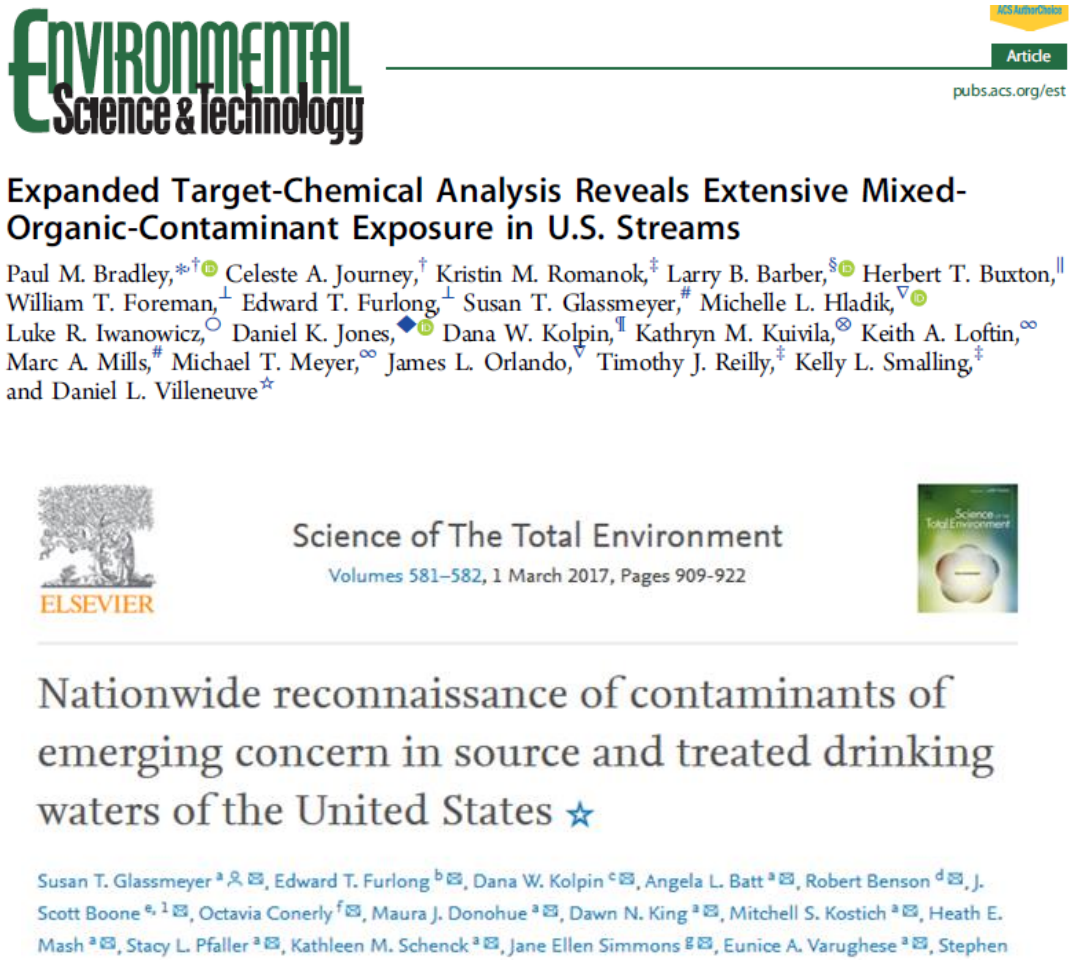
Novel Screening Methods to Assess Emerging Contaminants

Alvine Mehinto, PhD
Southern California Coastal Water Research Project

Emerging Contaminants (CECs) in U.S. Waters

- Ubiquitous CECs reported in freshwater and marine habitats nationwide
  - Pharmaceuticals, personal care products
  - Pesticides, flame retardants, plasticizers
  - Per- and polyfluoroalkyl substances (PFASs)…
- CECs monitored represent a small portion of chemicals in the environment
  - Little known about metabolites, bi-products
- Toxicity of complex mixtures is understudied



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Article

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Expanded Target-Chemical Analysis Reveals Extensive Mixed-Organic-Contaminant Exposure in U.S. Streams

Paul M. Bradley,*[†] Celeste A. Journey,[†] Kristin M. Romanok,[‡] Larry B. Barber,[§] Herbert T. Buxton,[∥] William T. Foreman,[⊥] Edward T. Furlong,[⊥] Susan T. Glassmeyer,[#] Michelle L. Hladik,[▽] Luke R. Iwanowicz,[○] Daniel K. Jones,[◆] Dana W. Kolpin,[¶] Kathryn M. Kuivila,[⊗] Keith A. Loftin,[∞] Marc A. Mills,[#] Michael T. Meyer,[∞] James L. Orlando,[▽] Timothy J. Reilly,[‡] Kelly L. Smalling,[‡] and Daniel L. Villeneuve[☆]

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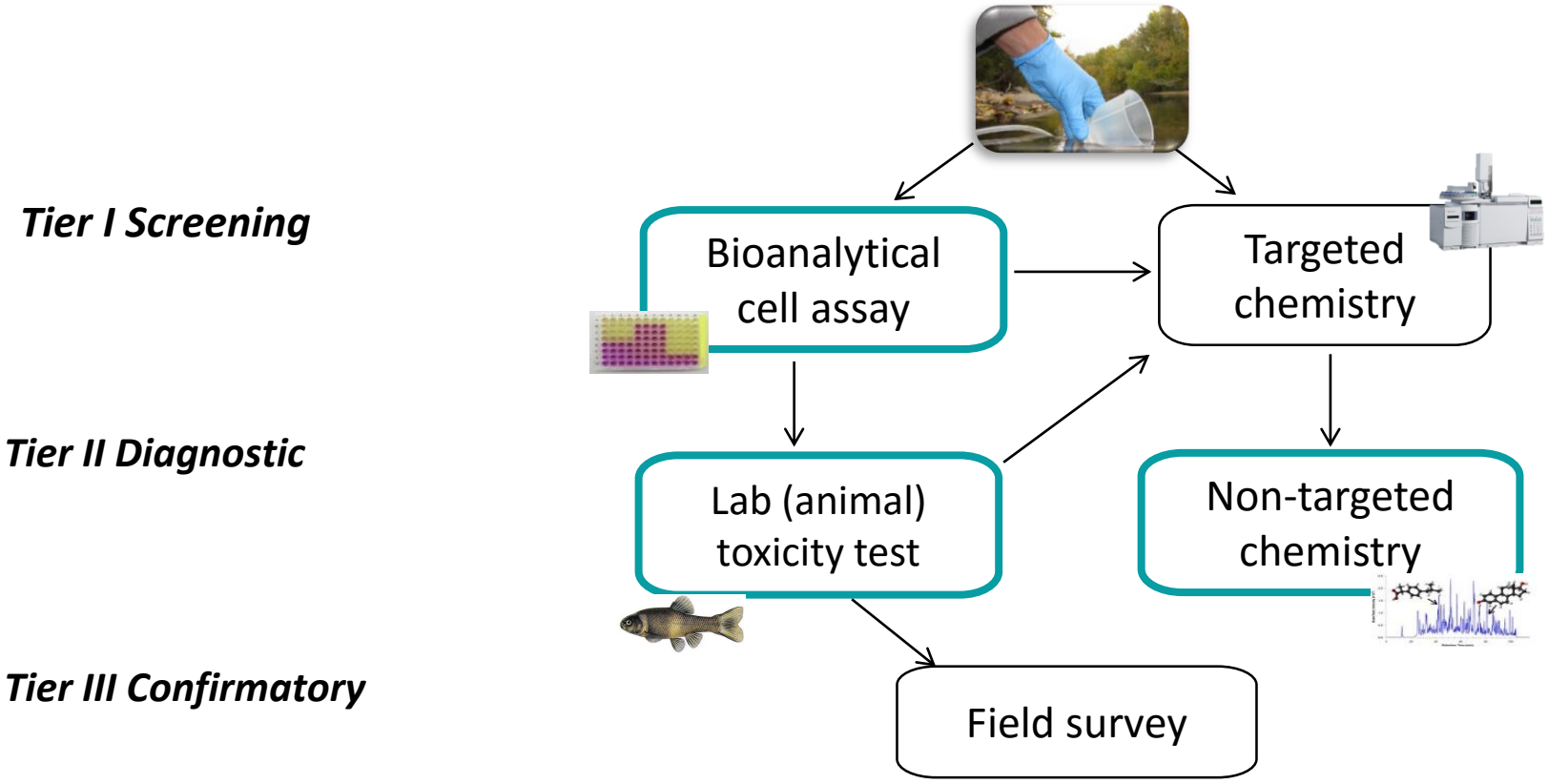
Nationwide reconnaissance of contaminants of emerging concern in source and treated drinking waters of the United States ☆

Susan T. Glassmeyer [a] ✉, Edward T. Furlong [b] ✉, Dana W. Kolpin [c] ✉, Angela L. Batt [a] ✉, Robert Benson [d] ✉, J. Scott Boone [e, 1] ✉, Octavia Conerly [f] ✉, Maura J. Donohue [a] ✉, Dawn N. King [a] ✉, Mitchell S. Kostich [a] ✉, Heath E. Mash [a] ✉, Stacy L. Pfaller [a] ✉, Kathleen M. Schenck [a] ✉, Jane Ellen Simmons [g] ✉, Eunice A. Varughese [a] ✉, Stephen

Effects-Based Monitoring to Streamline Practices

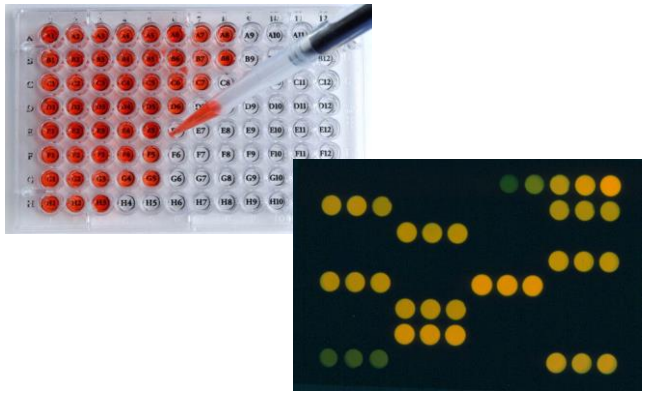


Proposed framework to expand coverage of analytes and tox. endpoints monitored; and improve ability to identify potentially harmful contaminants

Screening Tools Could Improve CEC Monitoring

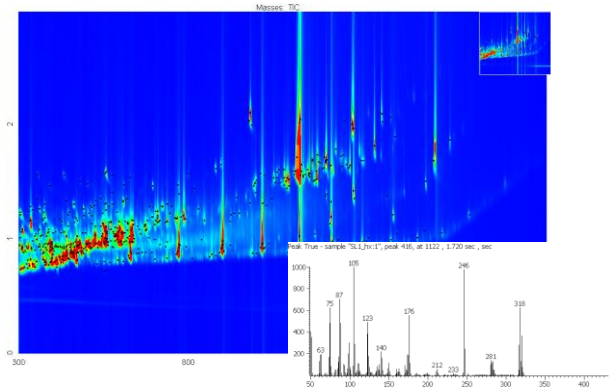
In vitro cell assays

Prioritization of sites/samples with bioactive contaminants



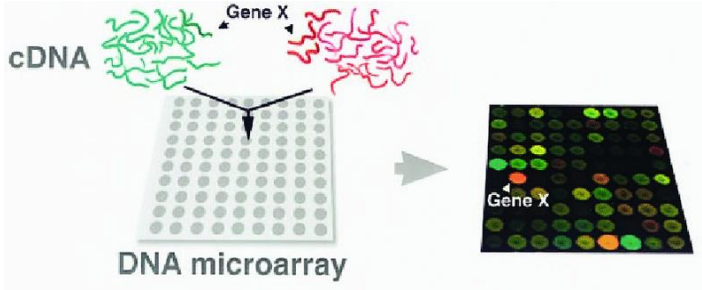
Non-targeted chemistry

Detection of unexpected compounds



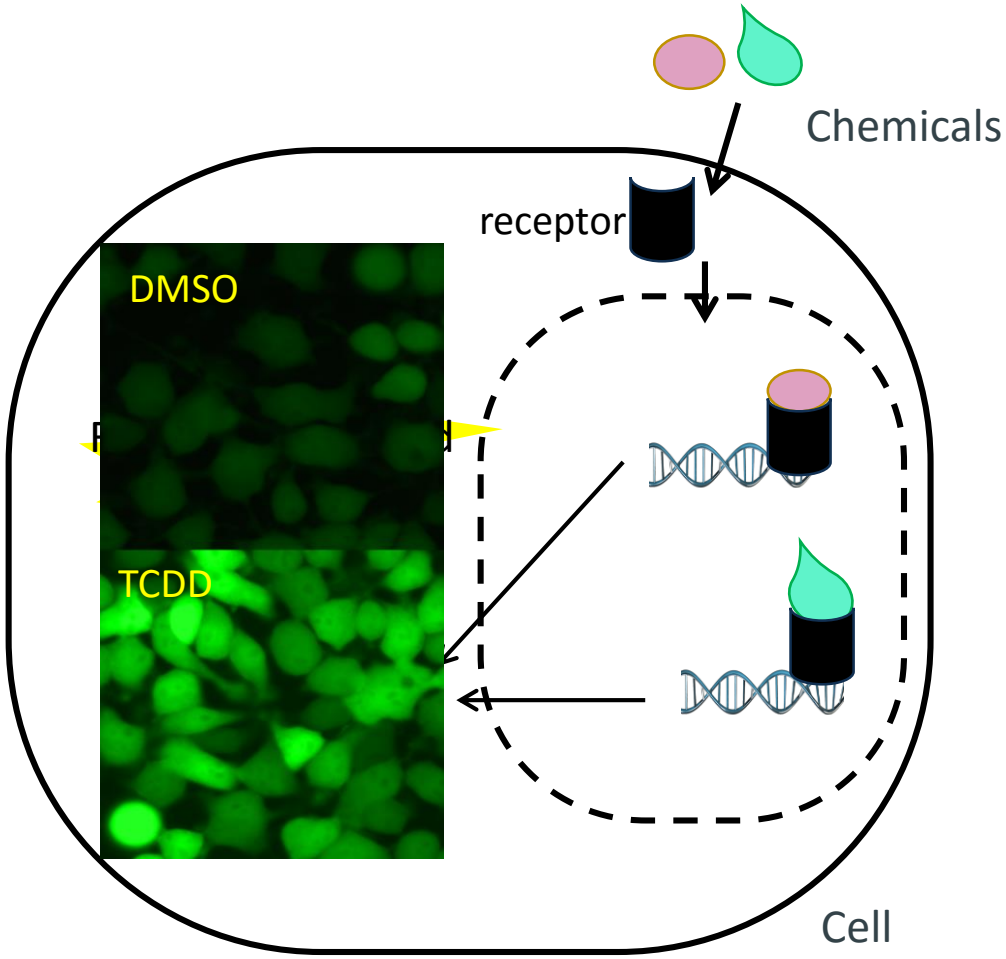
Omics technologies

Improved understanding of mixture effects and aquatic health



In Vitro Cell Assays

- High-throughput methods, rapid turnaround
- Cells engineered to track chemical interferences with biological pathways
  - Potential for linkage to toxicity
- Integrated measure of <u>all</u> chemicals acting via a common mode of action
  - Response calibrated against a known reference chemical

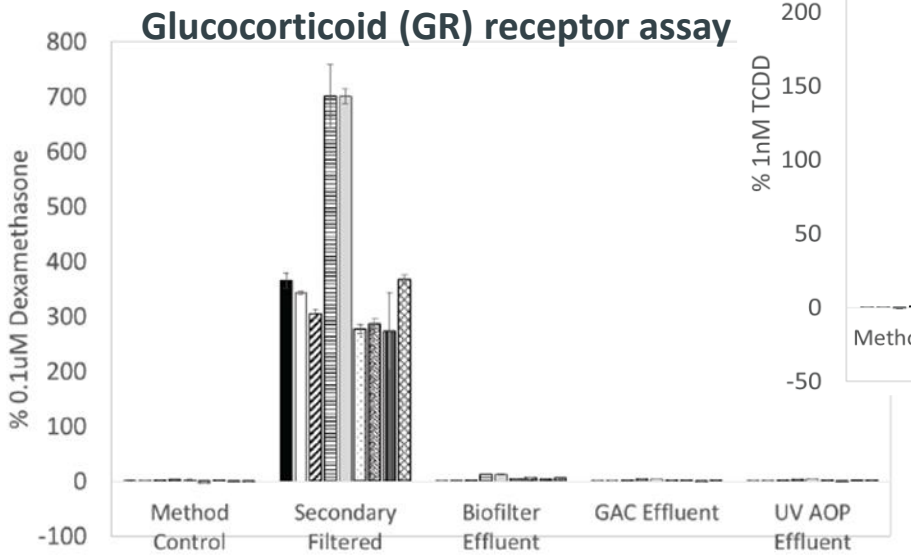


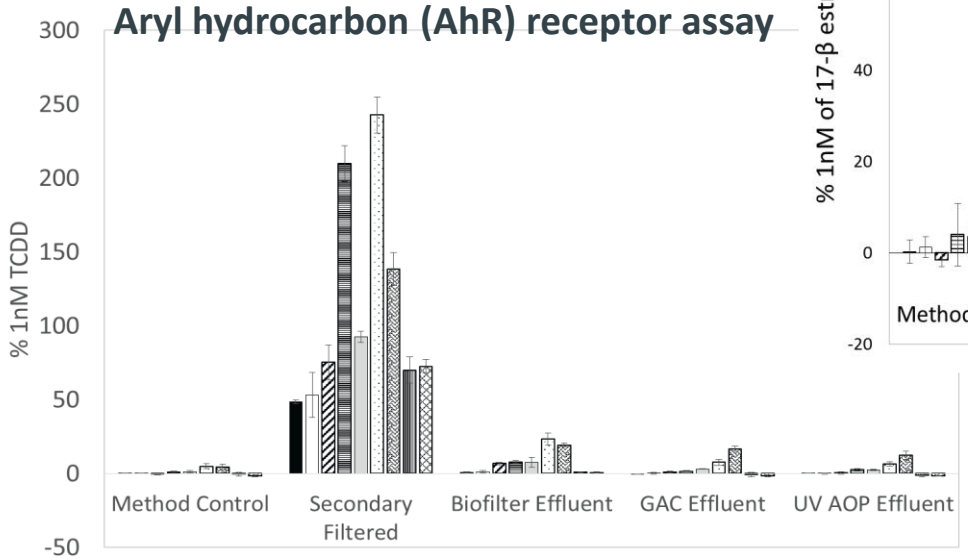
Cell Assays for Environmental Monitoring

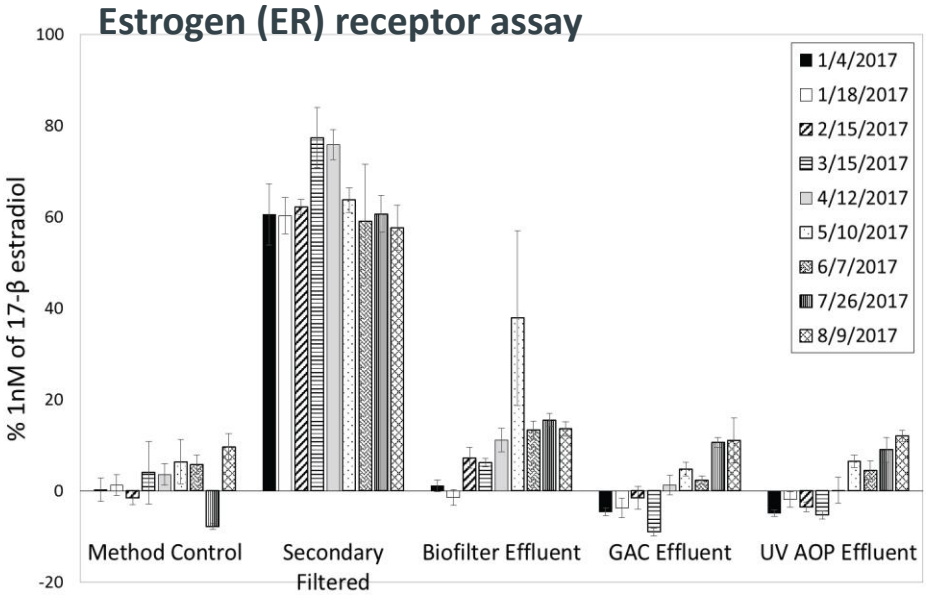
Receptor assay	Toxicity predicted	Known chemicals
Estrogen Receptor (ER)	Well established for aquatic life - *Impaired sexual development and reproduction*	Estrogens, alkylphenols
Aryl Hydrocarbon Receptor (AhR)	Well established for aquatic life and human - *Developmental anomalies, tumors*	Dioxin-like compounds, PCBs, PAHs
Glucocorticoid Receptor (GR)	Suspected impact on immune and metabolic functions	Anti-inflammatory steroids
Thyroid Receptor (TR)	Suspected impact on neurodevelopment and metabolism	Pesticides, bisphenols
Peroxisome Proliferated-activated Receptor (PPAR)	Suspected impact on metabolism	Pharmaceuticals, phthalates
Pregnane X Receptor (PXR)	Relatively non-specific mode of action - *Possible impaired liver functions*	Broad classes of CECs

Benchmarking Water Quality

- Monthly sampling of a direct potable reuse pilot plant
- Bioactivity reflected level of treatment and removal of contaminants







Carollo Engineers, Inc. 2017. Reuse Demo. Project

Surrogate Measure of Chemical Exposure

- 10 study sites in the Russian River watershed
- Samples with ER bioactivity had detectable levels of estradiol (E2) and estrone

Water samples

	Effluent	Mirabel	Piner Crk	El Roble
ER BEQ (ng/ E2/)	**1.9**	<0.5	<0.5	<0.5
Targeted chemical analyses (ng/L)				
Estradiol	**0.6**	<0.5	<0.5	<0.5
Estrone	**11.0**	0.5	0.6	<0.5
Bisphenol A	**12.0**	<10	55.0	< 10
4-Nonylphenol	**247**	25.4	53.3	63

Sediment samples

	Mirabel	Piner Crk	El Roble
ER BEQ (ng E2/g)	<0.01	**0.09**	<0.01
Targeted chemical analyses (ng/g)			
Estradiol	<0.12	**0.23**	<012
Estrone	0.14	**1.3**	0.28
Bifenthrin	<0.2	**130**	<0.2

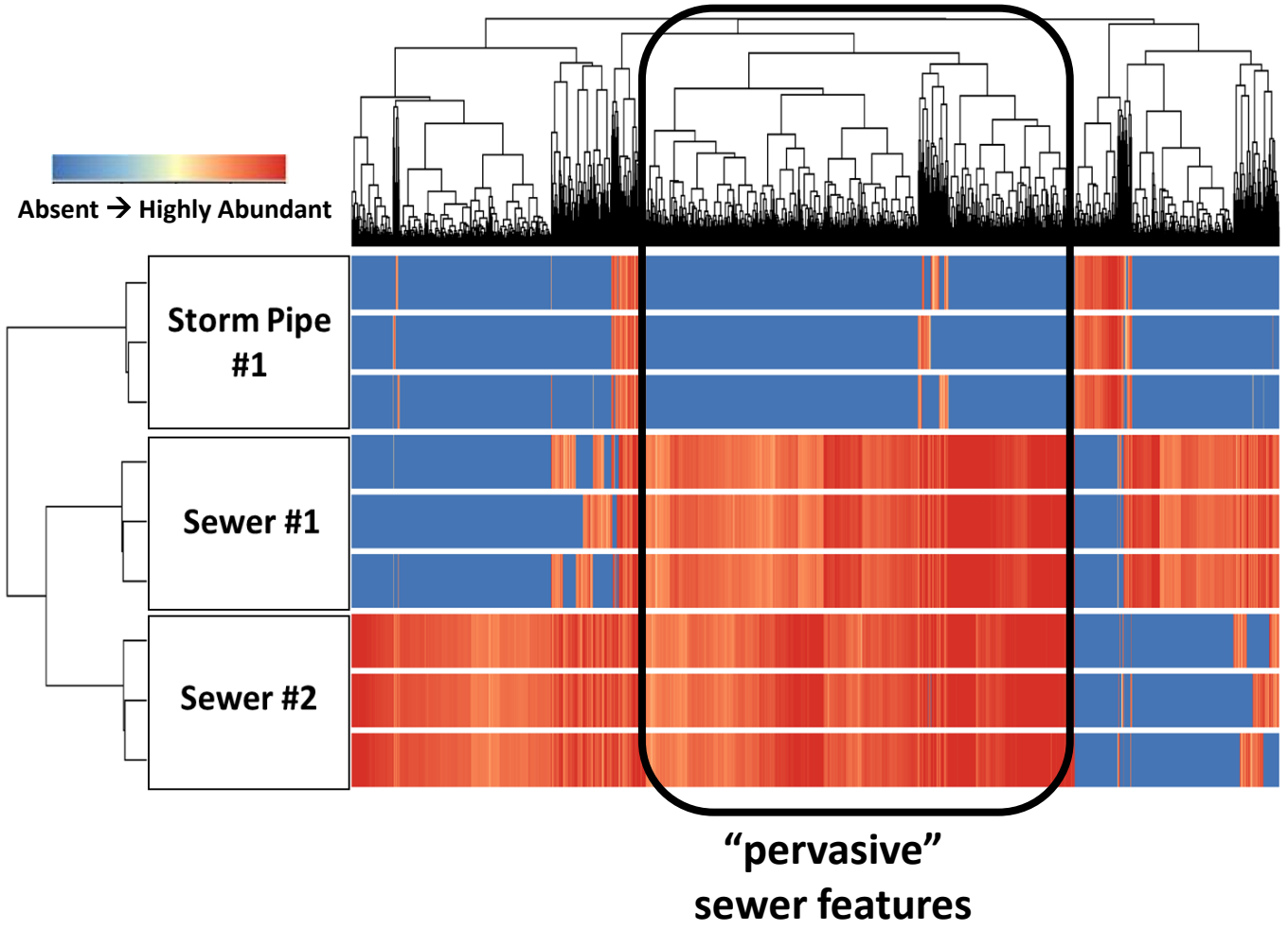
Maruya et al. 2018. SCCWRP 1020

Non-Target Chemical Analyses (NTA)

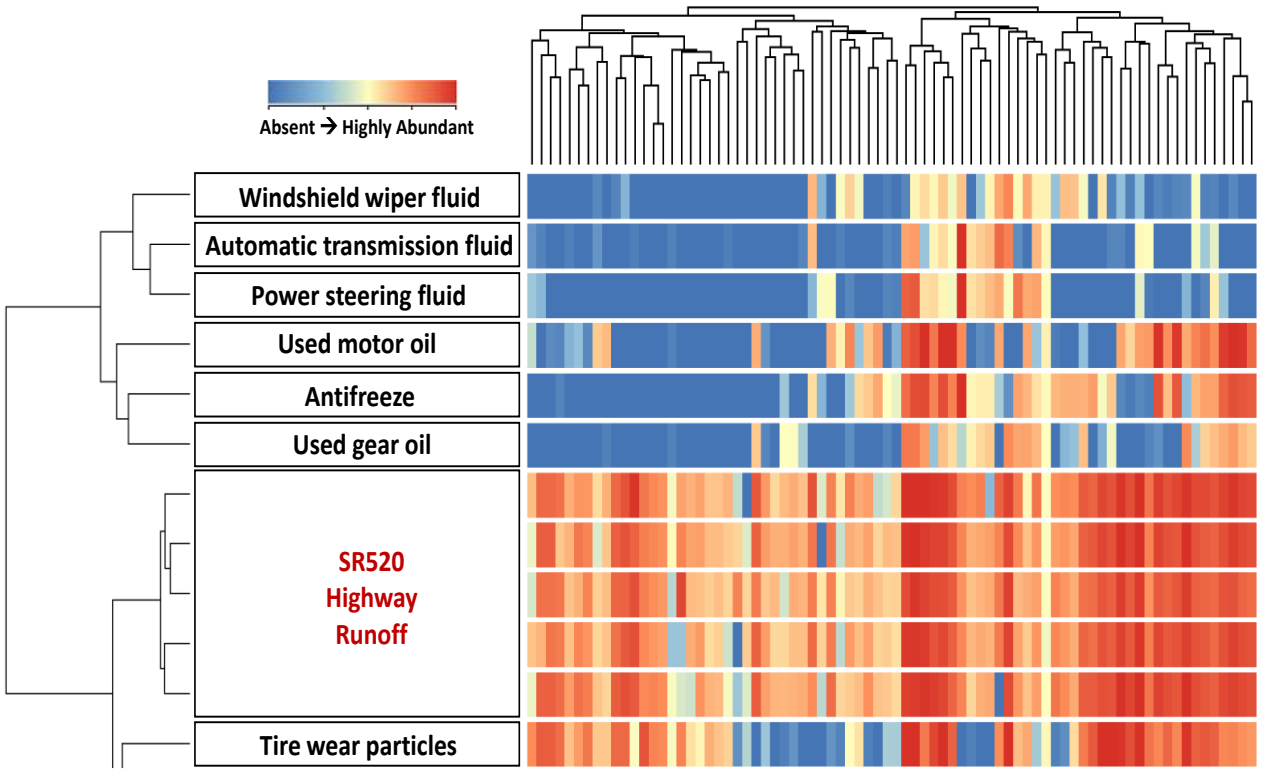
- Broad spectrum screening of all chemicals present
  - Identity of specific chemicals confirmed later using reference standards
- Promote discovery of new/emerging contaminants that may be toxic
- Potential to develop unique fingerprinting signature for source tracking

Chemical Fingerprinting for Source Tracking…

- Limited availability of effective source tracking tools
- Preliminary fingerprints show potential of NT for source apportionment



… and Toxicity Identification

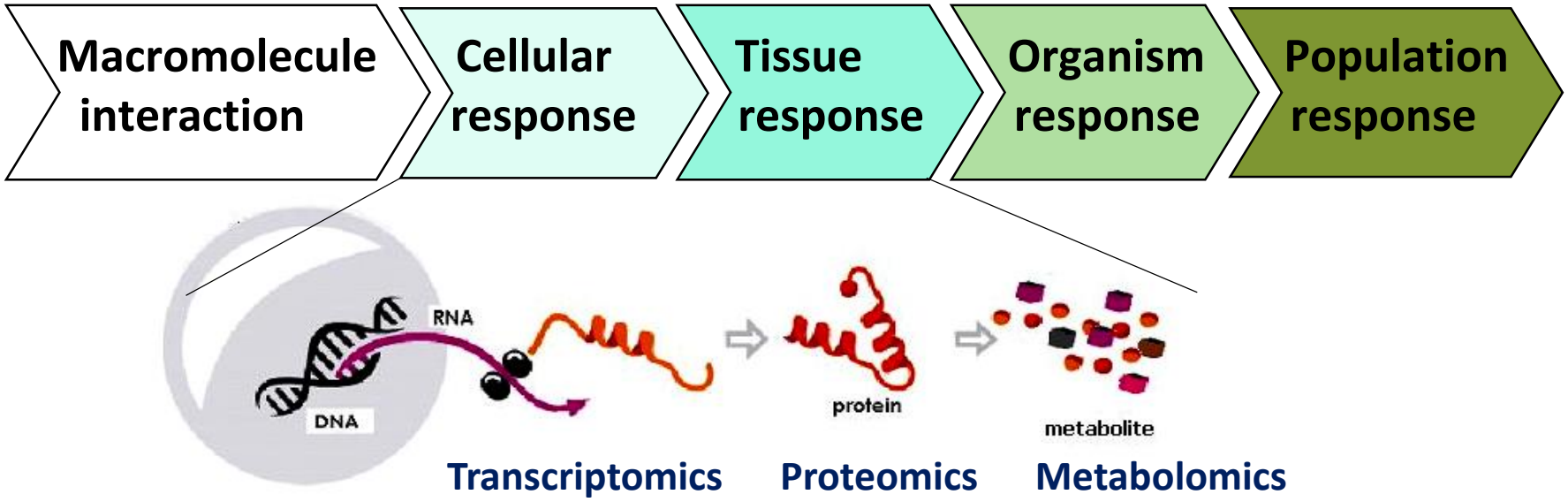


- Fingerprinting of automotive fluids, urban runoff and receiving waters
- Tire dust & motor oil identified as principal sources of pollution in urban runoff
- Lab and field studies indicate that tire wear particles caused fish mortality

Peter et al. ES&T 2018

Omics Technologies

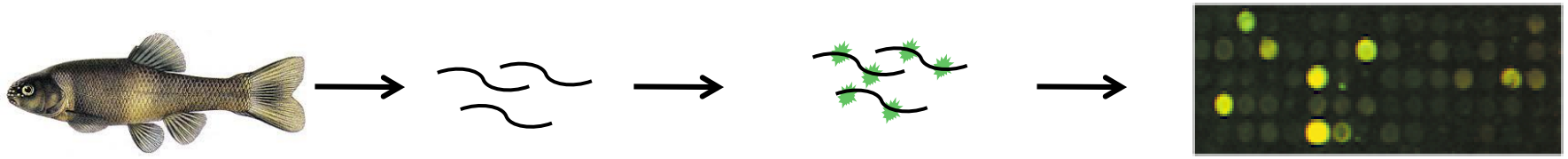
- Study of small molecules (genes, proteins, metabolites) and associated biological pathways
- Potential to link to adverse effects at the organismal and/or predict toxicity
- Omics technologies could provide early warnings before damage becomes irreversible



Biomarkers for Predictive Toxicology

- Prolonged exposure to estrogens known to impact sexual development and reproduction
    - Leading to collapse of the population

- Lab and field studies conducted to determine whether gene expression profiles can help predict adverse effects

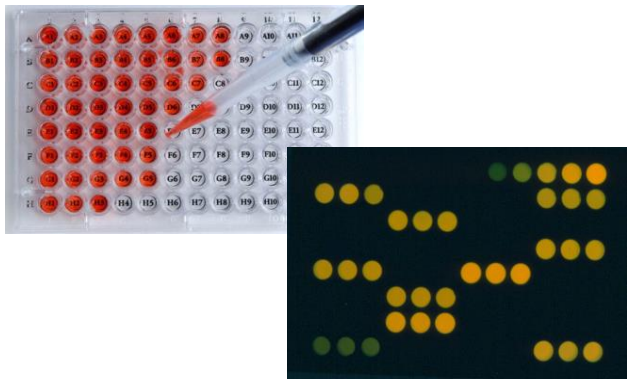


Biomarkers for Predictive Toxicology

Treatment	Molecular Changes	Tissue Effects
Control	-	-
E2 – 4 ng/L	43 genes (stress pathways)	-
E2 – 18 ng/L	168 genes incl. ↑ vitellogenin	-
E2 – 54 ng/L	692 genes incl. ↑ vtg and ERa gene vtg protein increase	-
E2 – 180 ng/L	1260, many linked to steroid hormone signaling pathways Vtg gene and protein increase	Decreased # and size of tubercles, reduced reproduction

Using Screening Tools for Routine Monitoring - Next Steps

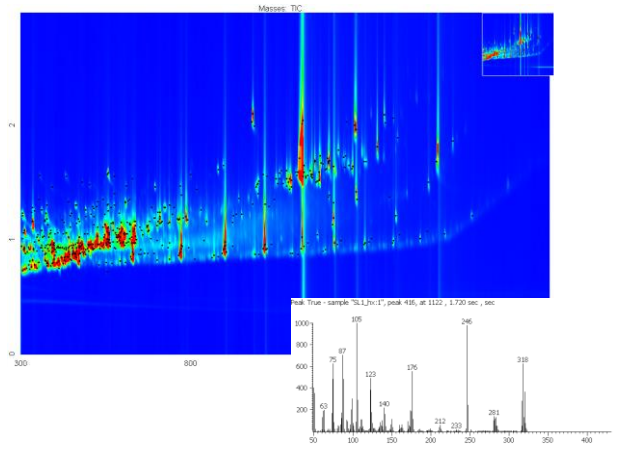
***In vitro* cell assays**



1. Build confidence among water quality managers
   - Demonstrate utility via pilot studies
   - Participate in intercalibration exercises
2. Expand the toolbox
   - Develop protocols with QA/QC for more endpoints
3. Develop sound interpretation framework
   - Develop effects-based screening thresholds

Using Screening Tools for Routine Monitoring - Next Steps

Non-targeted chemistry



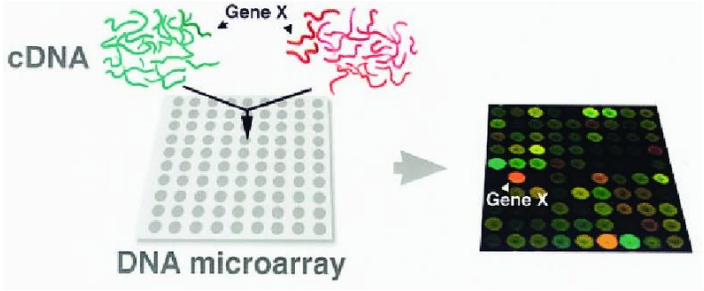
1. Complete source fingerprinting
   Chemical fingerprints for various matrices/seasons

2. Standardize workflows
   Develop mass spectral databases

3. Conduct pilot studies to demonstrate utility

Using Screening Tools for Routine Monitoring - Next Steps

Omics technologies



1. Develop putative adverse outcome pathways (in silico modeling)
    - Identify biomarkers/key events predictive of a specific toxicity outcome

2. Conduct lab and field studies to identify reliable biomarkers for resident species

Thank You!

alvinam@sccwrp.org

Collaborators:

SCCWRP– Keith Maruya, Steve Bay, Wayne Lao, Lucy Mao

UC Riverside– Dan Schlenk

University of Florida– Nancy Denslow, Kevin Kroll, Candice Lavelle

LACSD– Joe Gully, Eric Nelson, Shawn Thompson, Misty Brown

UC Davis– Mike Denison