

Modelling the response of fish to major infrastructure upgrades in wastewater treatment plants

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Rainbow darter (*Etheostoma caeruleum*)



Arlos, M.J., W.J. Parker, J. Bicudo, P. Law; K.A. Hicks, M. Fuzzen, S. Andrews, M.R. Servos. 2018a. Modeling the exposure of wild fish to endocrine active chemicals: potential linkages of total estrogenicity to field-observed intersex. *Water Research* 139:187-197.

Arlos, M.J., W.J. Parker, P. Law, J. Bicudo, P. Marjan, S.A. Andrews, M.R. Servos. 2018b. Multi-year prediction of estrogenicity in municipal wastewater effluents. *Science of the Total Environment* 610-611C:1103-1112.



Patricia Marjan, Meghan Fuzzen, Keegan Hicks, Maricor Arlos, Katie McCann, Alex Crichton, Samantha Deeming, Paulina Bahamonde, Brendan Smith, Chris Robinson, Carolyn Brown, Jennifer Ings, Gerald Tetreault, Heather Loomer, Jenn Kormos, Ken Oakes, Xu Zhang, Chloe Wang, Paul Togunde, Hadi Dhiyebi, Leslie Bragg, and many others



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WATERLOO
SCIENCE





Grand River Watershed in Southern Ontario

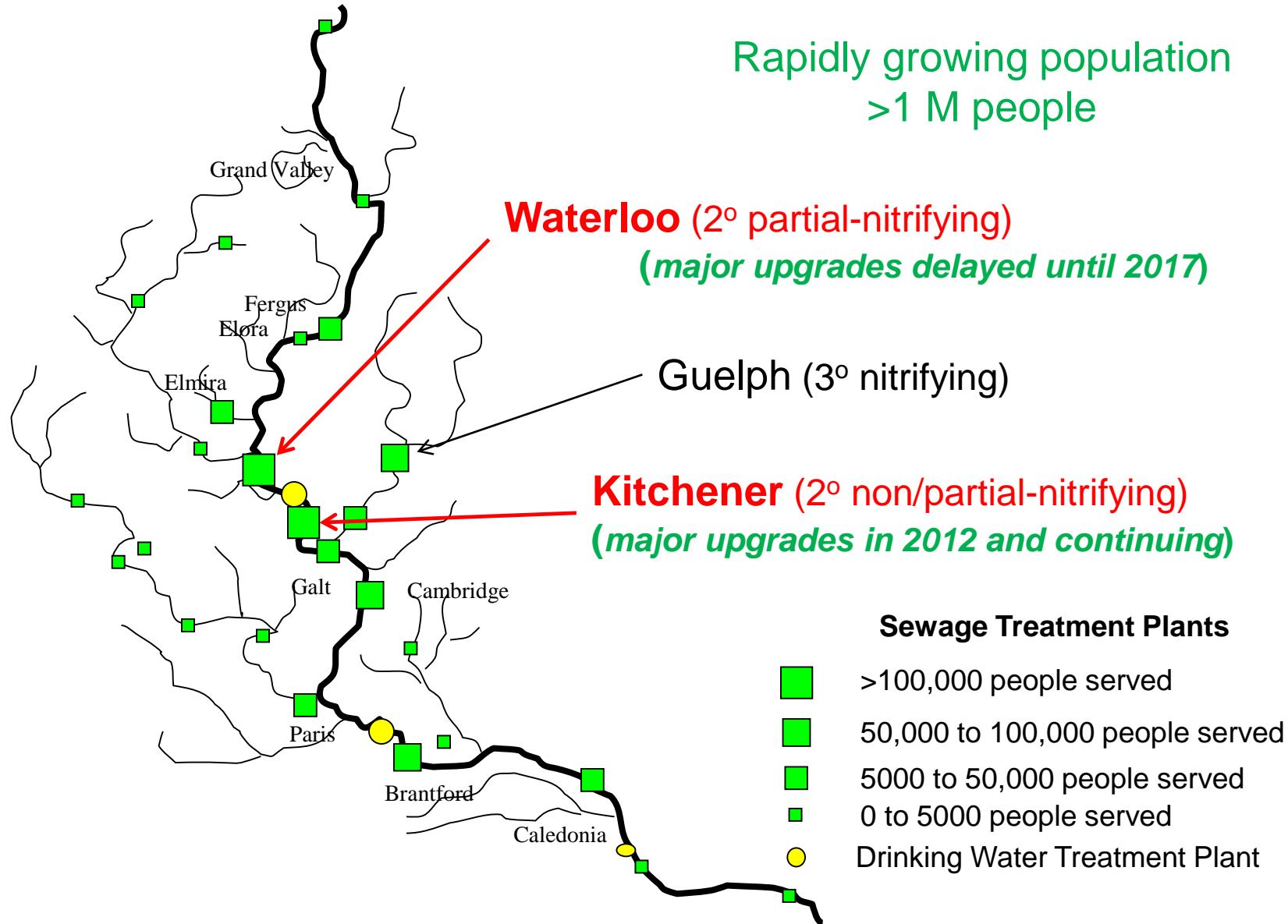
Guelph
Waterloo
Lake Erie
McMaster

Landscape ecology watershed, southern Canada

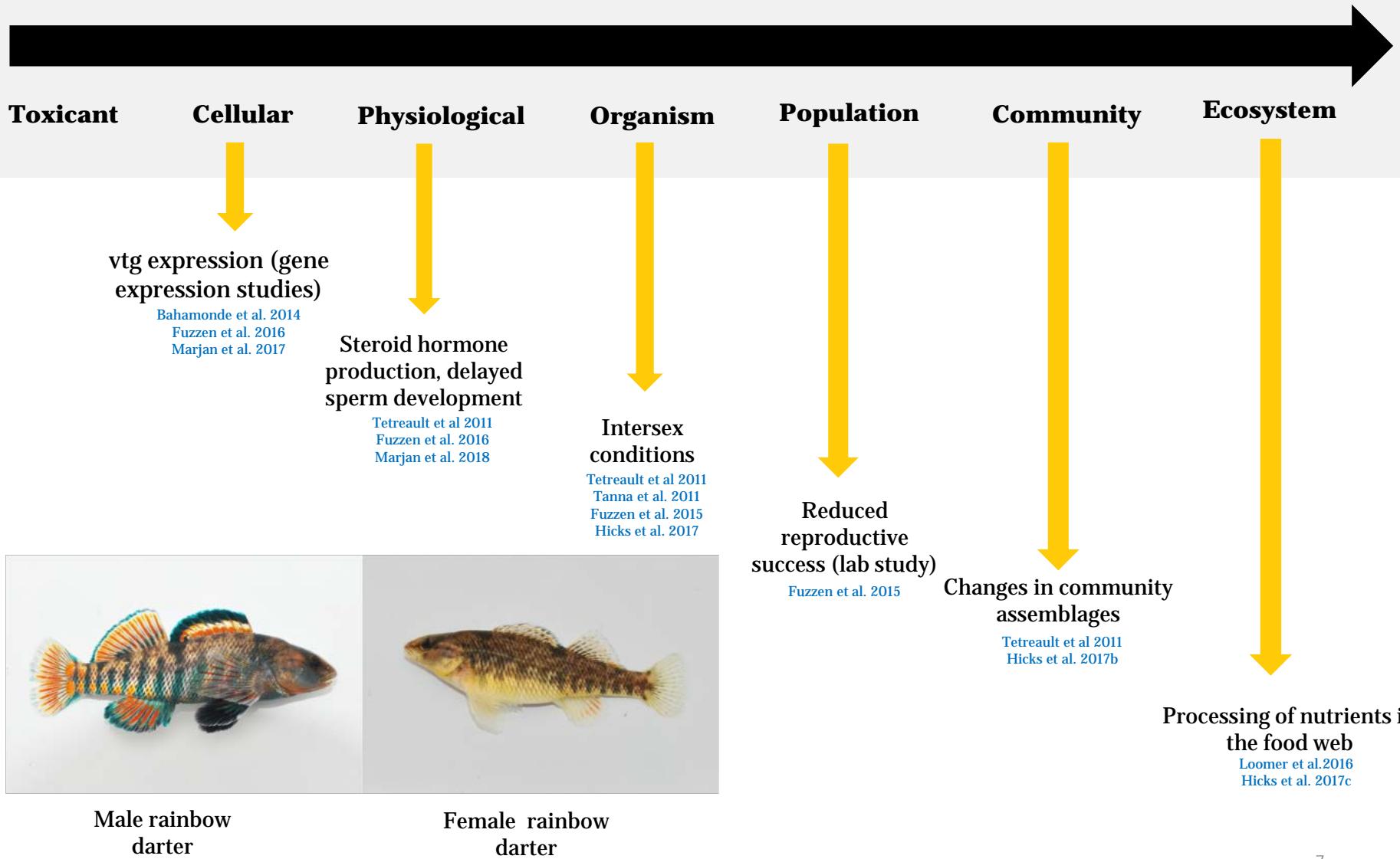
- o Lake Erie – 6,985 km²
 - 1 ~**one million**
 - cultural
 - m **30** municipal WWTPs



Wastewater Treatment Plants in the central Grand River are a major concern for water quality?



Clear biological signals across many levels of biological organization



Intersex condition is the most consistent

Fuzzen et al. 2016, PLOS One

Toxicant

Cellular

Physiological

Organism

Population

Community

Ecosystem



Healthy Male



Exposed Male

Intersex



Continuing to follow responses
to upgrades, 2007-2019

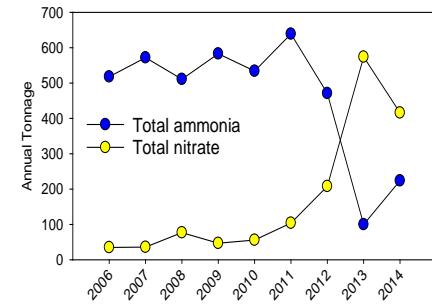
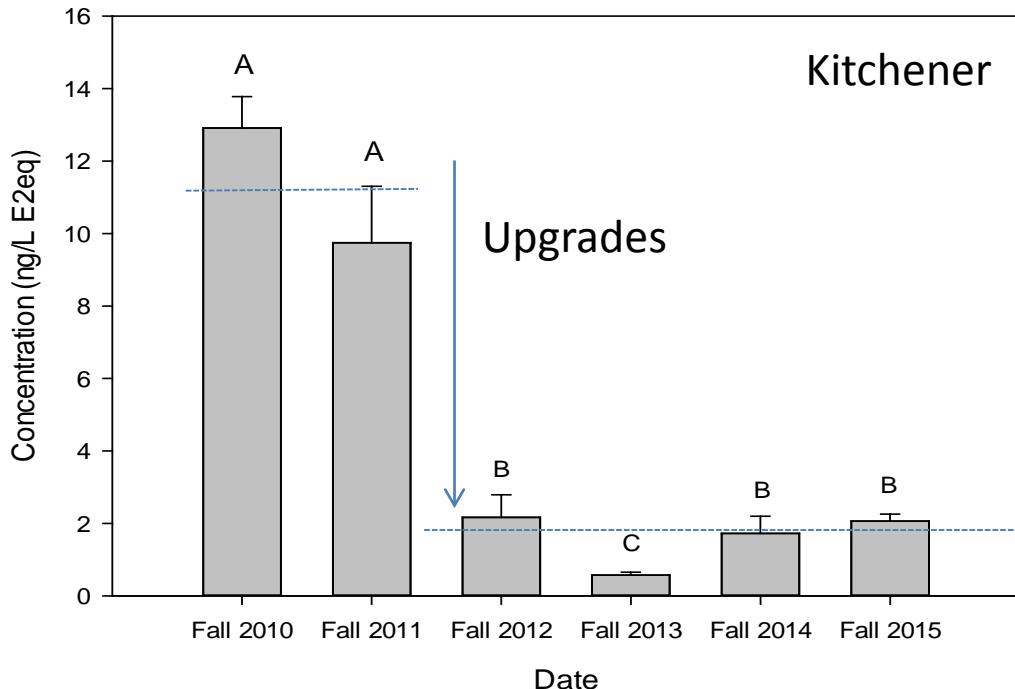


Waterloo (delayed to 2017)

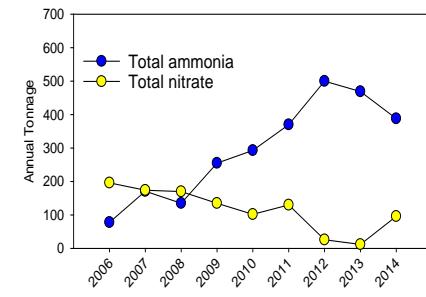
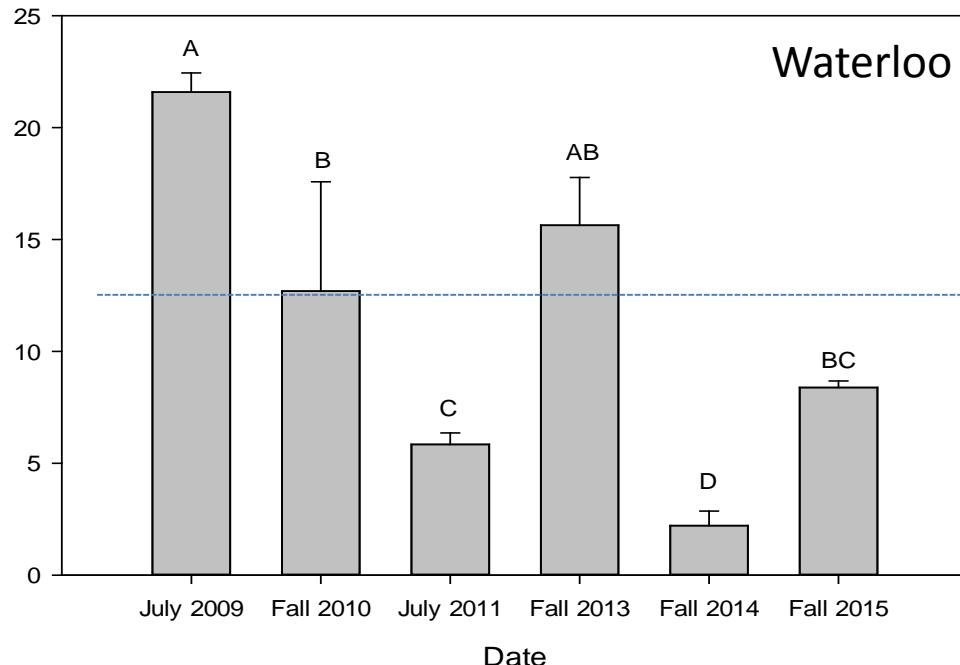


Kitchener (major upgrade in 2012 and continuing)

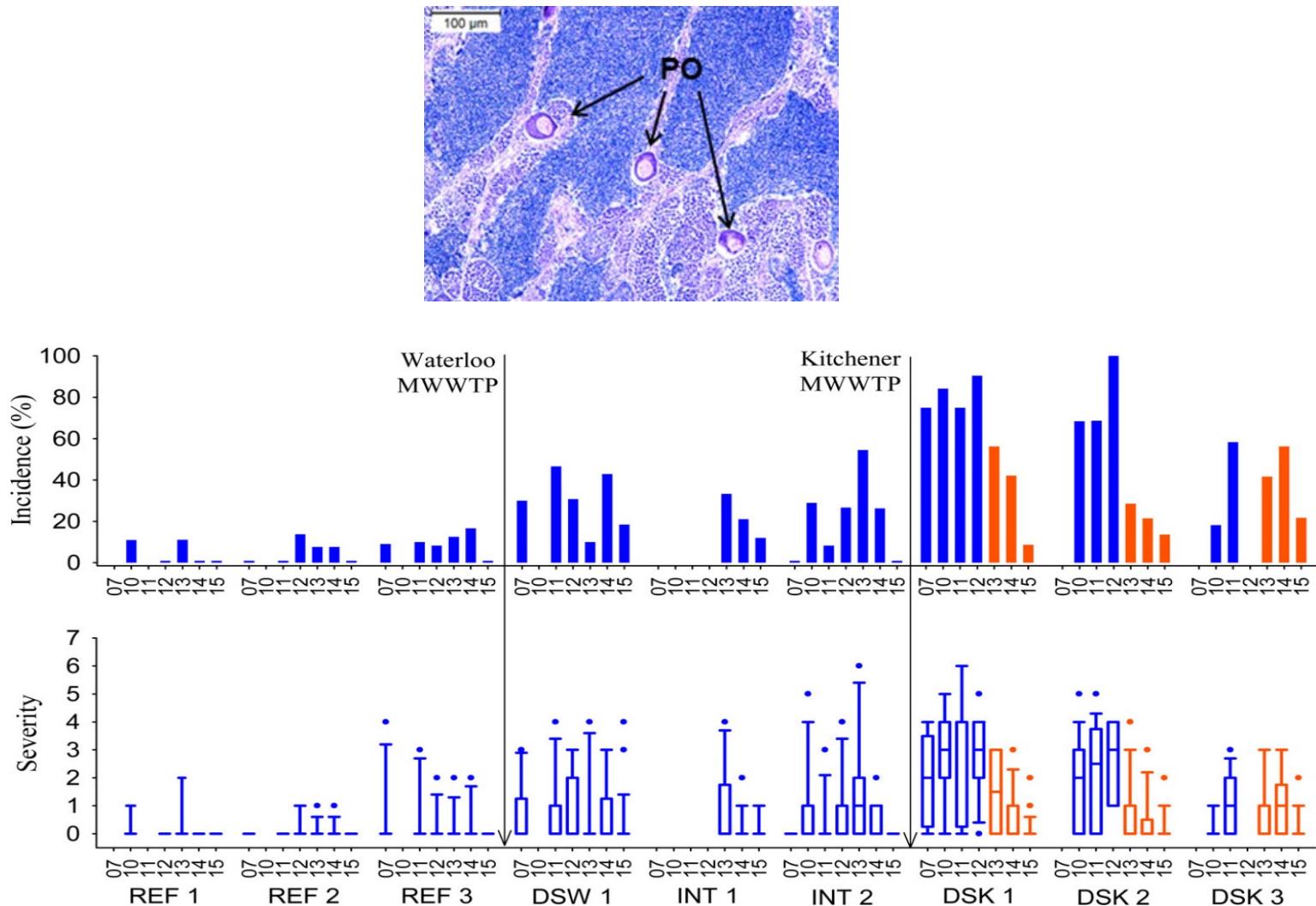
Estrogenicity - YES



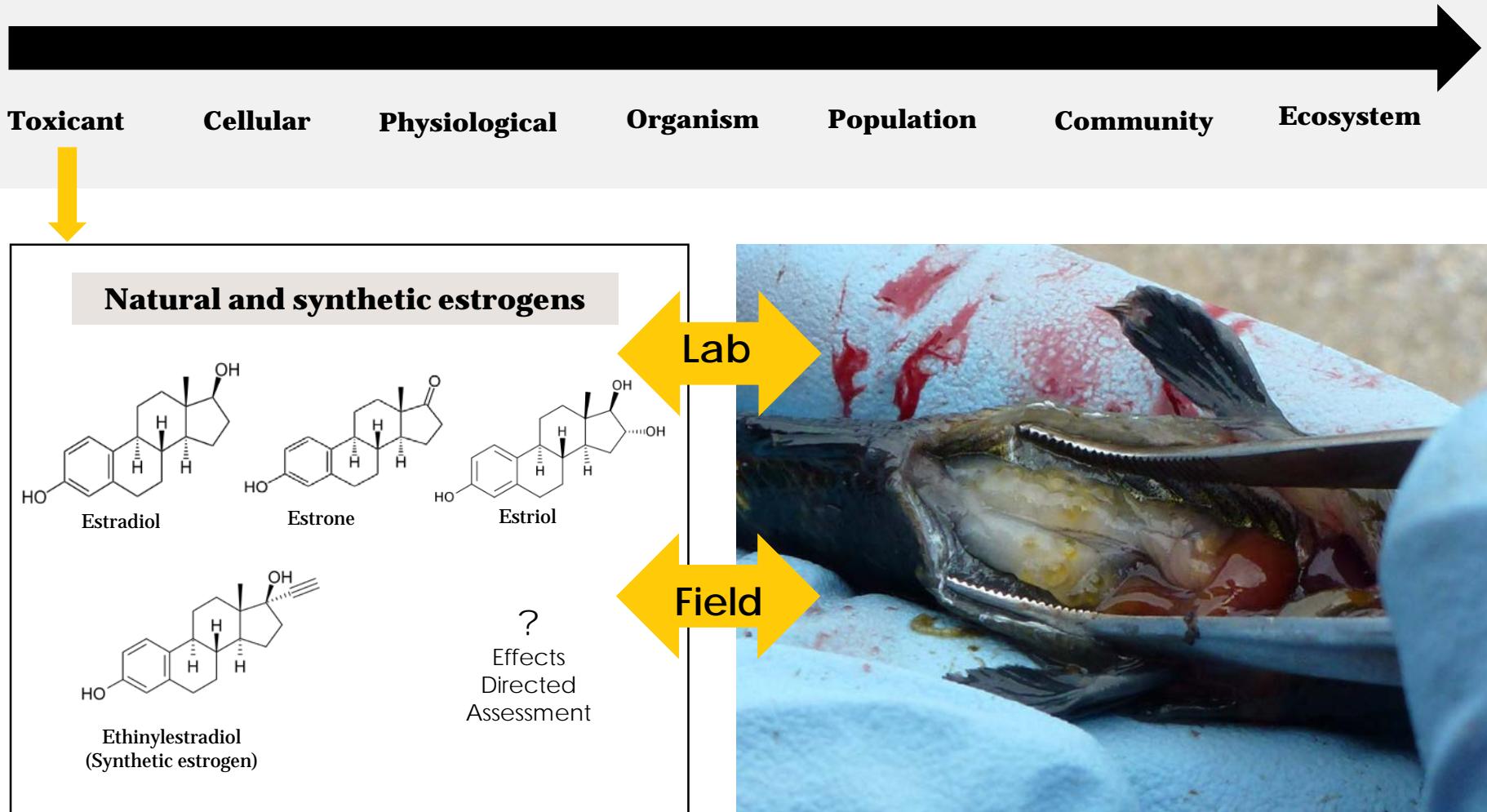
Coconcentration (ng/L E2eq)



Intersex incidence in rainbow darter in the Grand River

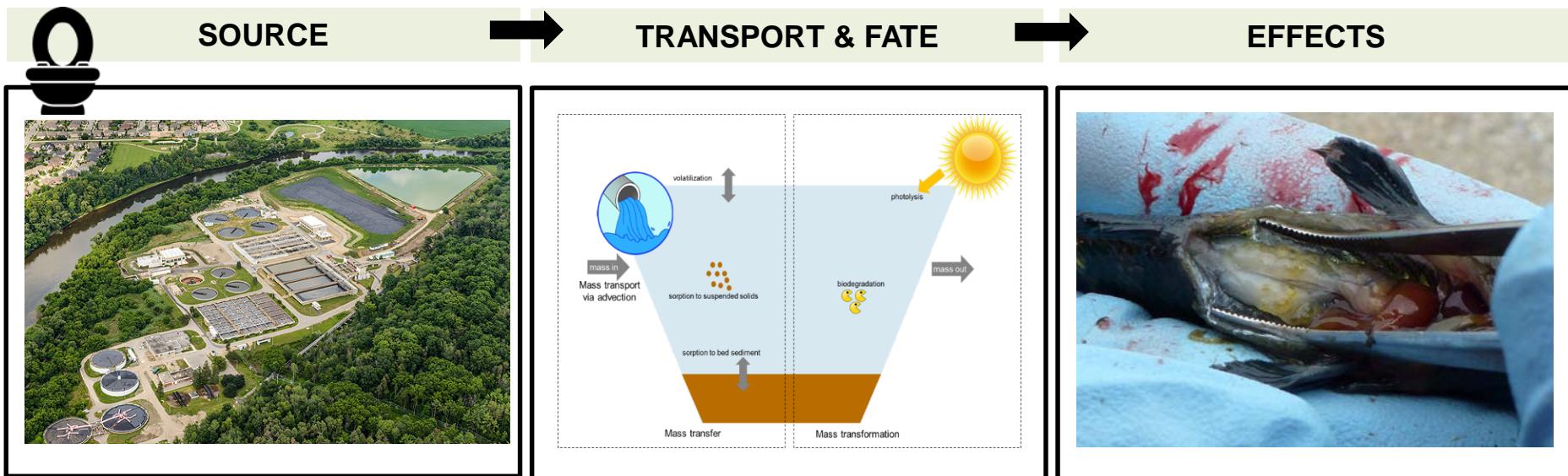


Highly associated with the presence of estrogens



Very difficult analysis

Modeling the exposure of rainbow darters) to endocrine disrupting chemicals: linkages of stressor concentrations (estrogens) to physiological consequences?



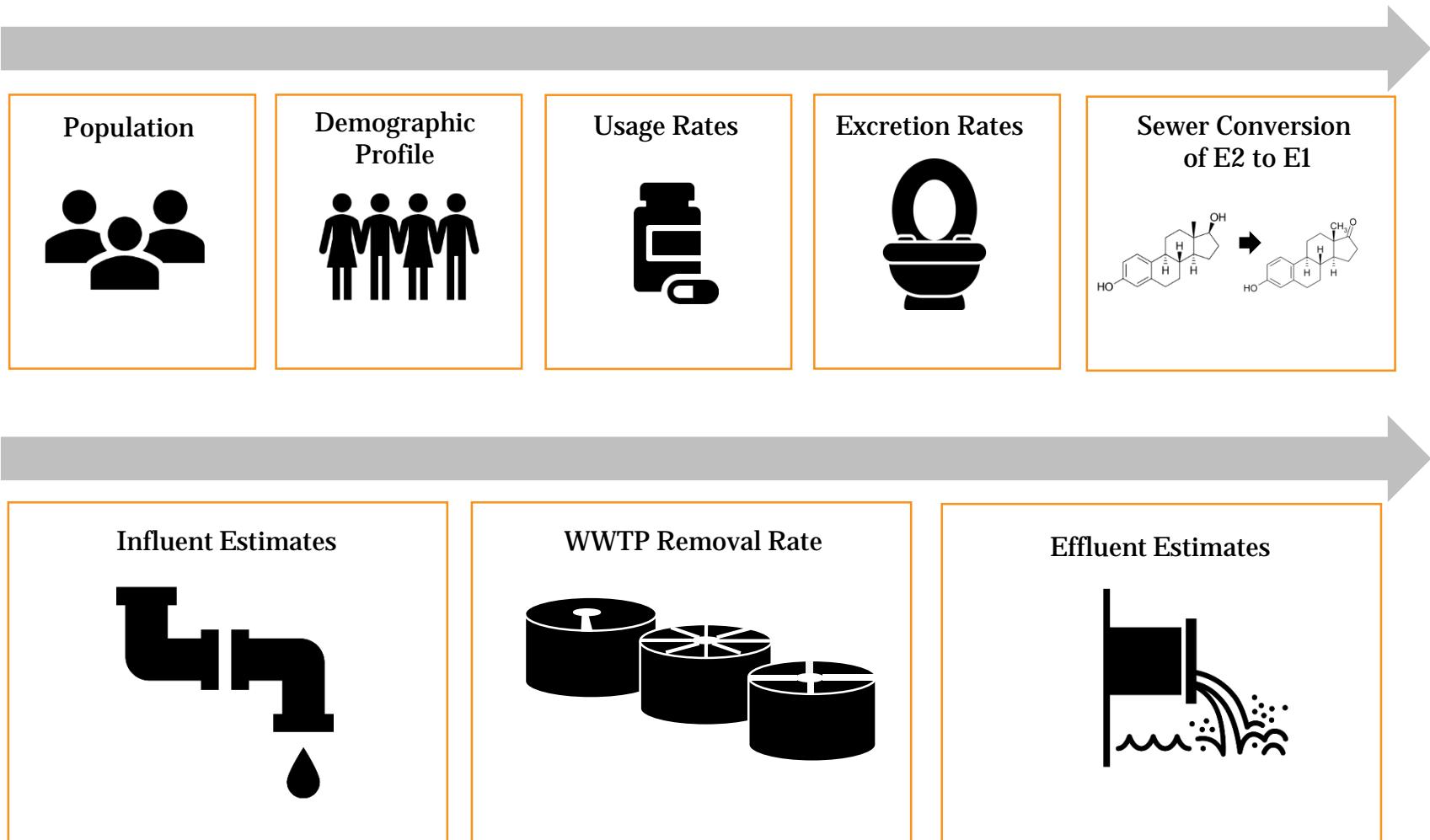
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3

Modelling Part 1: Source

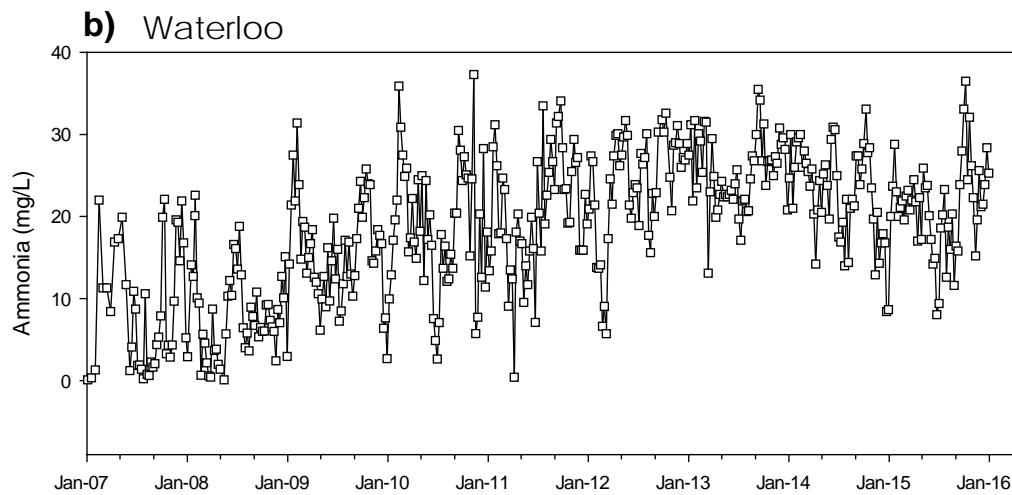
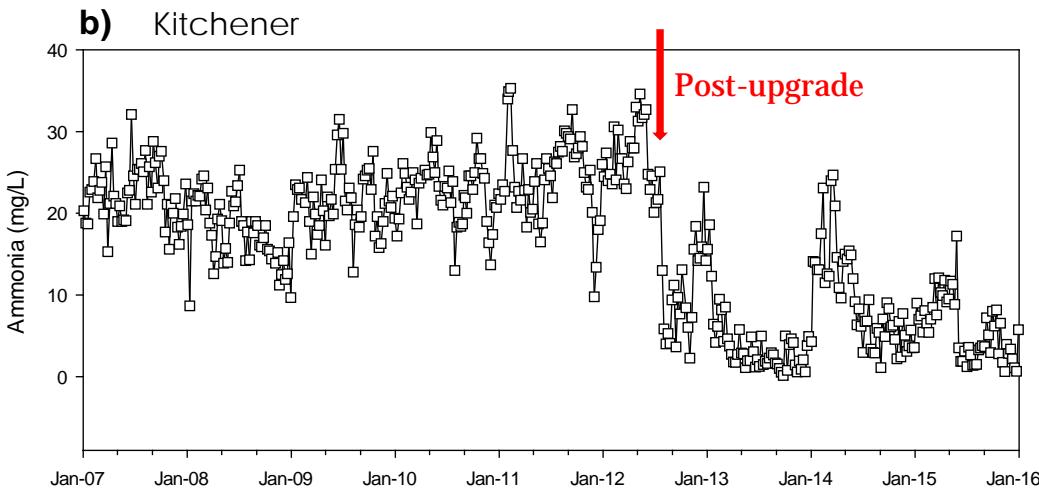
Multi-year prediction of estrogenicity in municipal wastewater effluents



$$\text{Estradiol Equivalence (EEQ)}_{mixture} = \sum C_i \times EEF$$

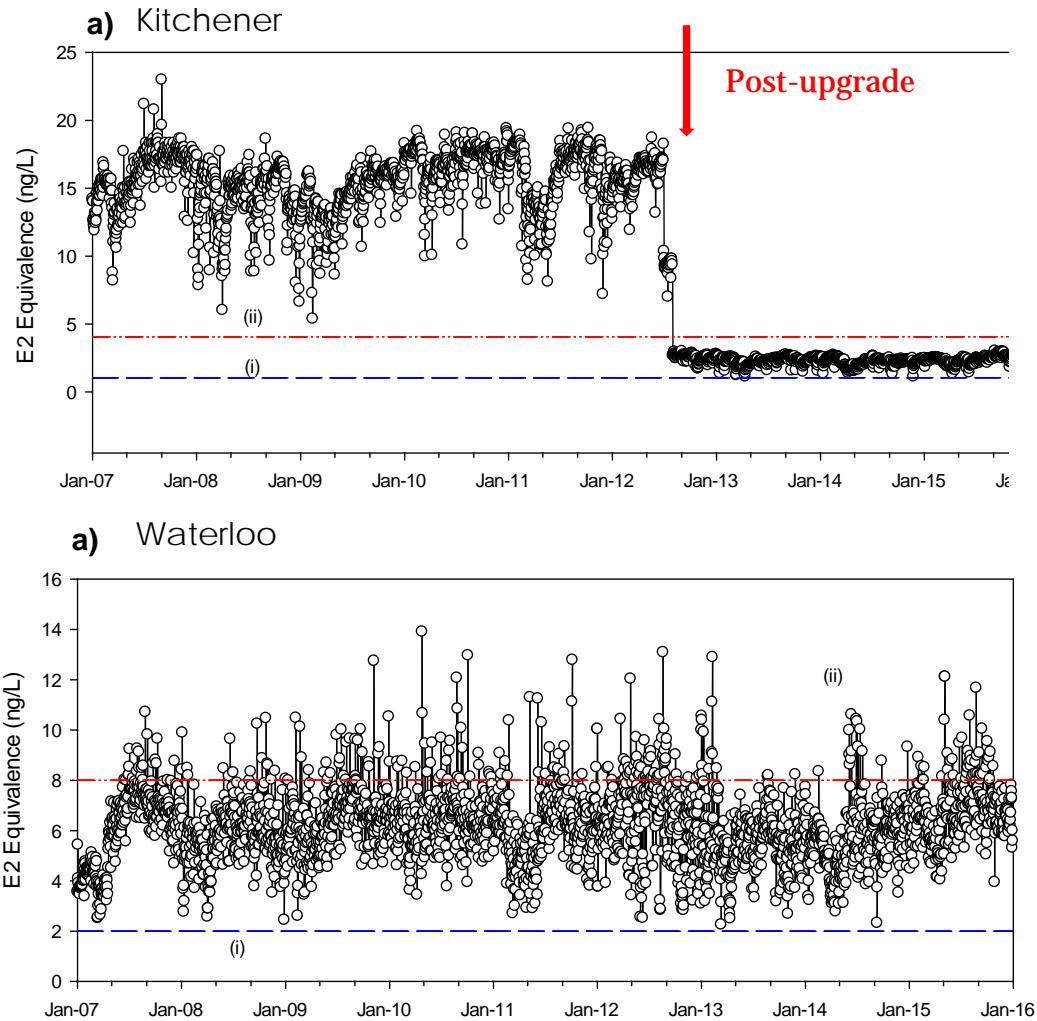
Modelling Part 1: Source

Ammonia (indication of treatment)



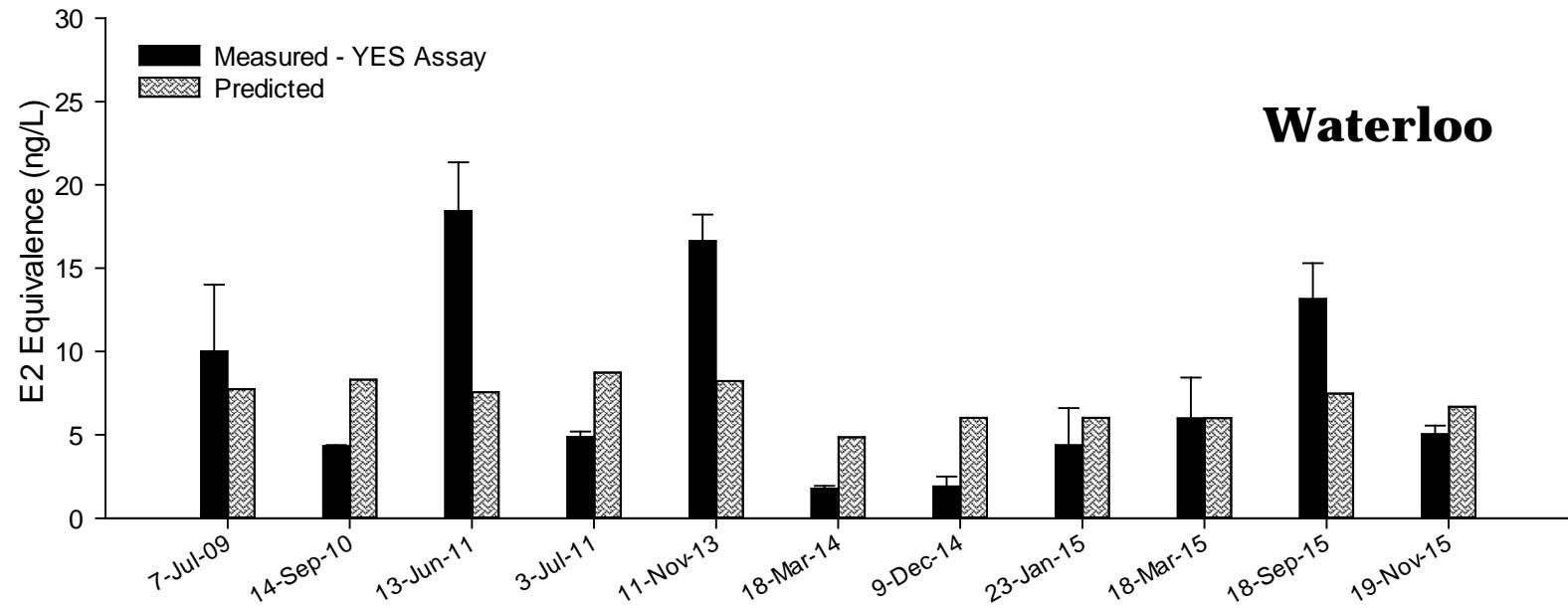
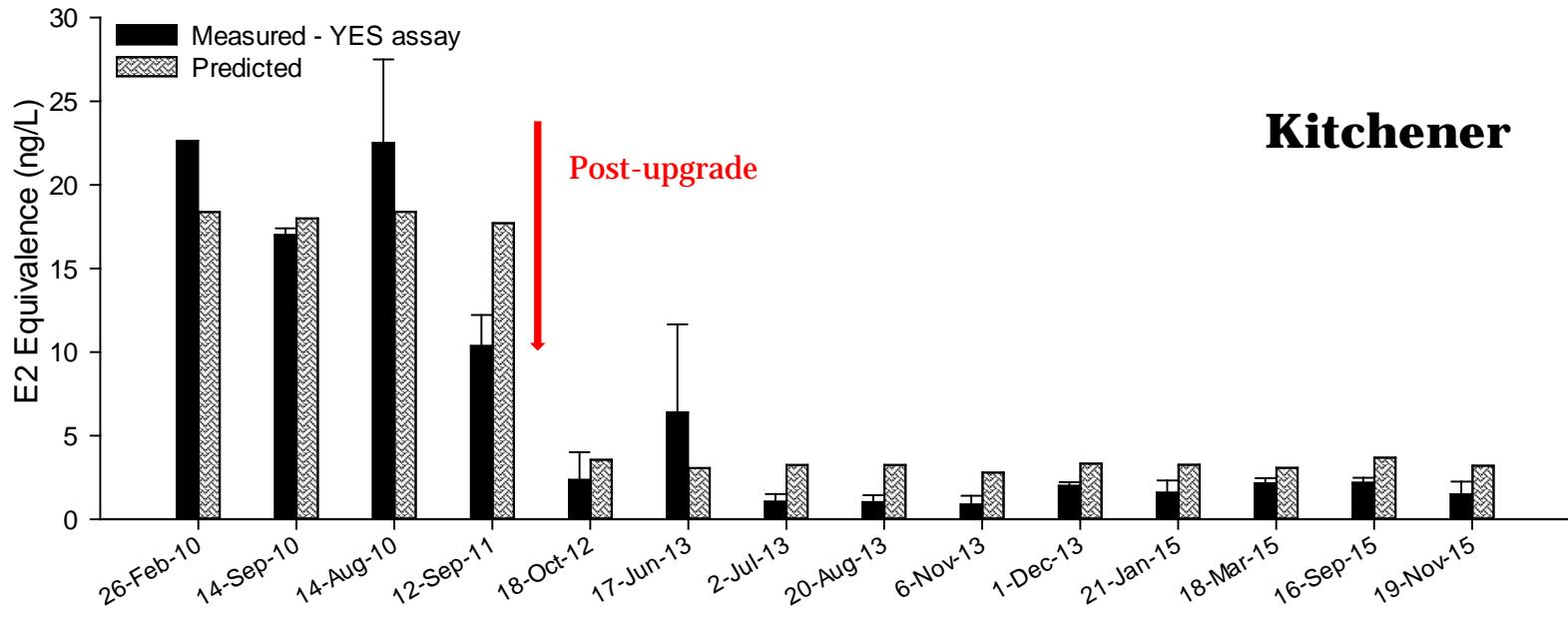
Modelling Part 1: Source

Estimated Total Estrogenicity (E2 Equivalency)

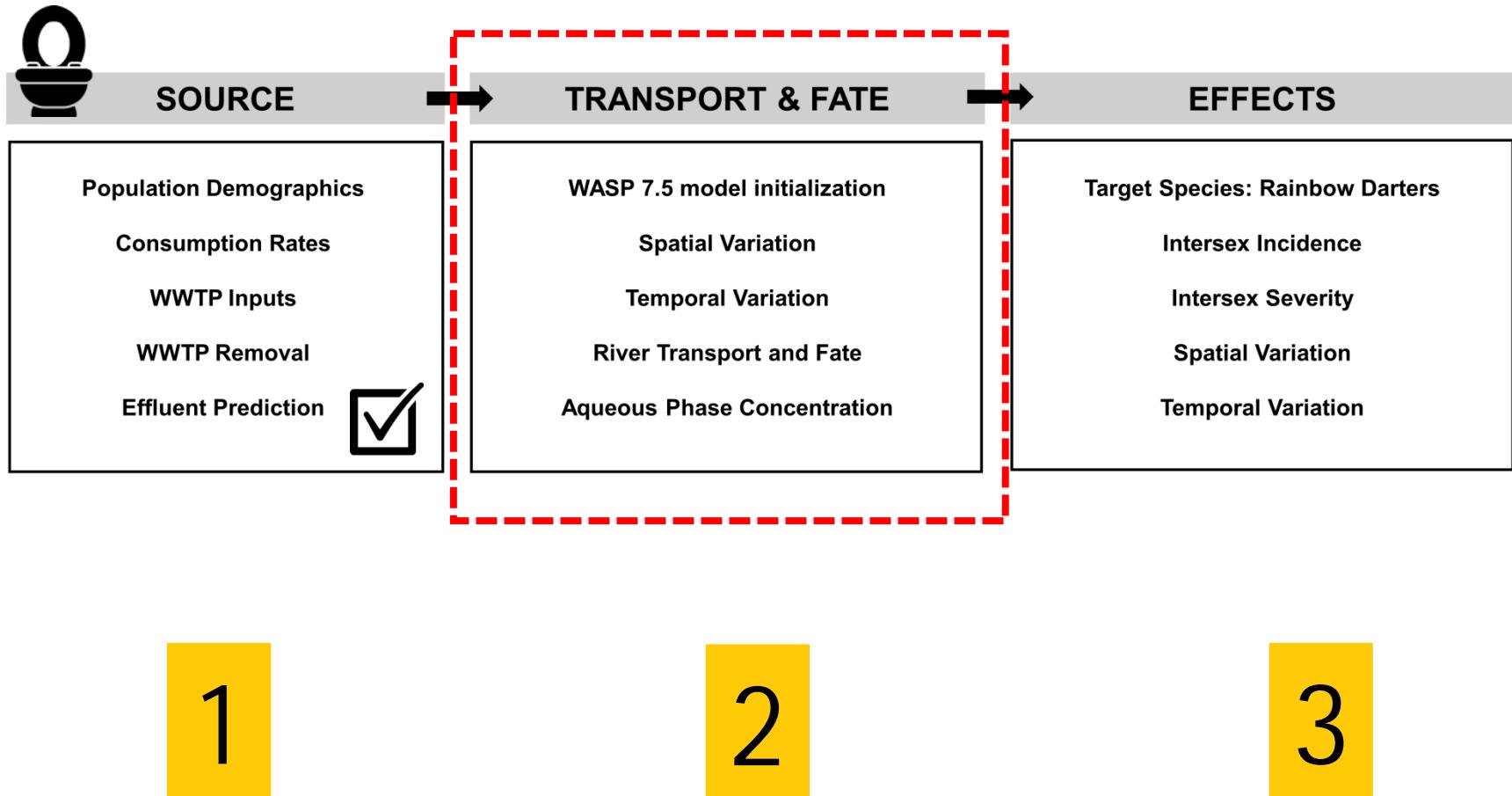


$$\text{Estradiol Equivalence (EEQ)}_{\text{mixture}} = \sum C_i \times \text{EEF}$$

Modelling Part 1: Source



Modelling Part 2: River Fate



Modelling Part 2: River Fate

Model Segmentation

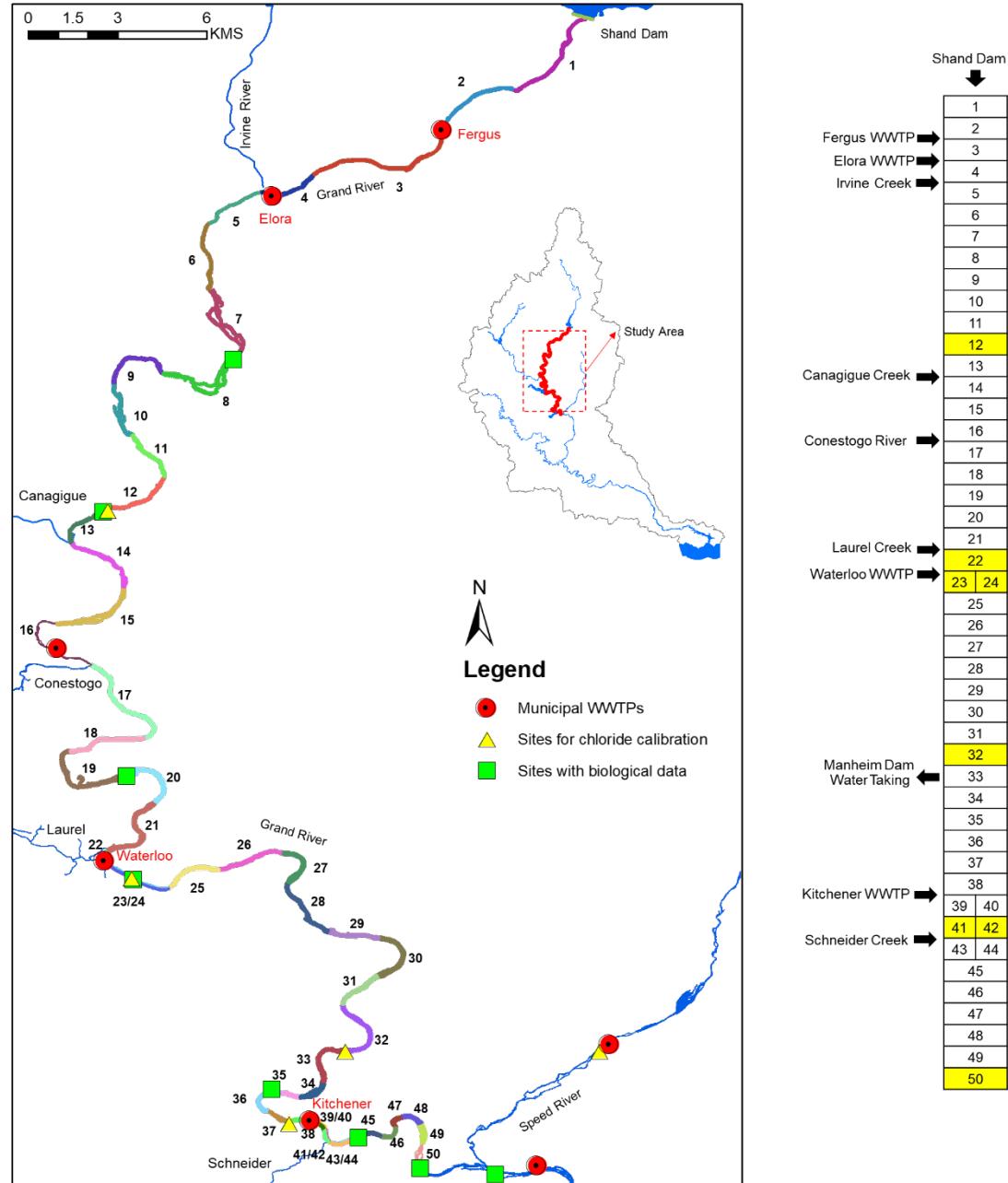
- 50 segments
- 80 km
- 4 MWWTPs
- 1 water withdrawal
- 5 creeks and tributaries
- 8 years
- 9 sites with biological data

Hydraulics Validation

- Water levels
- Chloride concentration

Model Platform

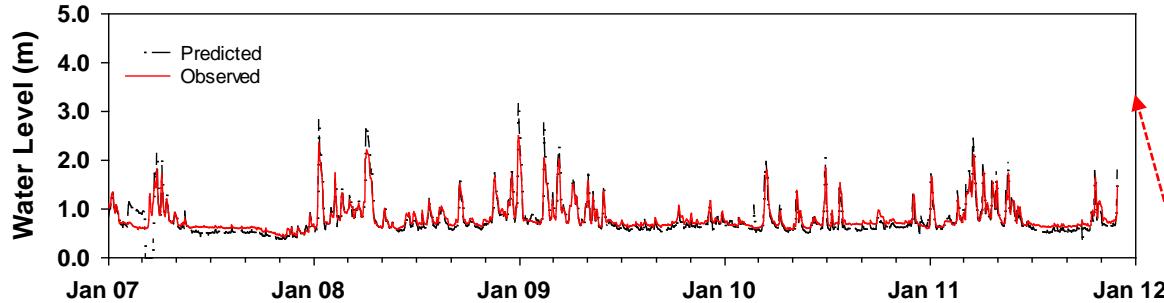
- WASP 7.5 by the US EPA



Modelling Part 2: River Fate

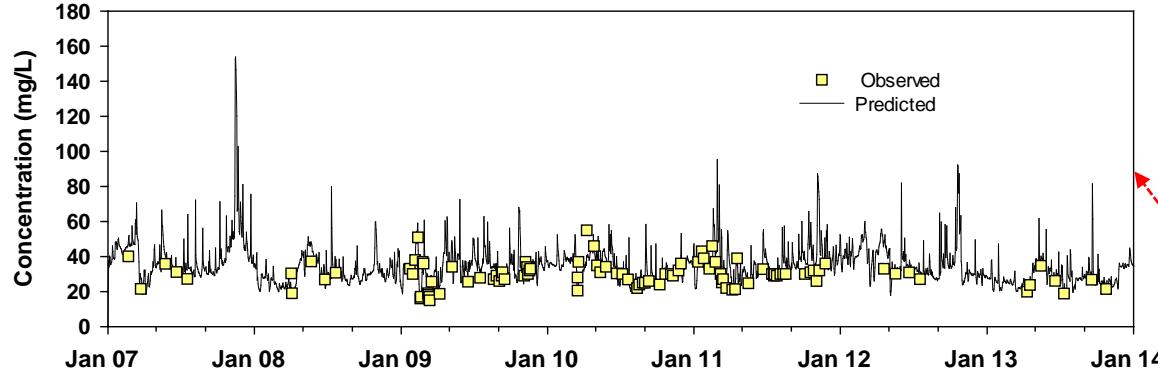
Hydraulics Validation

a) WL at Segment 37

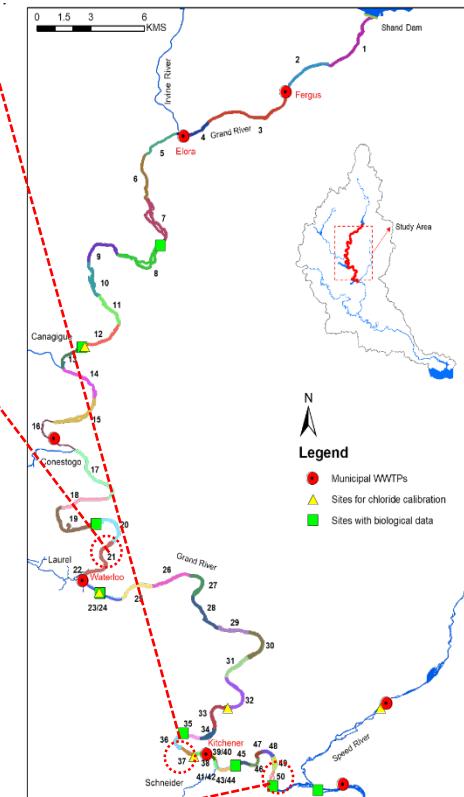
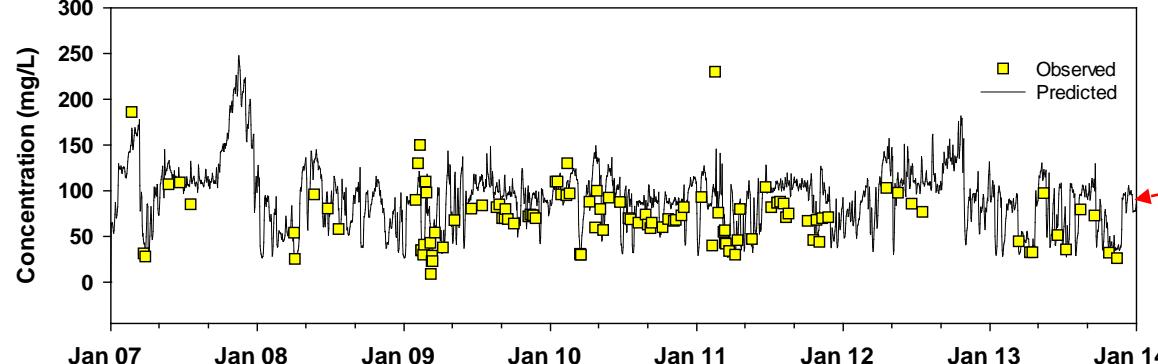


- Water levels
- Chloride concentration

b) Chloride at Segment 21 Waterloo



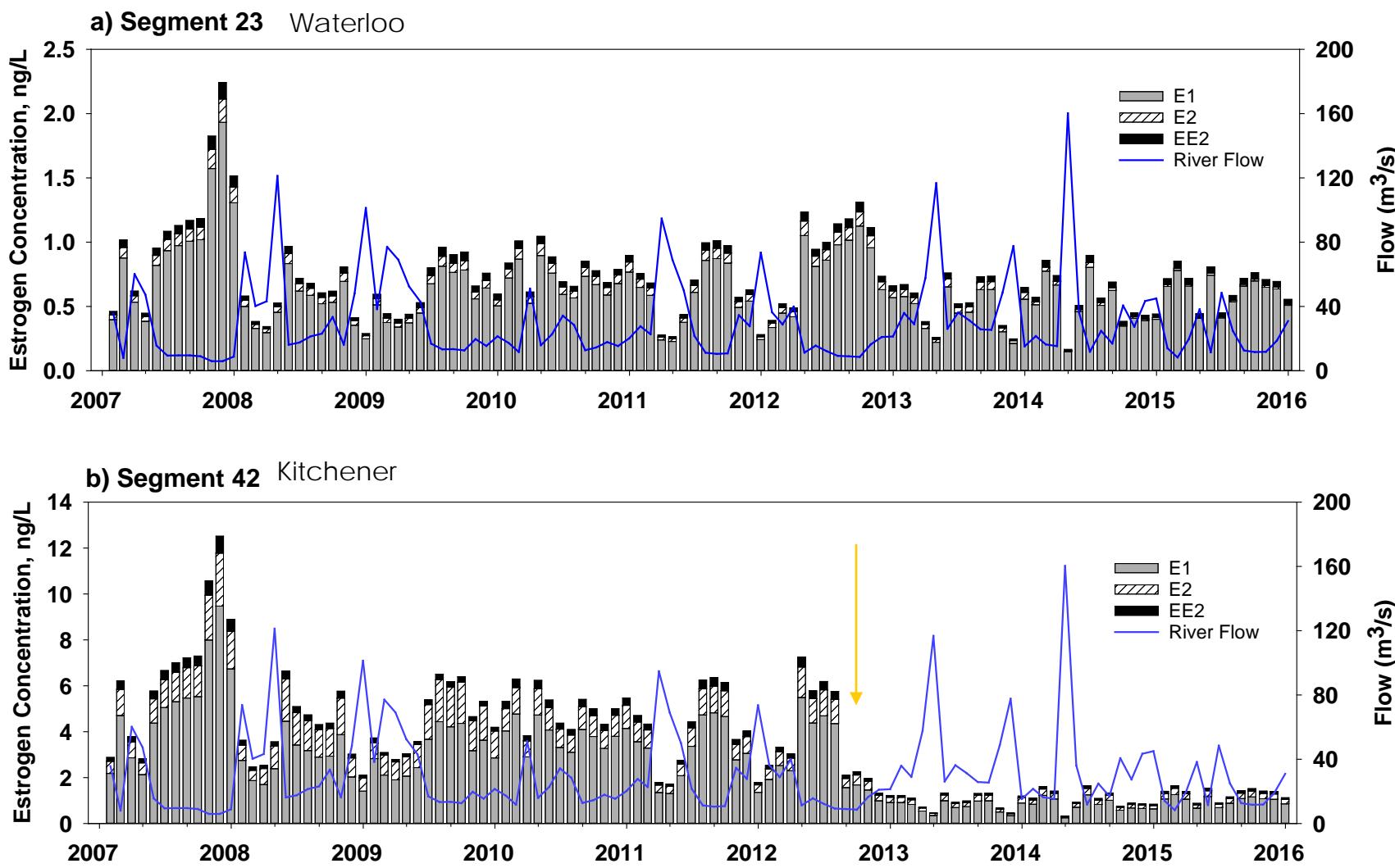
c) Chloride at Segment 50 Kitchener



Modelling Part 2: River Fate

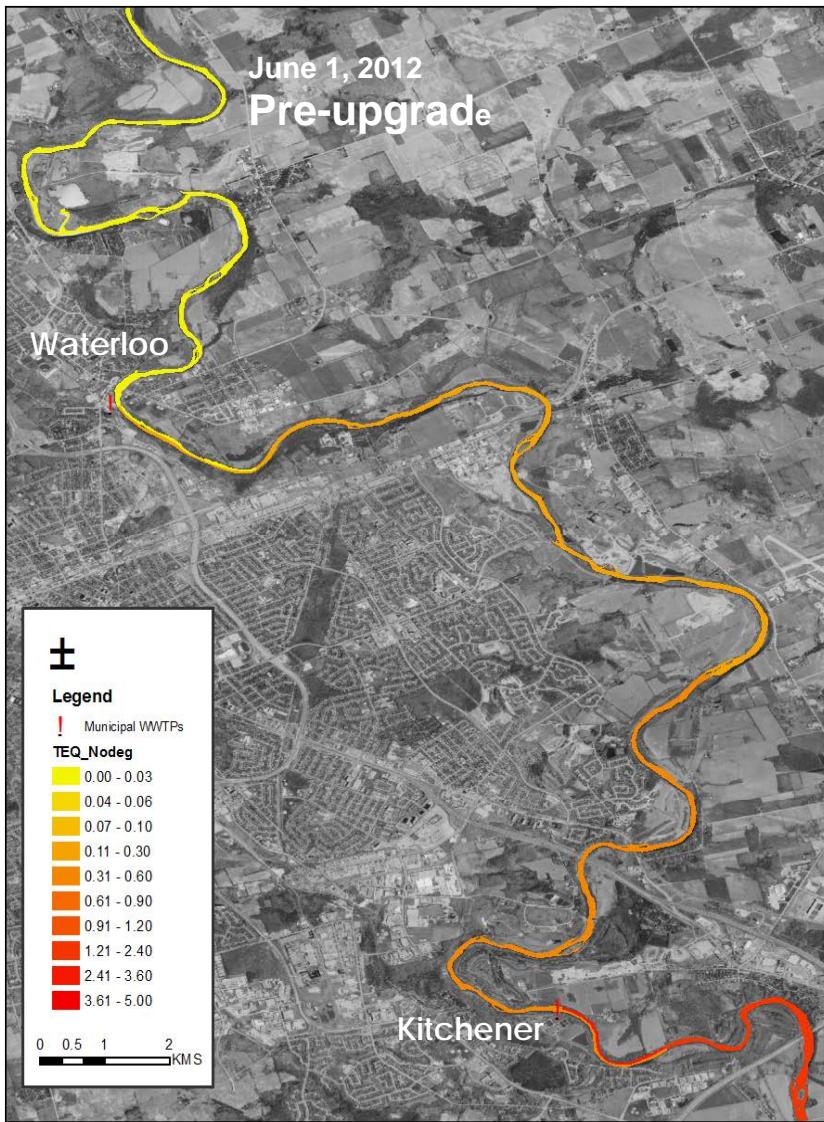
Temporal Patterns

- Very dependent on flow and treatment change
- Transformation important for some chemicals



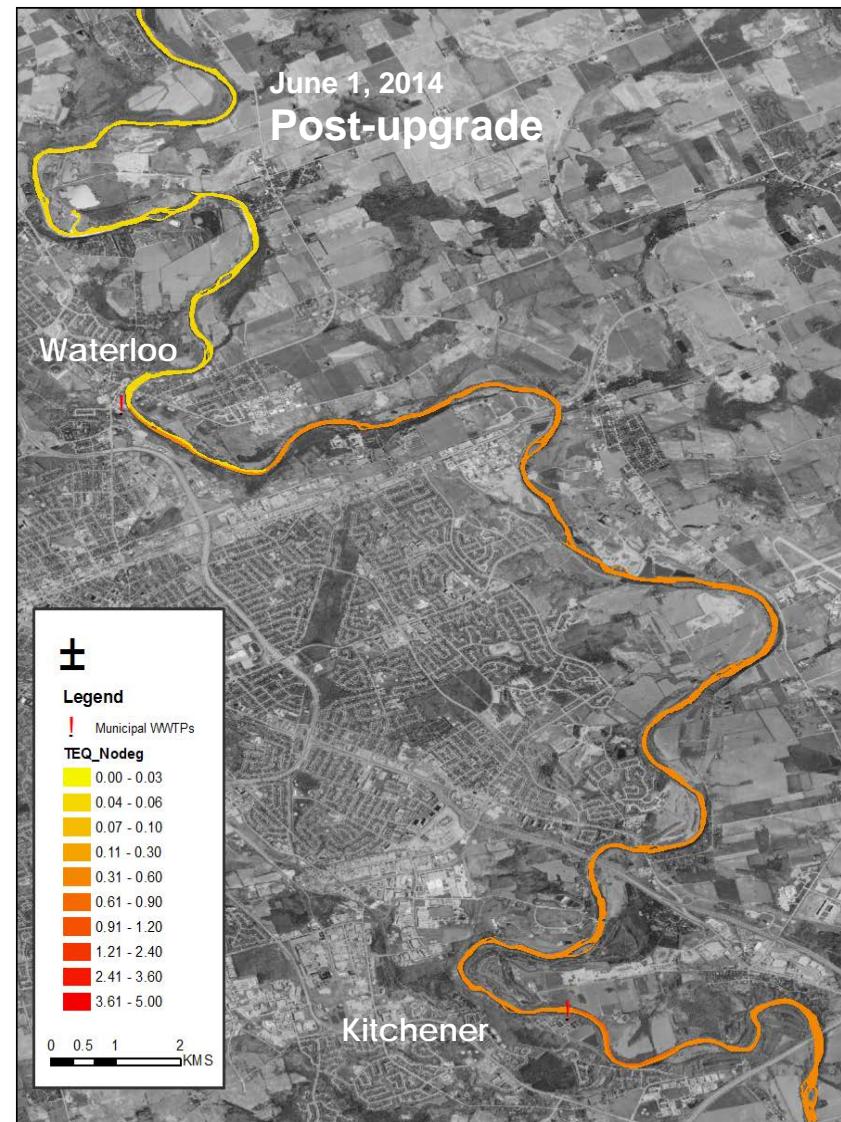
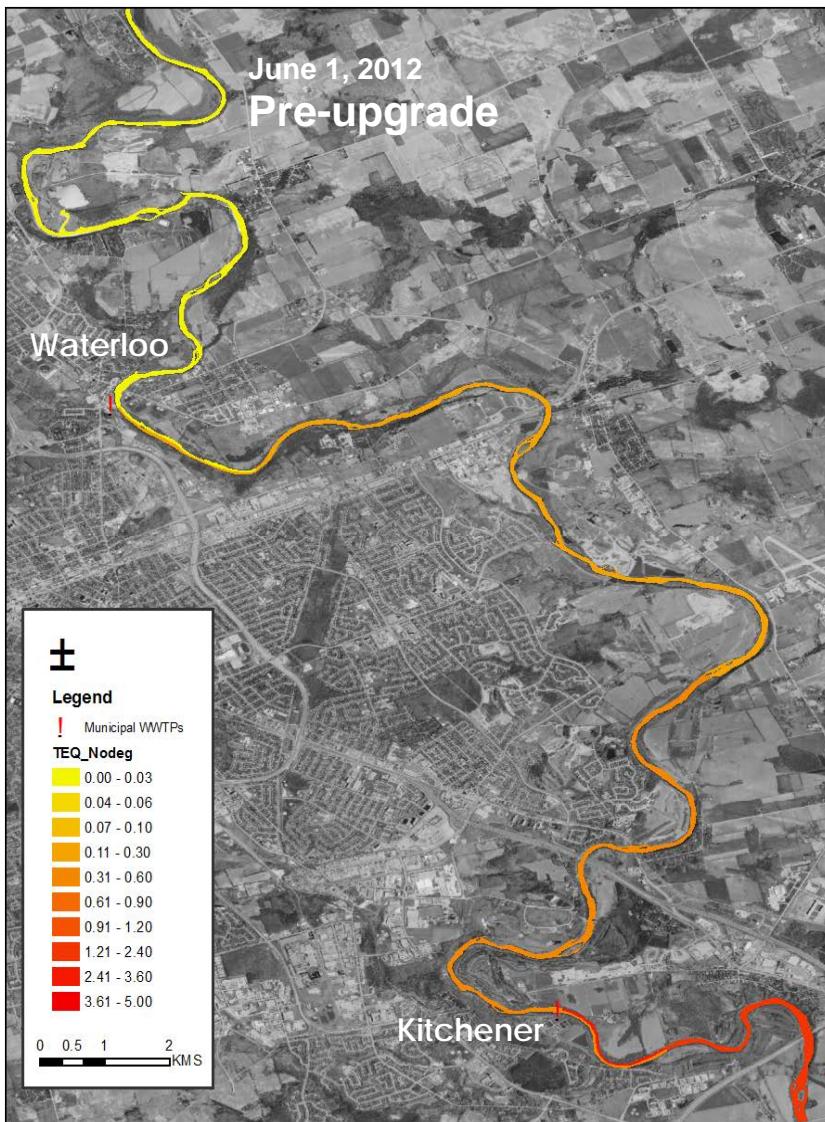
Modelling Part 2: River Fate

Spatial Patterns – Summer Low Flow

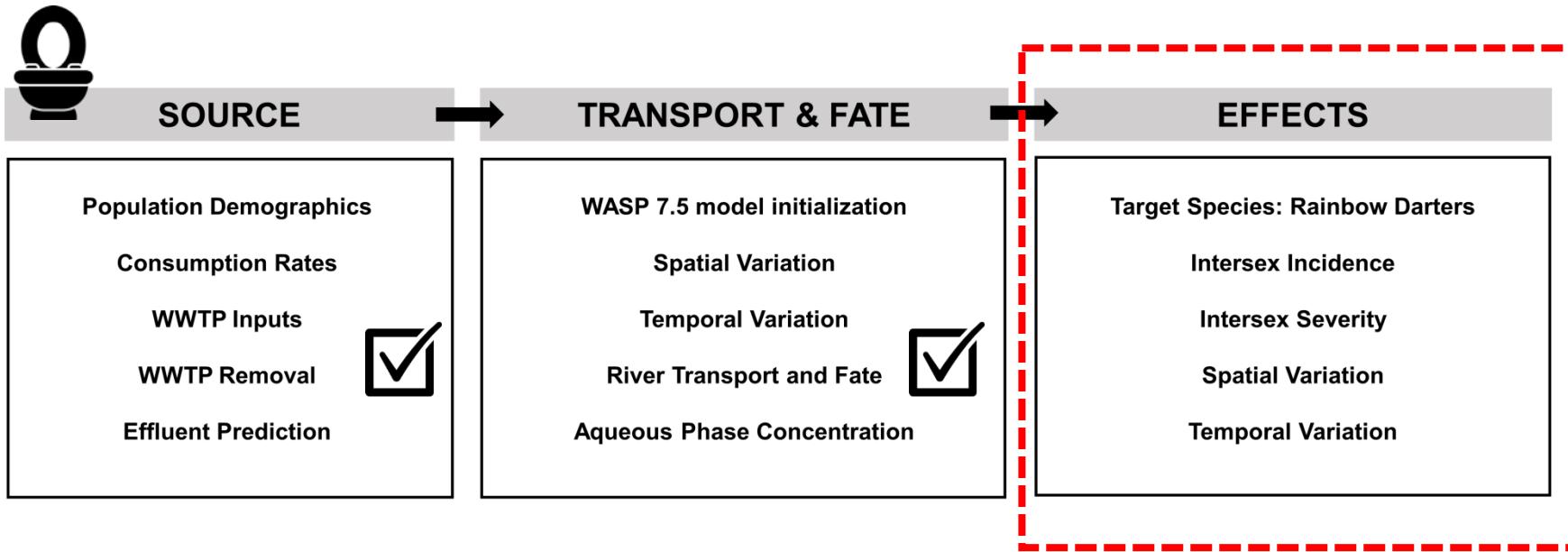


Modelling Part 2: River Fate

Spatial Patterns – Summer Low Flow



Modelling the exposure of rainbow darters to estrogens: comparison to field data?

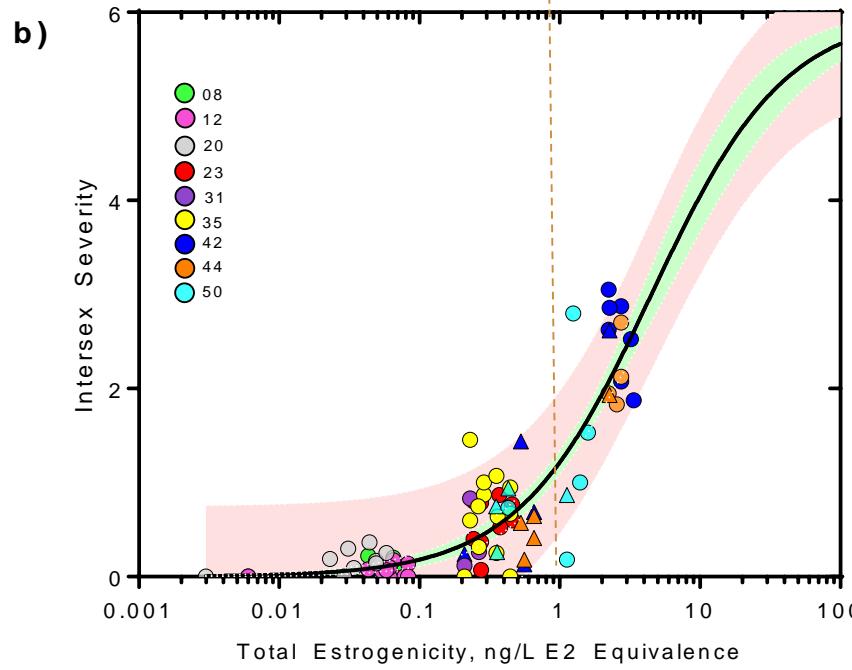
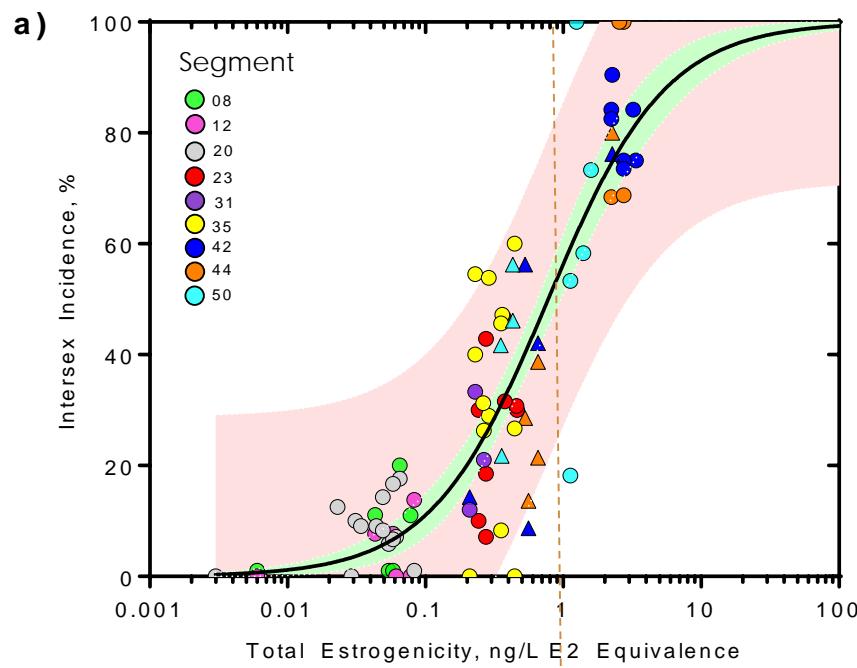


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Modelling Part 3: Linkages to Effects

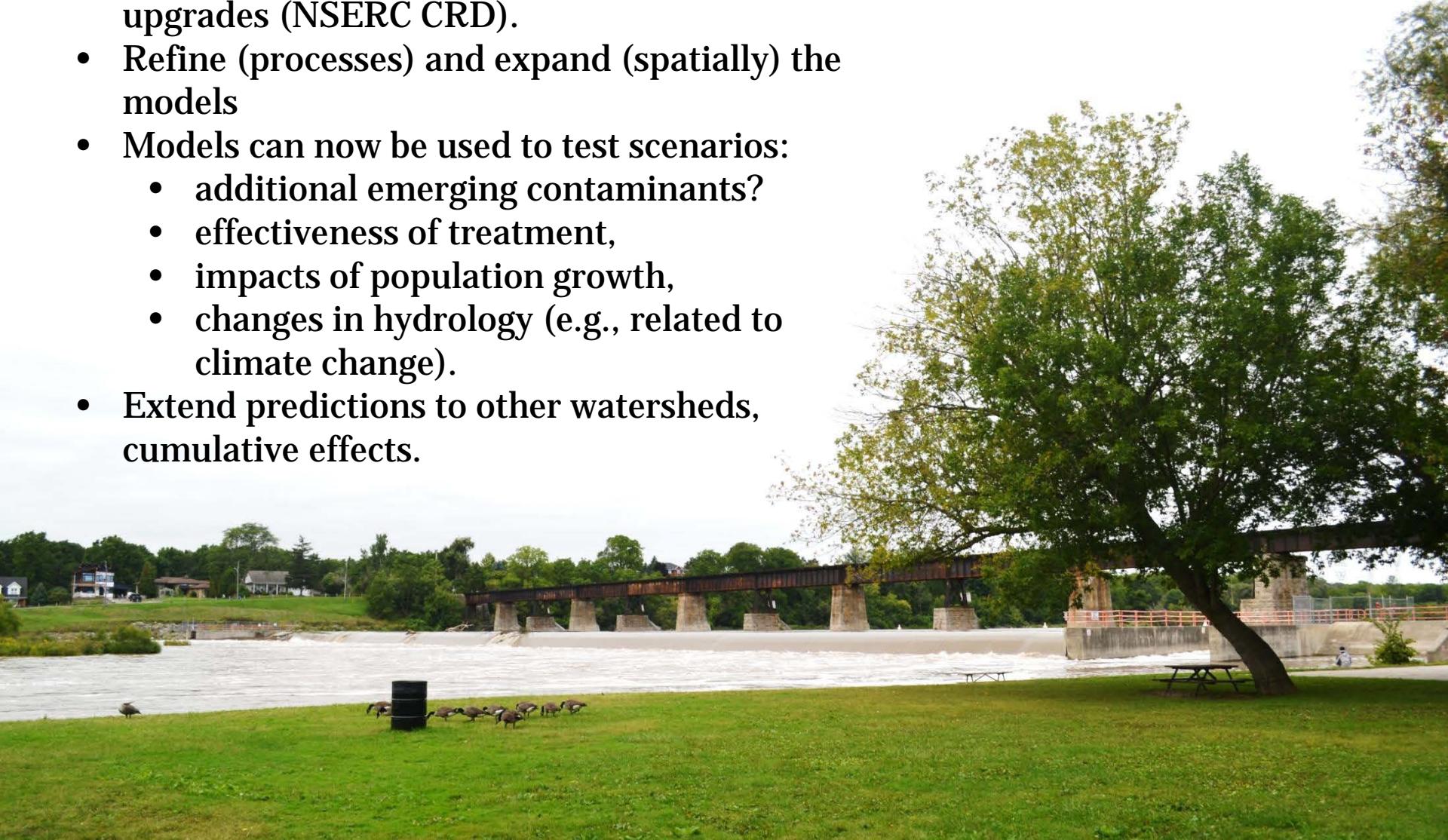


Intersex
Waterloo 2016

Moving Forward



- Studies that follow changes in the Grand River in response to the on-going major MWTP upgrades (NSERC CRD).
- Refine (processes) and expand (spatially) the models
- Models can now be used to test scenarios:
 - additional emerging contaminants?
 - effectiveness of treatment,
 - impacts of population growth,
 - changes in hydrology (e.g., related to climate change).
- Extend predictions to other watersheds, cumulative effects.



Effects directed analysis

Major Assumption

The estrogens estrone (E1), estradiol (E2), and ethinylestradiol (EE2) are the major contributors to the total estrogenicity

