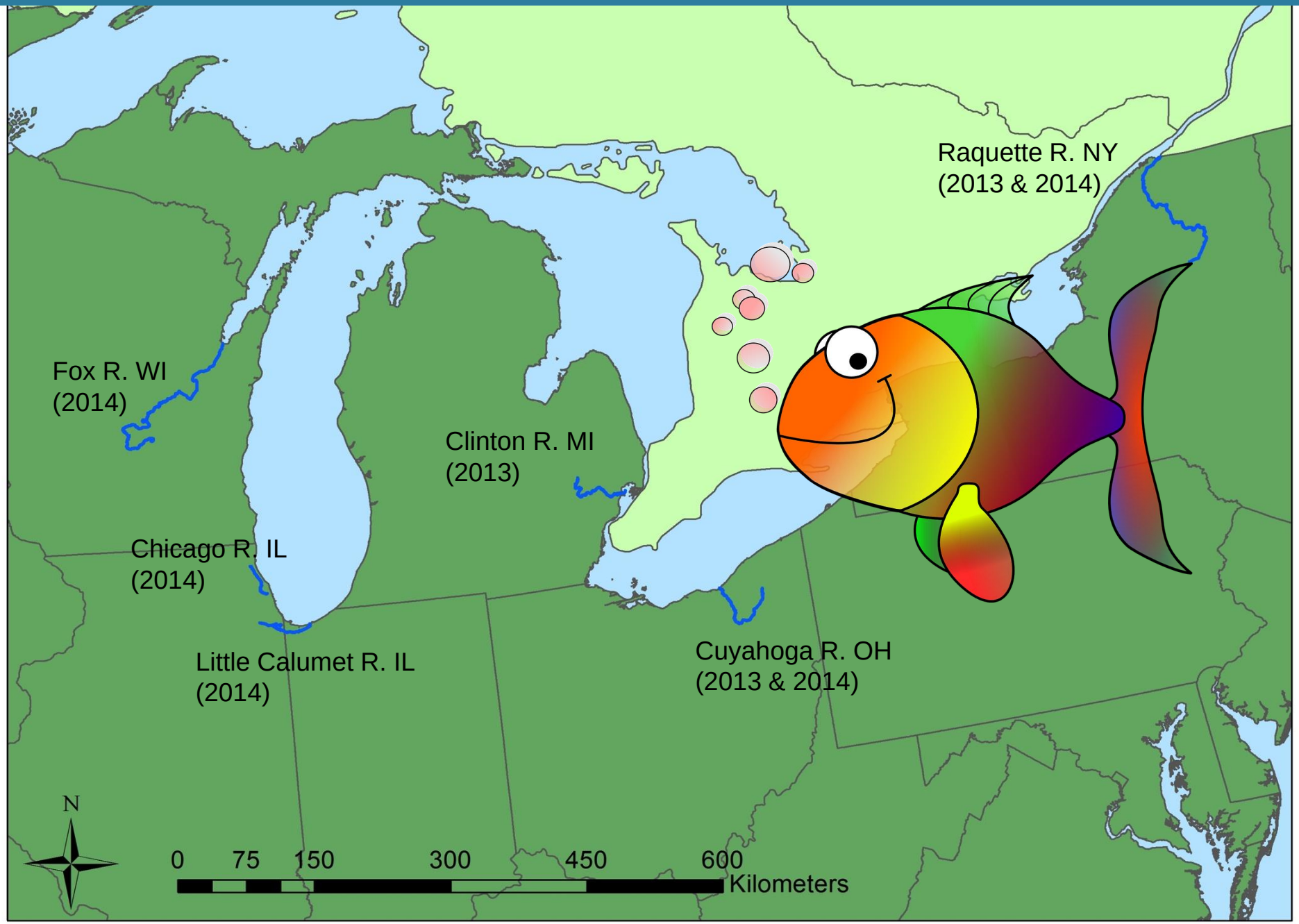
Acknowledgements & Disclaimer

The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service or the U.S. Environmental Protection Agency

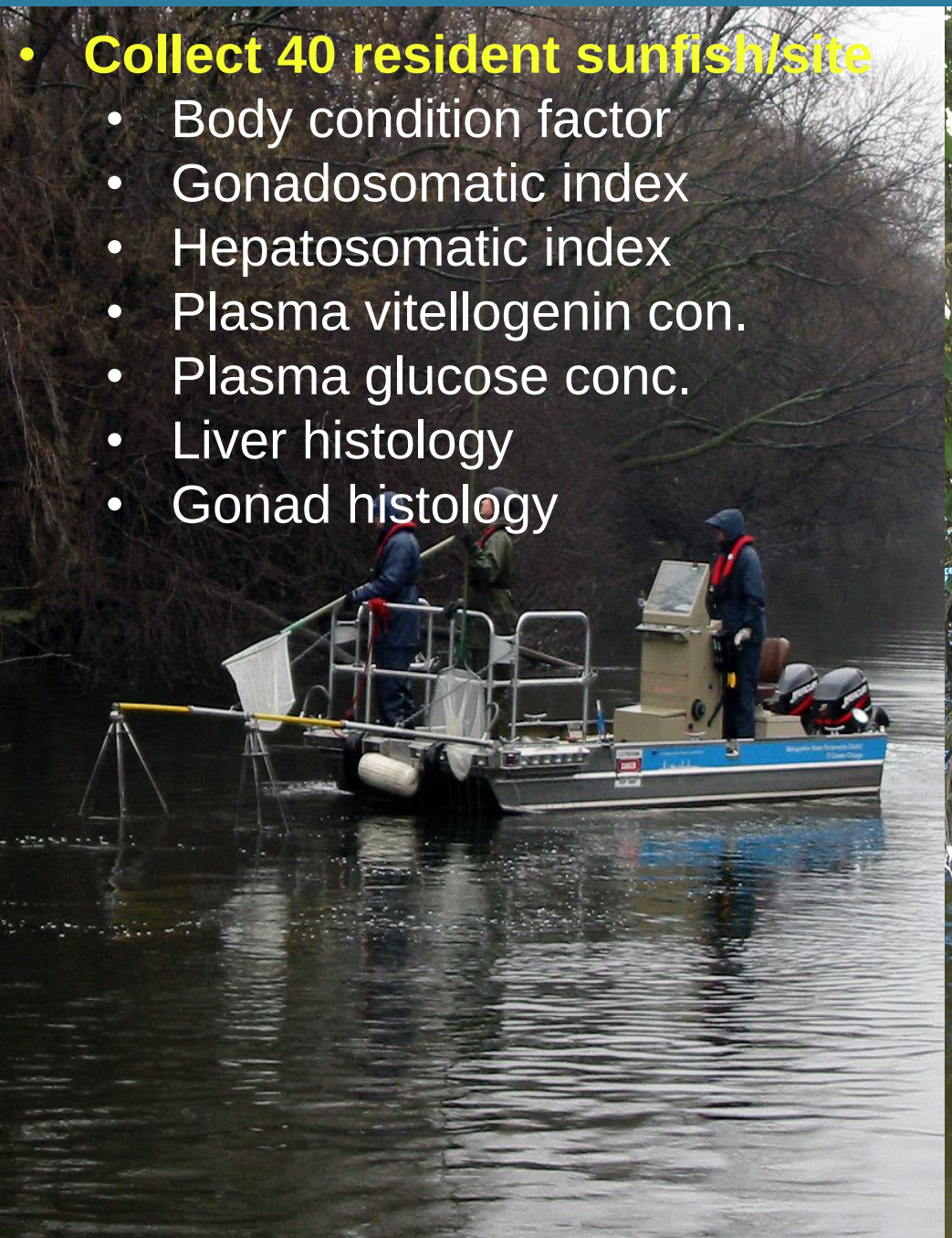

Are fish populations affected by the presence of Contaminants of Emerging Concern in the Laurentian Great Lakes?

Biological Effects of CECs



Effects of CECs in "Natural" Ecosystems

- **Collect 40 resident sunfish/site**
  - Body condition factor
  - Gonadosomatic index
  - Hepatosomatic index
  - Plasma vitellogenin con.
  - Plasma glucose conc.
  - Liver histology
  - Gonad histology



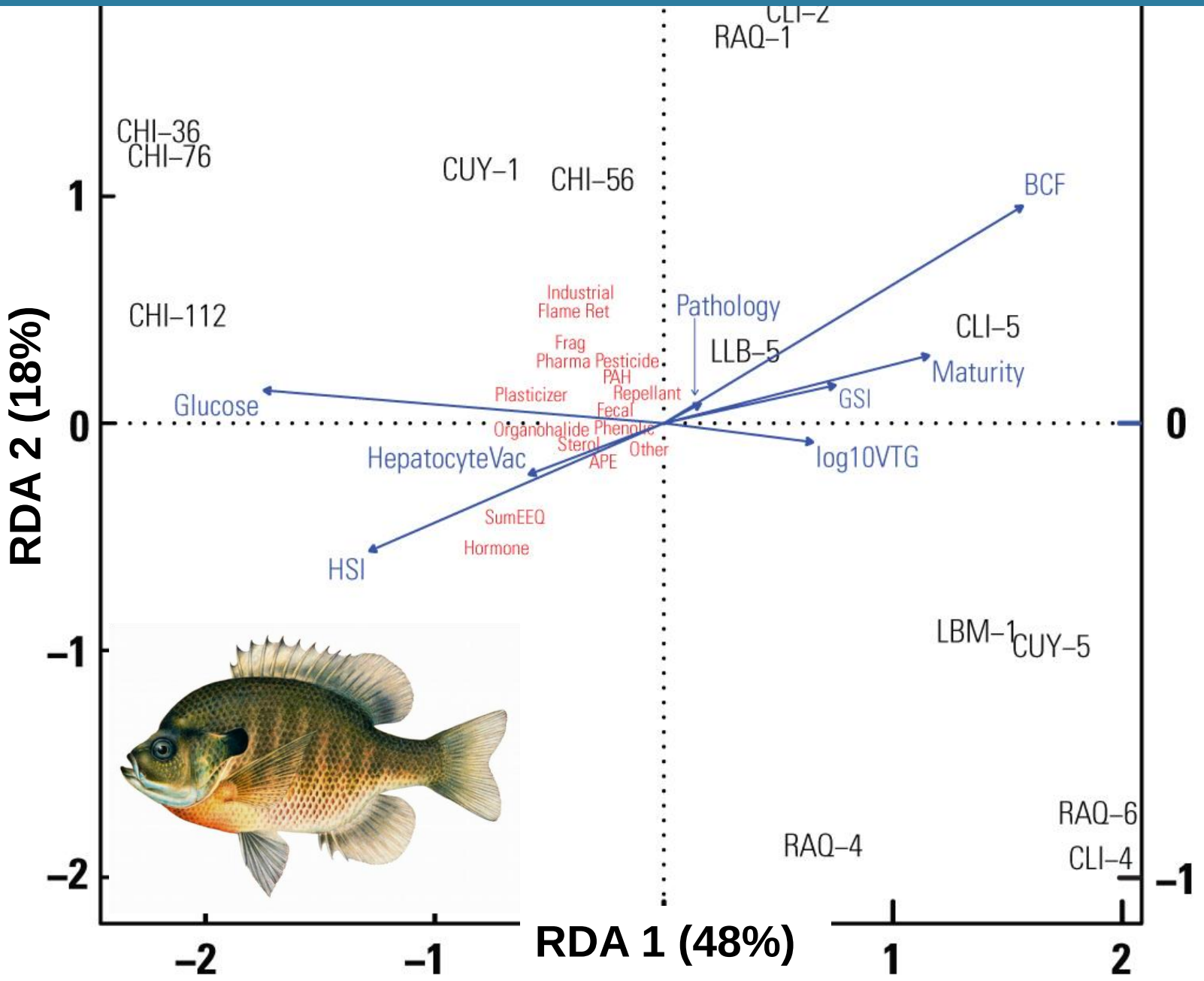
- **Cage 40 sunfish/site**
  - Body condition factor
  - Gonadosomatic index
  - Hepatosomatic index
  - Plasma vitellogenin con.
  - Plasma glucose conc.
  - Liver histology
  - Gonad histology

Fish Collections

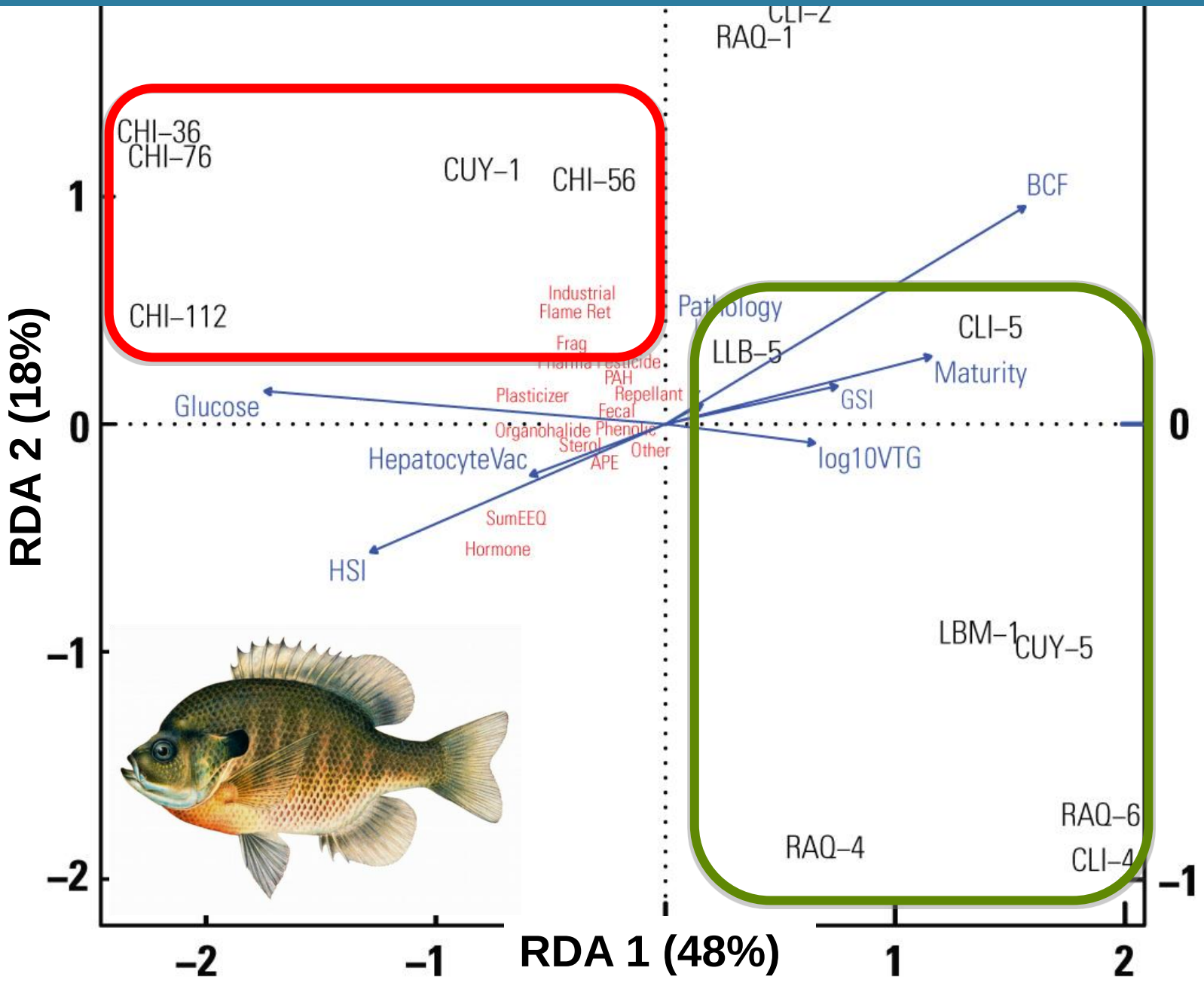
			Bass (Micropterus sp.)		*Catostomus*	Sunfish (*Lepomis ssp.*)		Caged	
			Largemouth	Smallmouth	White Sucker	Bluegill	Other Sunfish	Caged	Recovery
Fox R. WI	2014	*downstream*	*23*	*17*	*2*	*10*	*0*	*100*	27%
		middle (WWTP)	*19*	*1*	*35*	*8*	*18*	*50*	54%
		upstream	*12*	*2*	*40*	*34*	*6*	*100*	28%
Chicago R. IL	2014	*downstream*	*0*	*0*	*0*	*27*	*13*	*52*	100%
		middle (WWTP)	*0*	*0*	*0*	*n/a*	*n/a*	*52*	96%
		upstream	*0*	*0*	*0*	*18*	*22*	*52*	98%
Little Calumet R. IL	2014	*downstream*	*0*	*0*	*0*	*9*	*1*	*52*	94%
		middle (WWTP)	*0*	*0*	*0*	*n/a*	*n/a*	*52*	87%
		upstream	*0*	*0*	*0*	*50*	*0*	*52*	81%
Clinton R. MI	2013	*downstream*	*0*	*0*	*38*	*41*	*4*	*100*	32%
		middle (WWTP)	*0*	*0*	*3*	*49*	*0*	*50*	6%
		upstream	*0*	*0*	*0*	*30*	*10*	*100*	19%
Cuyahoga R. OH	2013	*downstream*	*13*	*7*	*33*	*25*	*25*	*100*	49%
		middle (WWTP)	*0*	*8*	*34*	*0*	*0*	*50*	62%
		upstream	*20*	*30*	*4*	*58*	*1*	*50*	80%
	2014	*downstream*	*2*	*16*	*8*	*9*	*1*	*50*	74%
		middle (WWTP)	*0*	*2*	*41*	*1*	*0*	*50*	92%
		upstream	*40*	*0*	*1*	*50*	*0*	*100*	88%
Raquette R. NY	2013	*downstream*	*0*	*25*	*0*	*2*	*34*	*110*	95%
		middle (WWTP)	*0*	*0*	*29*	*0*	*44*	*110*	96%
		upstream	*1*	*2*	*13*	*0*	*10*	*100*	100%
	2014	*downstream*	*32*	*11*	*2*	*0*	*42*	*112*	98%
		middle (WWTP)	*17*	*4*	*39*	*0*	*40*	*112*	71%
		upstream	*44*	*2*	*32*	*3*	*13*	*112*	94%
All Fish		*downstream*	*70*	*76*	*83*	*123*	*120*	*676*	71%
		middle (WWTP)	*36*	*15*	*181*	*58*	*102*	*422*	71%
		upstream	*117*	*36*	*90*	*243*	*62*	*666*	74%

~ 2,500 sunfish

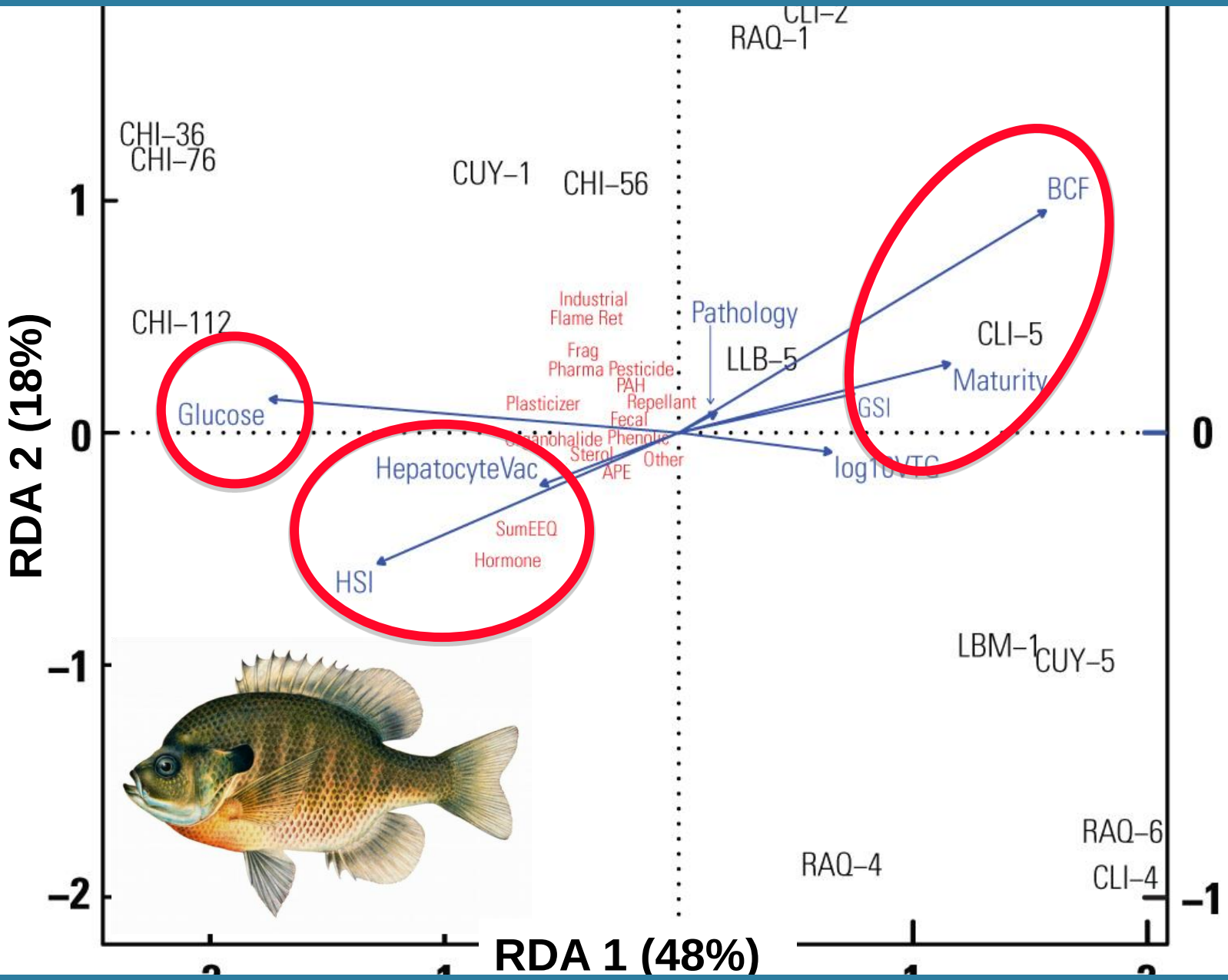
Canonical Redundancy Analysis (~100,000 values)



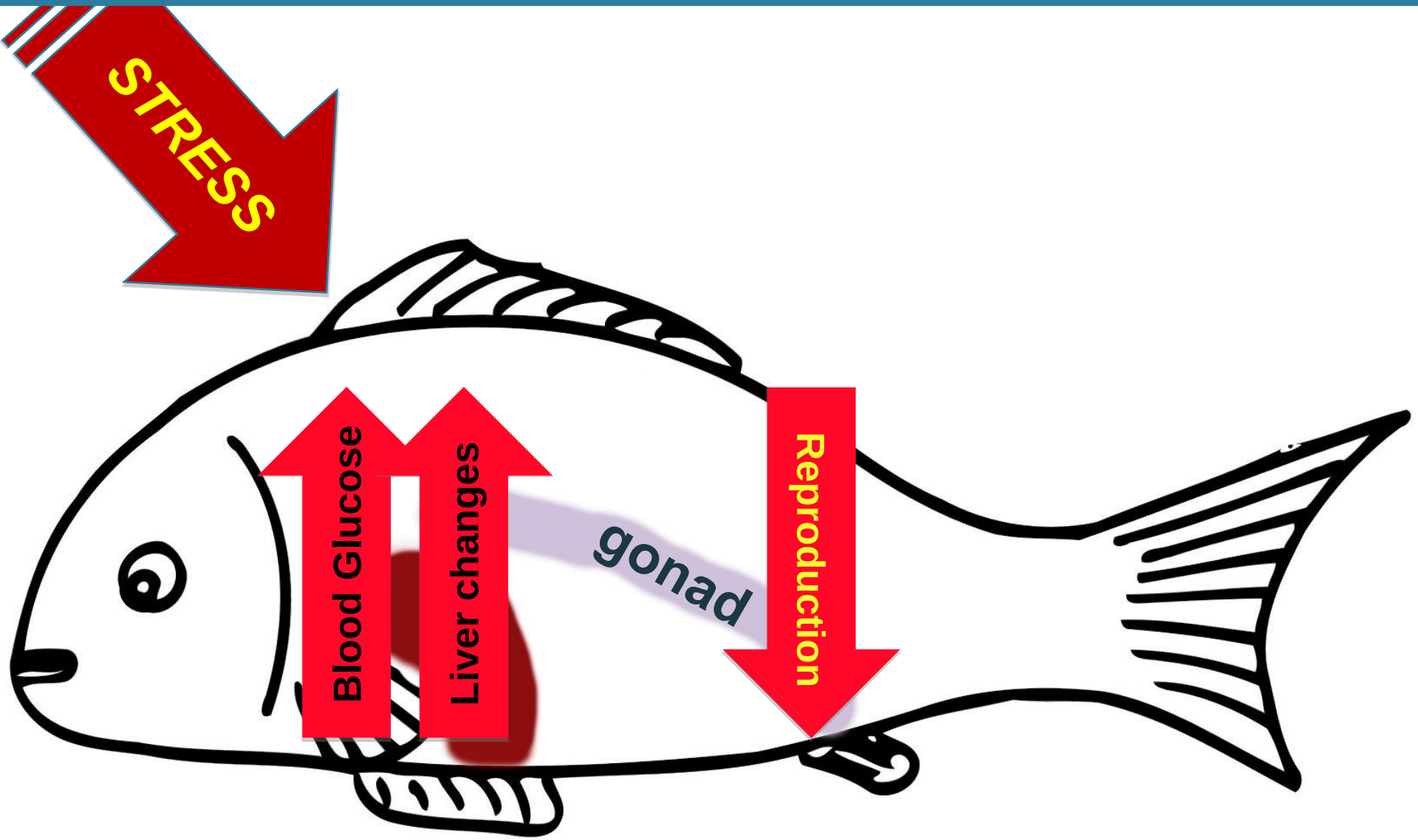
Canonical Redundancy Analysis: Grouping by Locations



Canonical Redundancy Analysis: Grouping by Biomarkers



Thomas et al., 2017 PLoS One



→ ***Fish in Great Lakes tributaries experience energetic stress that may affect reproduction.***

WATER & SEDIMENT combined

Caged Sunfish

females:	pharmaceuticals & PAHs
males:	pharmaceuticals & PAHs

Resident Sunfish

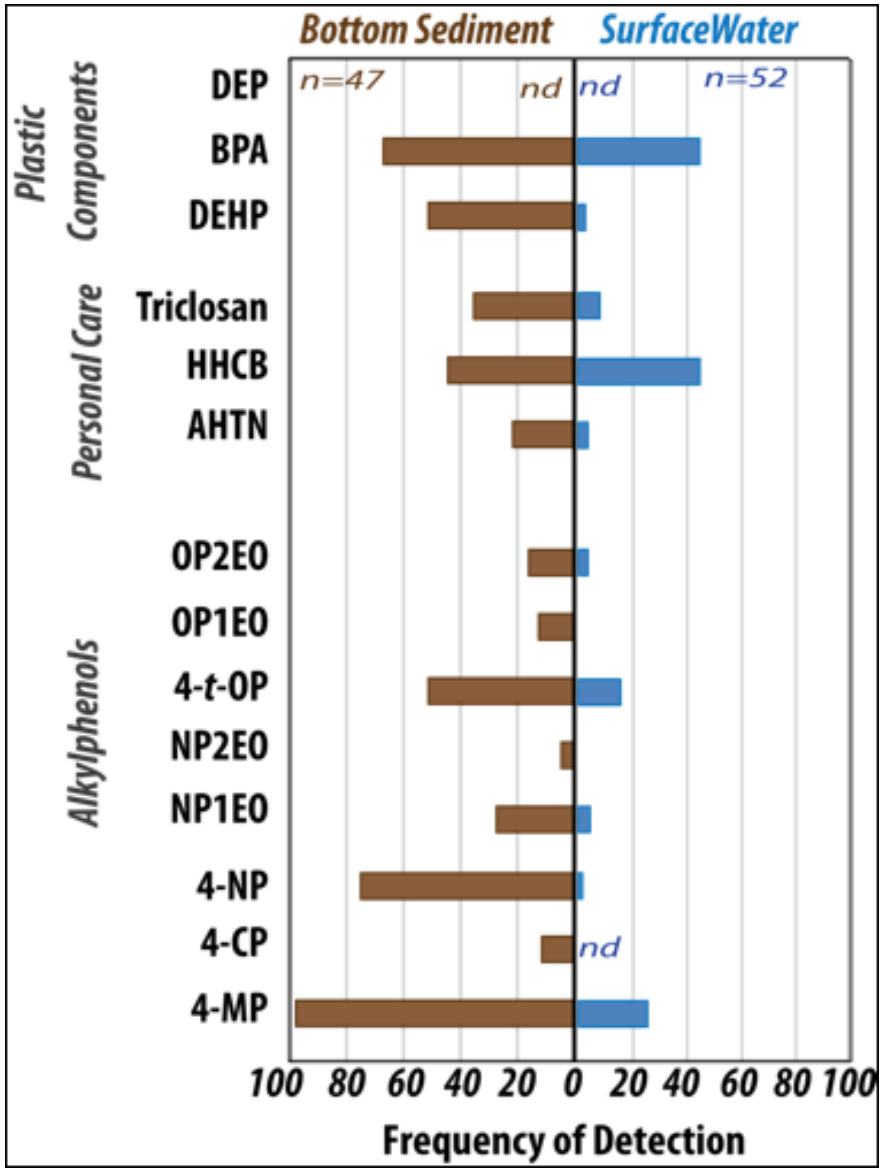
females:	n/s
males:	pharmaceuticals & PAHs

Patterns in CEC Occurrence

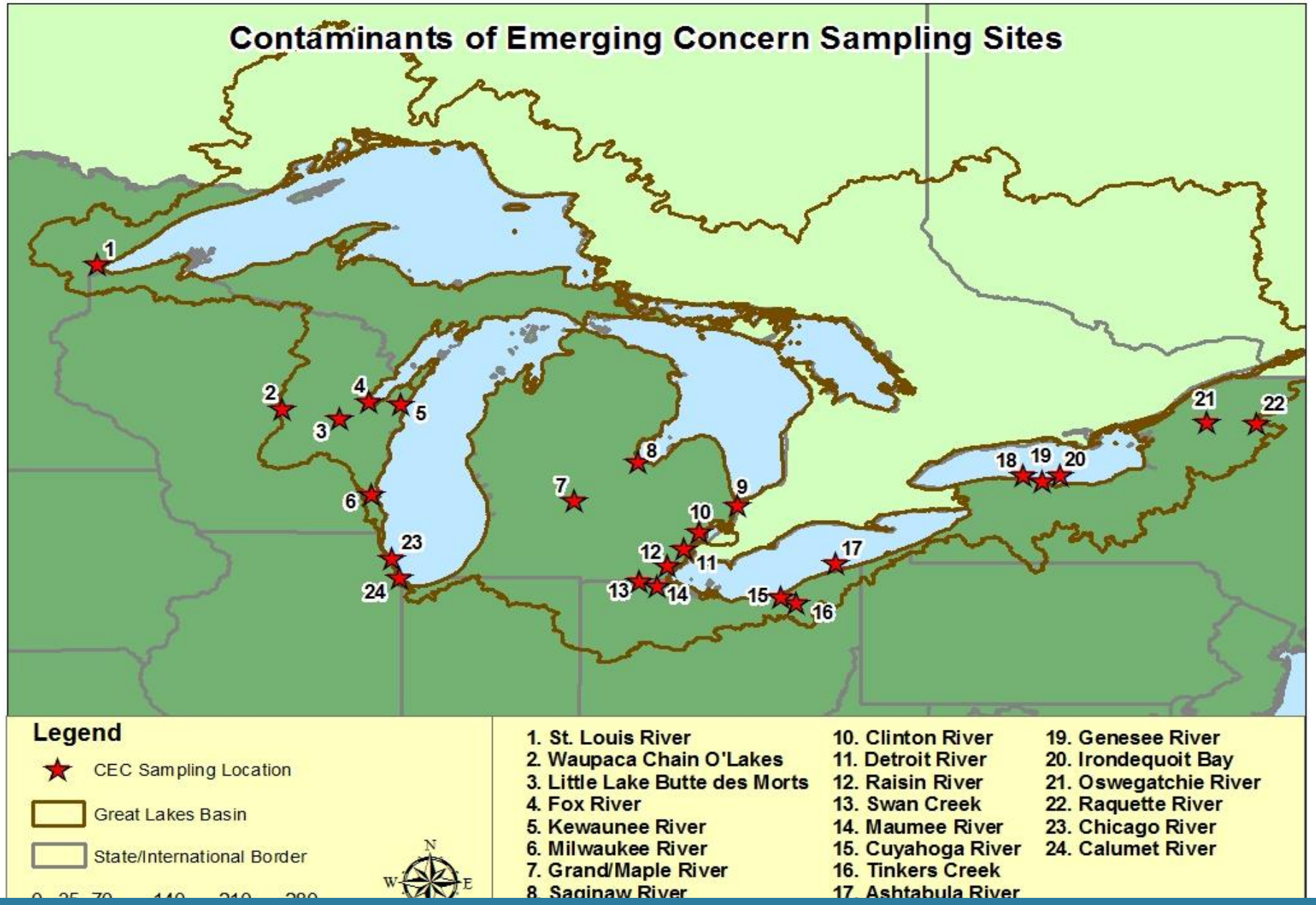
→ ***CECs are ubiquitous***

→ ***Fish experience energetic stress.***

→ ***Are there any patterns in CEC occurrence?***



Presence of CECs

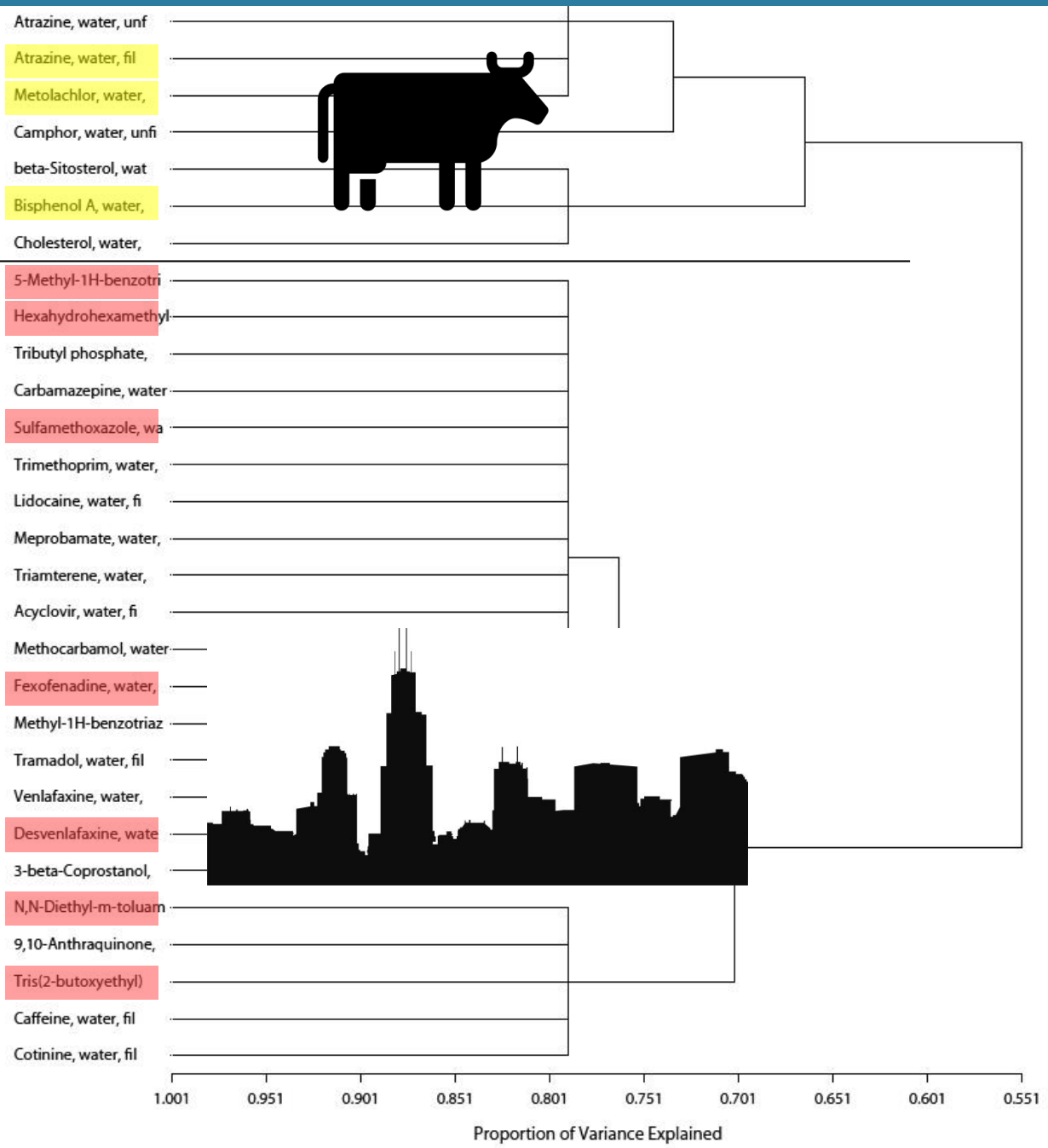


Elliott et al., 2017 PLoS One

Identification of Environmental CEC Mixtures

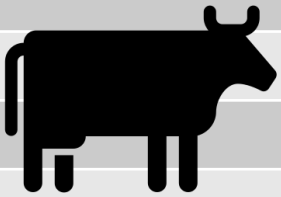
"ag" CECs

"urban" CECs

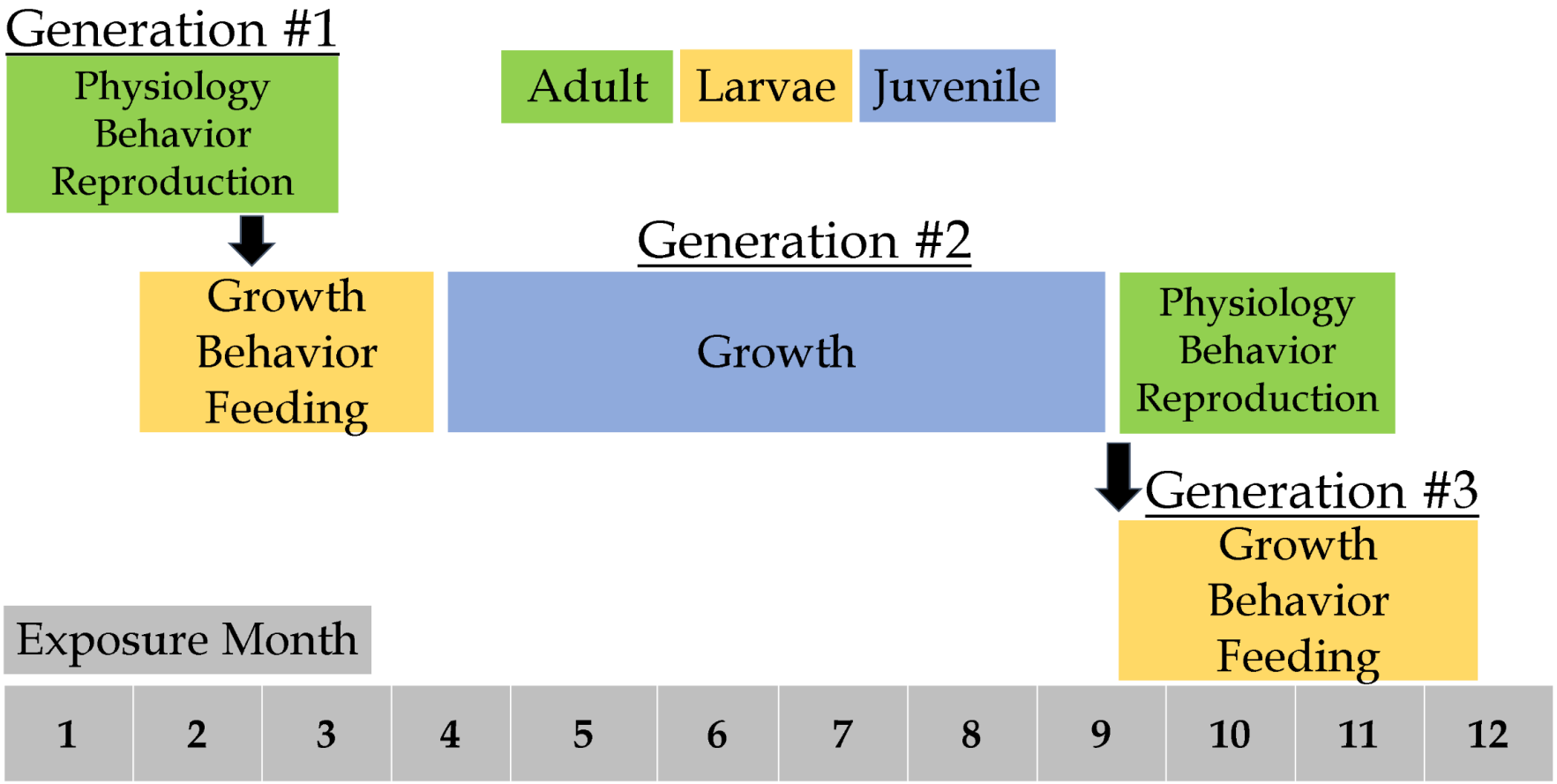


Cluster Analysis of CEC occurrence in Great Lake Tributary water samples – minimum of 30% detection frequency.
Elliott et al., IEAM 2018

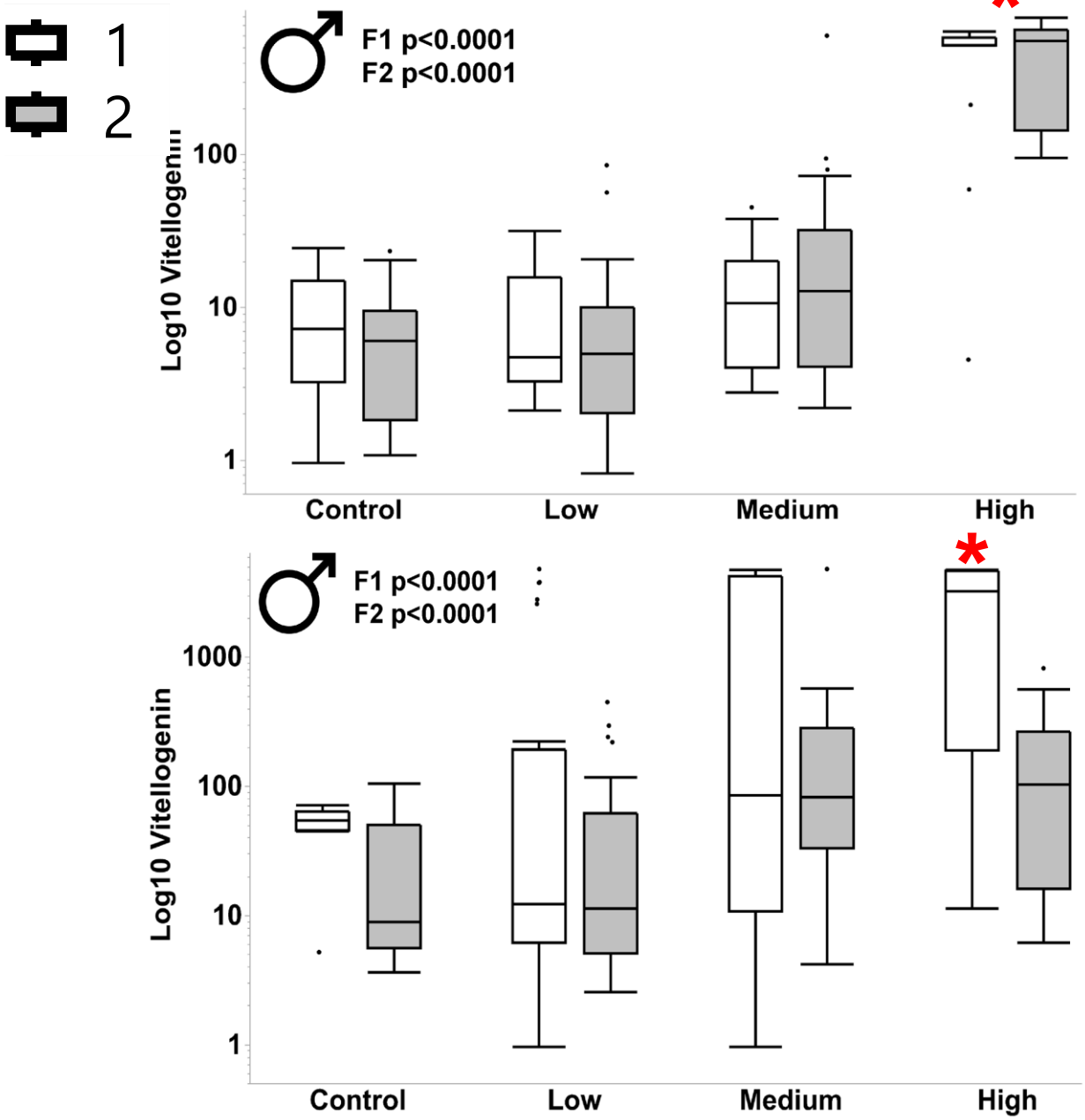
Laboratory Assessment of CEC Mixtures

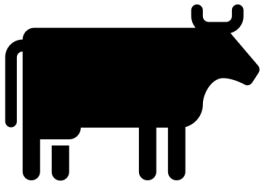
	Agricultural Mixture 5 mix concentrations	**Urban Mixture 3 mix concentrations**
Contaminant	**Environmental Concentration [ng/L]**	**Environmental Concentration [ng/L]**
Metolachlor	170	
Atrazine	400	
Bromacil	120	
DEET	200	1600
TBEP	210	13500
Estrone	**24**	7
Bisphenol A	60	**3000**
4-Nonylphenol	188	**3710**
Sulfamethoxazole		559
Fexofenadine		1000
Desvenlafaxine		583
Metformin		1210
HHCB (Galaxolide)		2180
Methyl-1H-benzotriazole		6680

Laboratory Assessment of CEC Mixtures

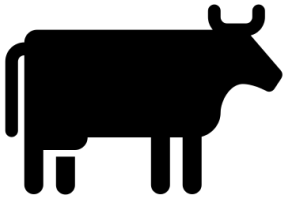


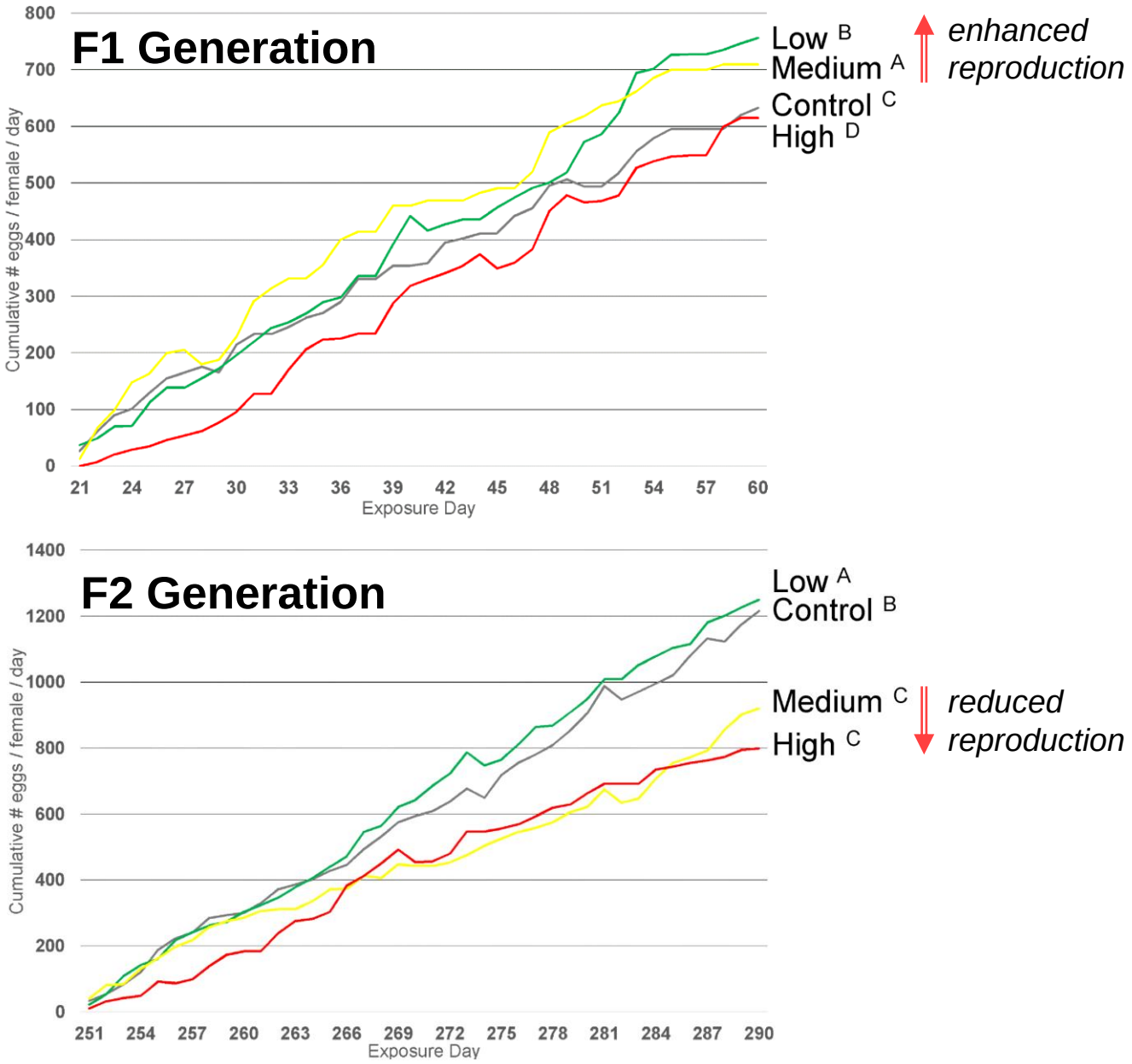
Physiological Effects of Exposure – Male Vitellogenin



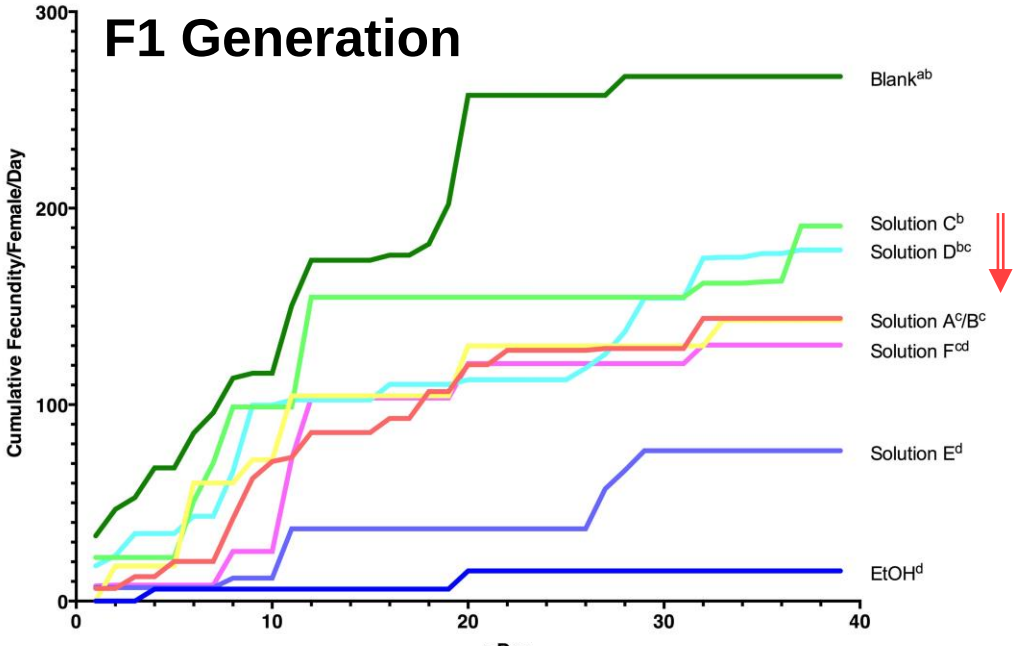


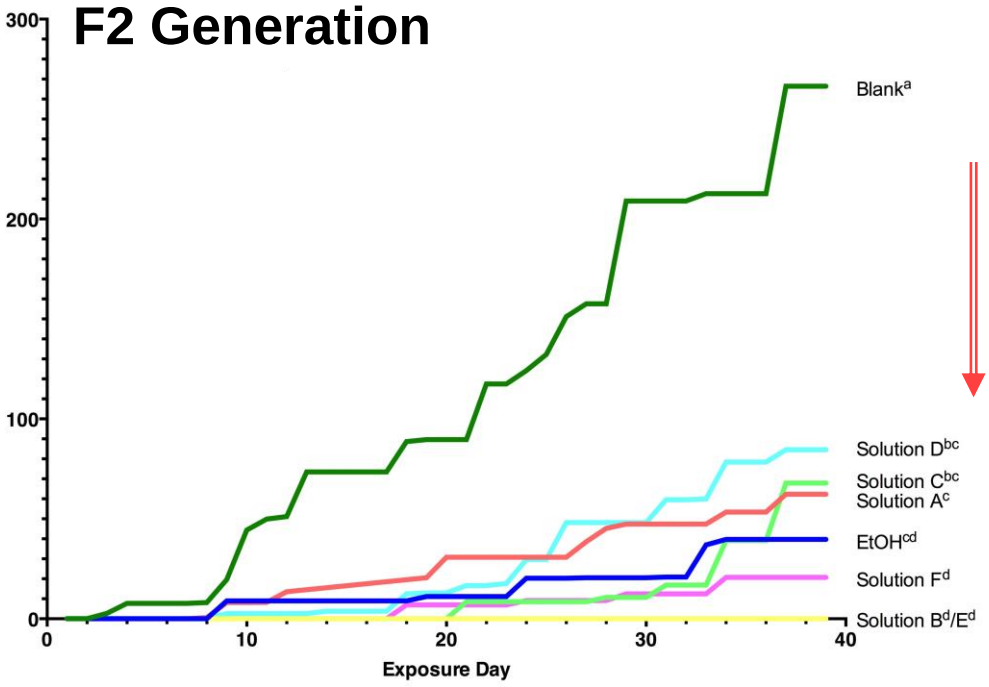
Cumulative Fecundity - Agricultural CEC Mixtures





Cumulative Fecundity - Urban CEC Mixtures





Mixture Concentrations:
*F > E > **D** > C > B > A*
(highest) → (lowest)

SUMMARY

- Both Ag and Urban Mixtures stimulate vitellogenin production – similar to Phase I studies (Thomas et al., 2017)
- Ag estrogenic response is greater than urban response.
- At low concentrations Ag mixture has fecundity-enhancing effect (F1).
- Long term exposure heightens the adverse impact of Ag and Urban Mixtures on fitness (reduced fecundity).

CONCLUSIONS

- ***CECs are ubiquitous in Great Lakes tributaries.***
- ***Resident fish are experiencing energetic stress that may result in declining fertility.***
- ***Laboratory exposed fish experience altered fertility, especially in the second generation of exposure.***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