Fate of Endocrine Disrupting Contaminants in WWTPs and Their Impact on Receiving Streams

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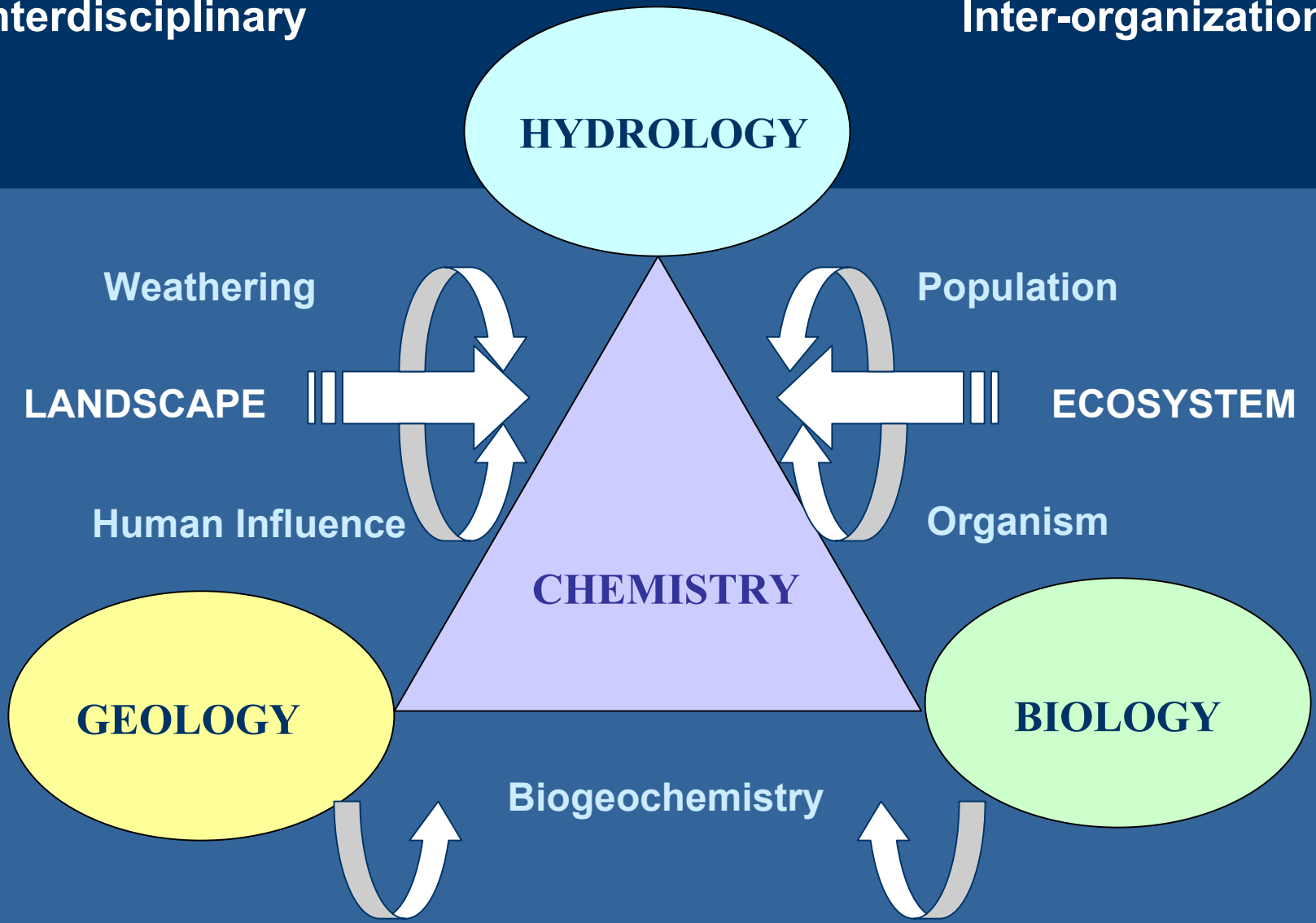
Boulder, Colorado

USGS

Interdisciplinary

Inter-organizational



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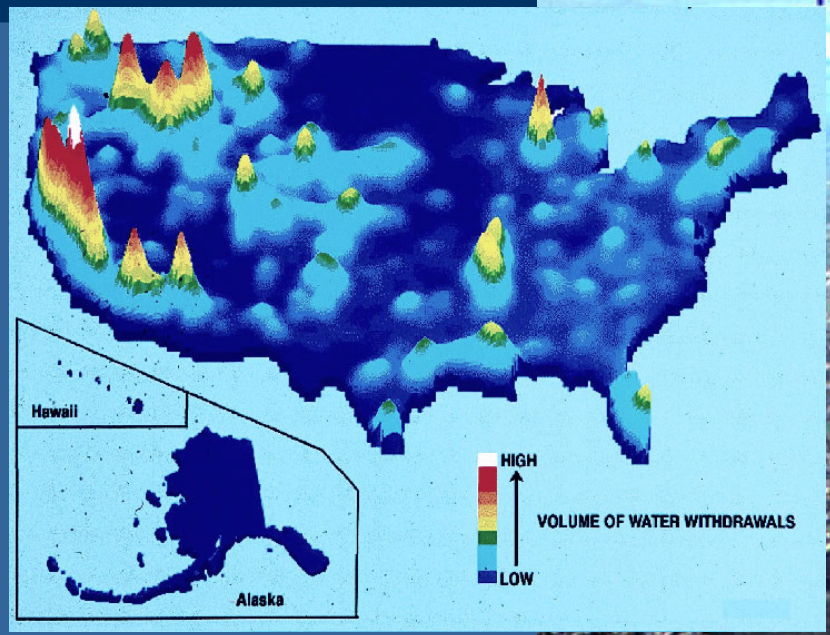
Water Reclamation Reuse



Intended Reuse

- **Direct**
- **Indirect**

Unintended

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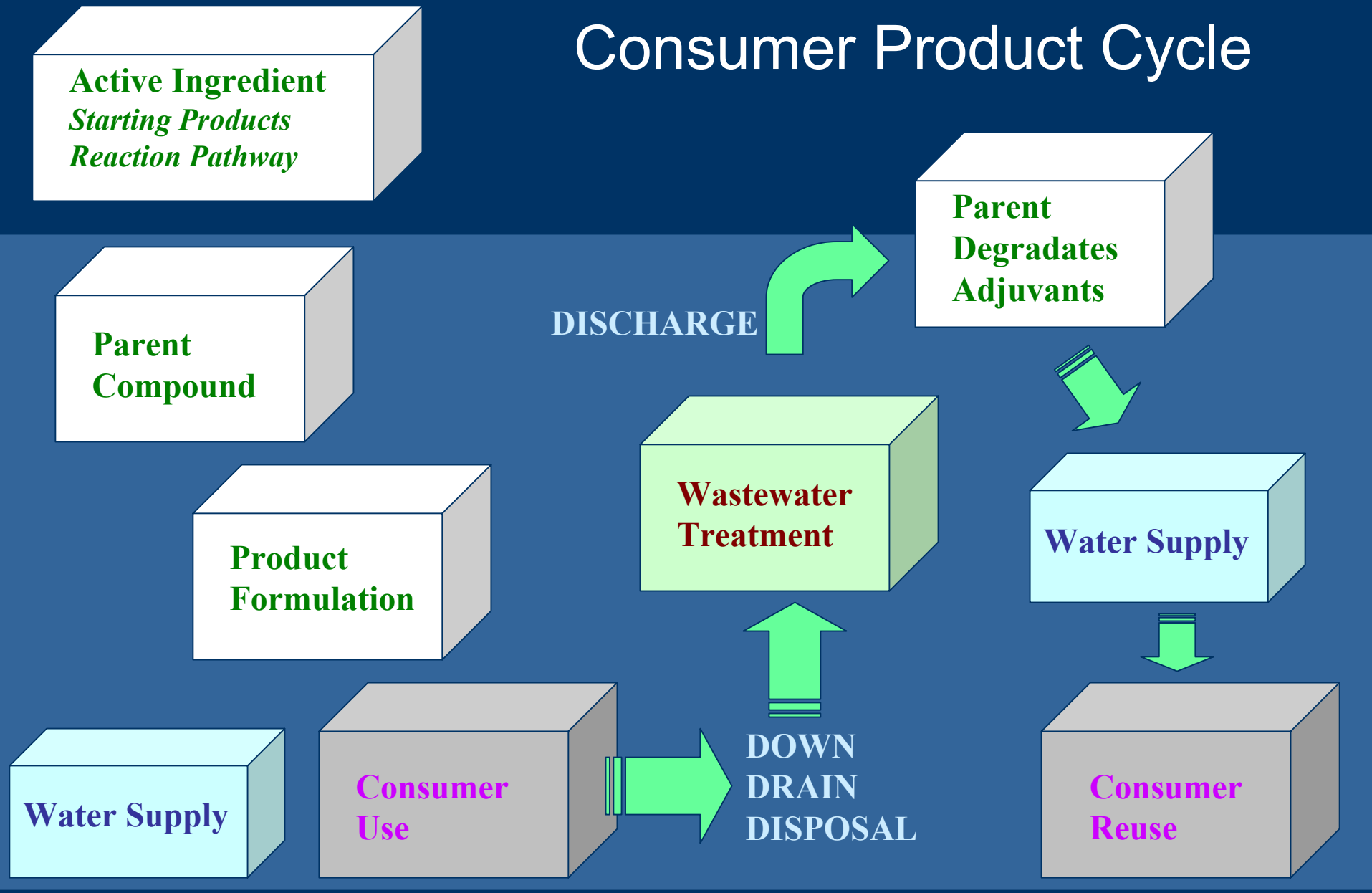
Consumer Products

Cleaning

Pharmaceutical

Agricultural

Consumer Product Cycle



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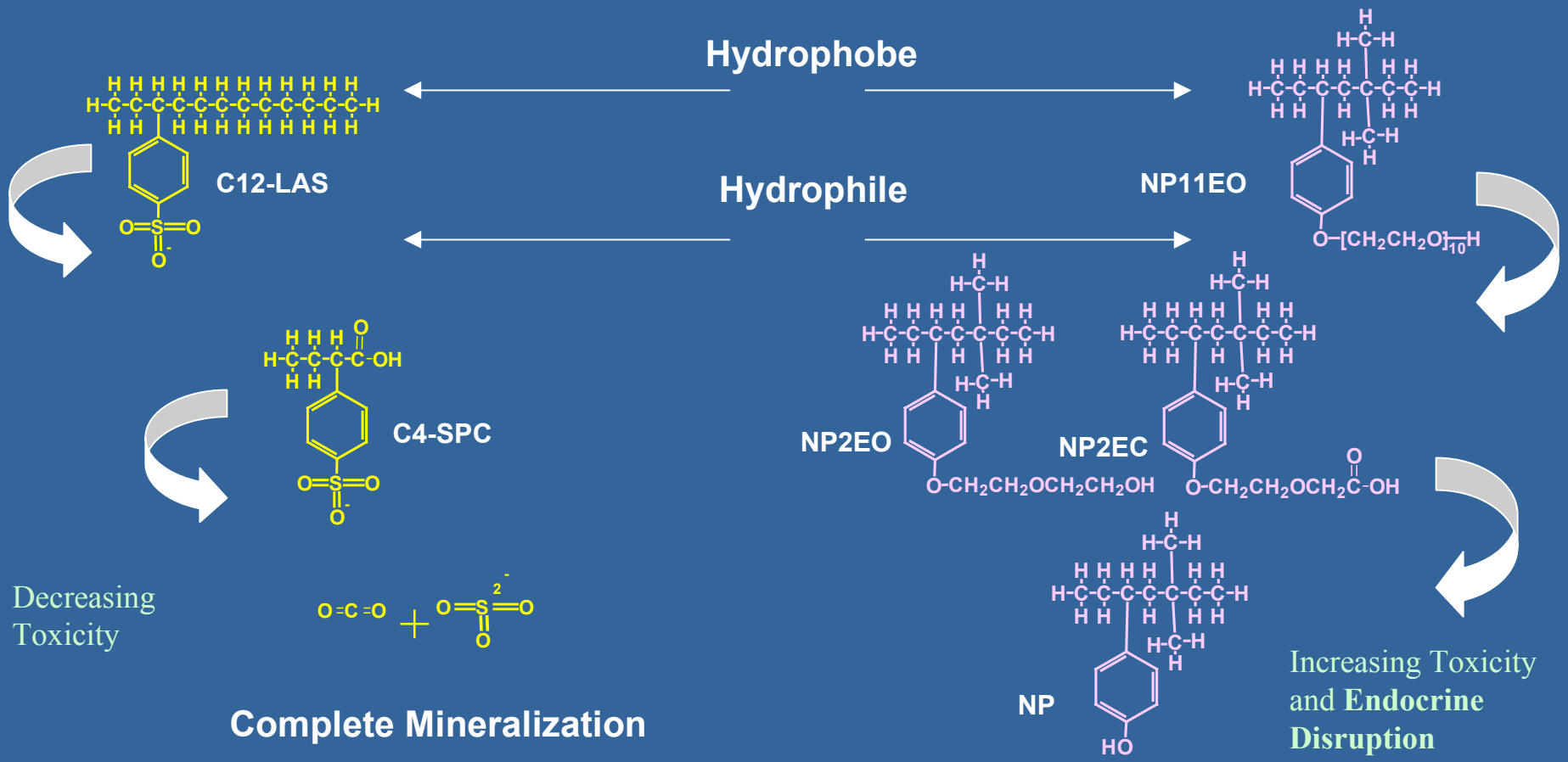
Aerobic Degradation of Surfactants

Anionic
Linearalkylbenzenesulfonate (LAS)

Nonionic
Alkylphenolethoxylates (APEO)



1991 LAS use = 390 million kg (Modler and others, 1993)

1988 APEO use = 200 million kg (Talmidge, 1994)

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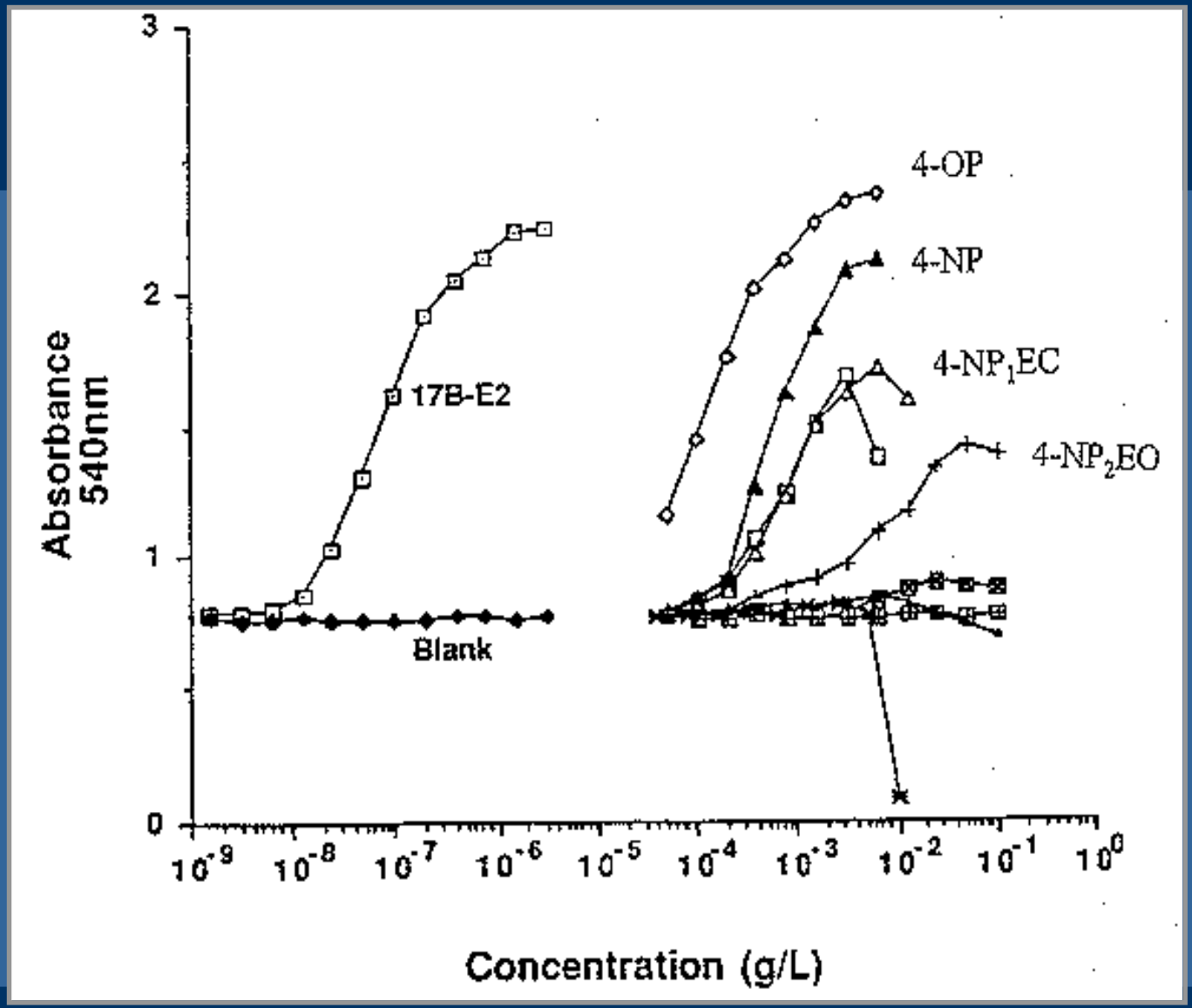
Endocrine Effects of Alkylphenols



Routledge and Sumpter, 1996

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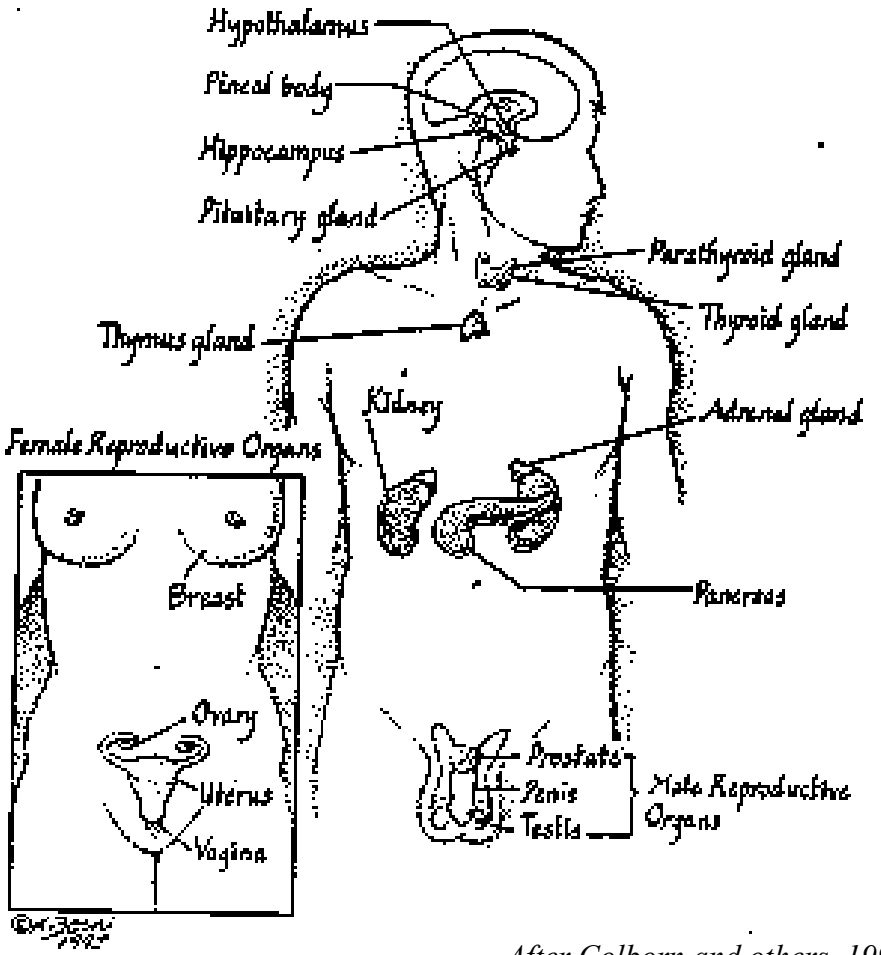
The Human Endocrine System



After Colborn and others, 1996

System of glands that produce hormones and corresponding receptors

- Sexual Development
- Reproduction
- Growth
- Metabolism
- Neurological Development
- Cancers

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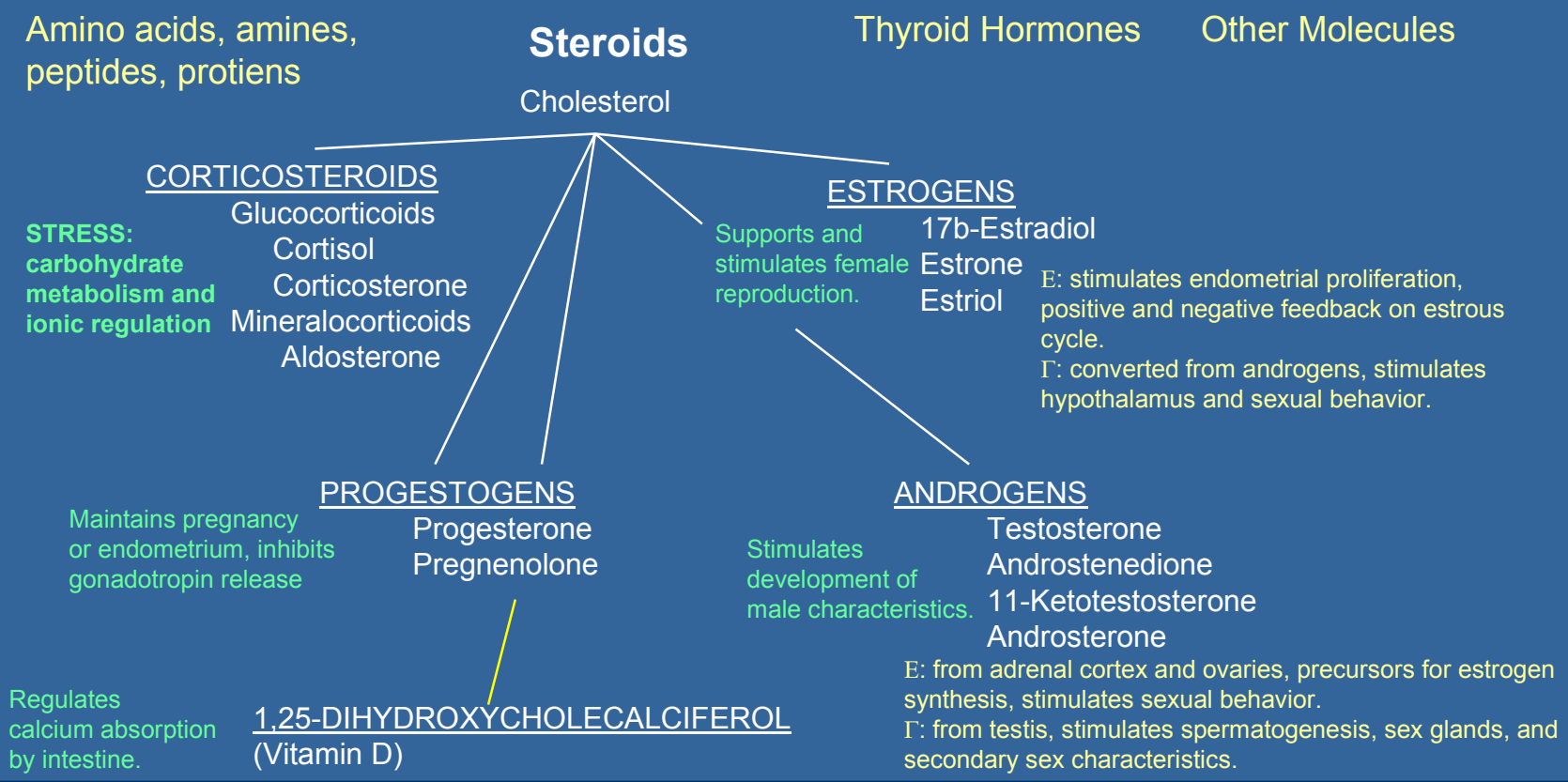
What are hormones?

Chemical regulators, secreted by glands to the blood that effect a change at a target site.

Types of chemical regulators



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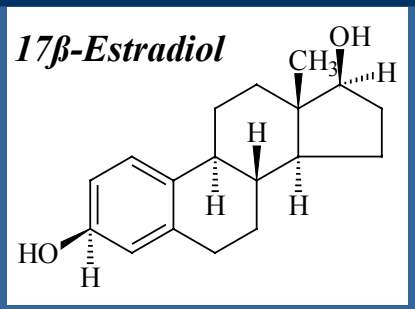
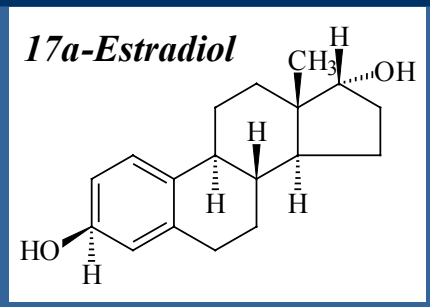
Biogenic and Synthetic Steroidal Hormones

Natural





Contraception

10 million use oral contraceptives

88 kg/yr, PEC =

Hormone Replacement Therapy

13 million use hormone replacement

1688 kg/yr, PEC =

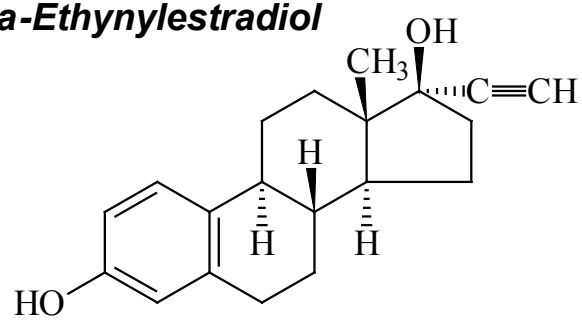
Biogenic

98 million excrete ~0.1 mg/day/person

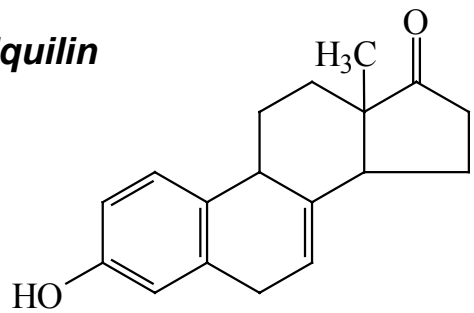
3577 kg/yr, PEC =

Pharmaceutical

17α-Ethynylestradiol



Equilin



Premarin - 45 million prescriptions in 2001 = $2,000,000,000 (C&E News)

Arcand-Hoy and others, 1998

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Effects of Endocrine Disrupting Chemicals

Ecosystem

Population

Individual reproduction

Secondary behavior and morphology

Primary molecular and biochemical responses

Exposure to potential environmental agents

Campbell and Hutchinson, 1998

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Emerging Contaminant Reconnaissance

Kolpin and others, 2002, Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. Streams, 1999-2000: A national Reconnaissance: ES&T, v. 36.

139	Streams in 30 States
62	Intense AFO Activities
52	Intense Urbanization
17	Mixed Land Use
8	Minimally Developed
22	Antibiotics
14	Prescription Drugs
5	Nonprescription Drugs
15	Hormones and Steroids
39	Household and Industrial

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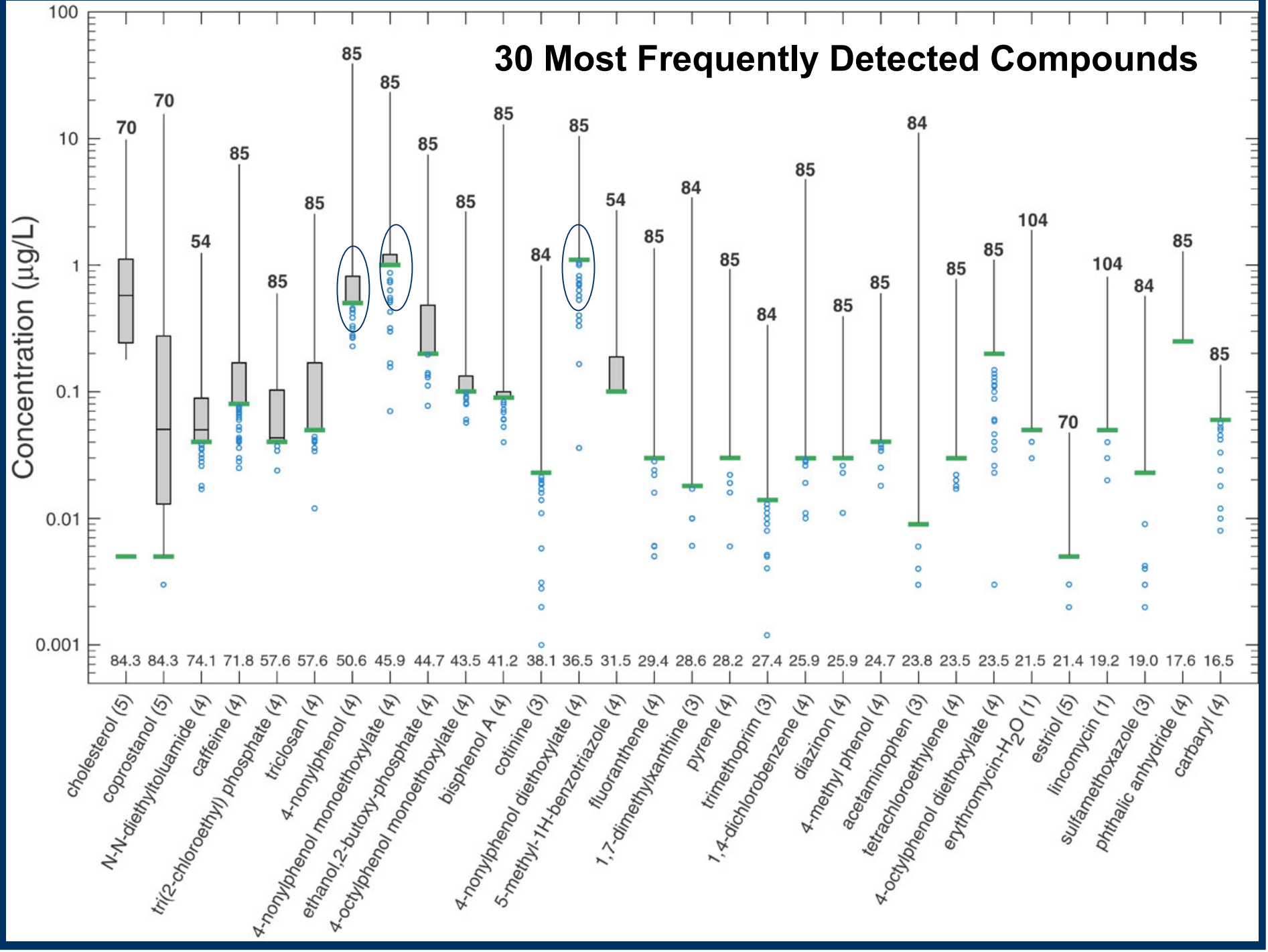
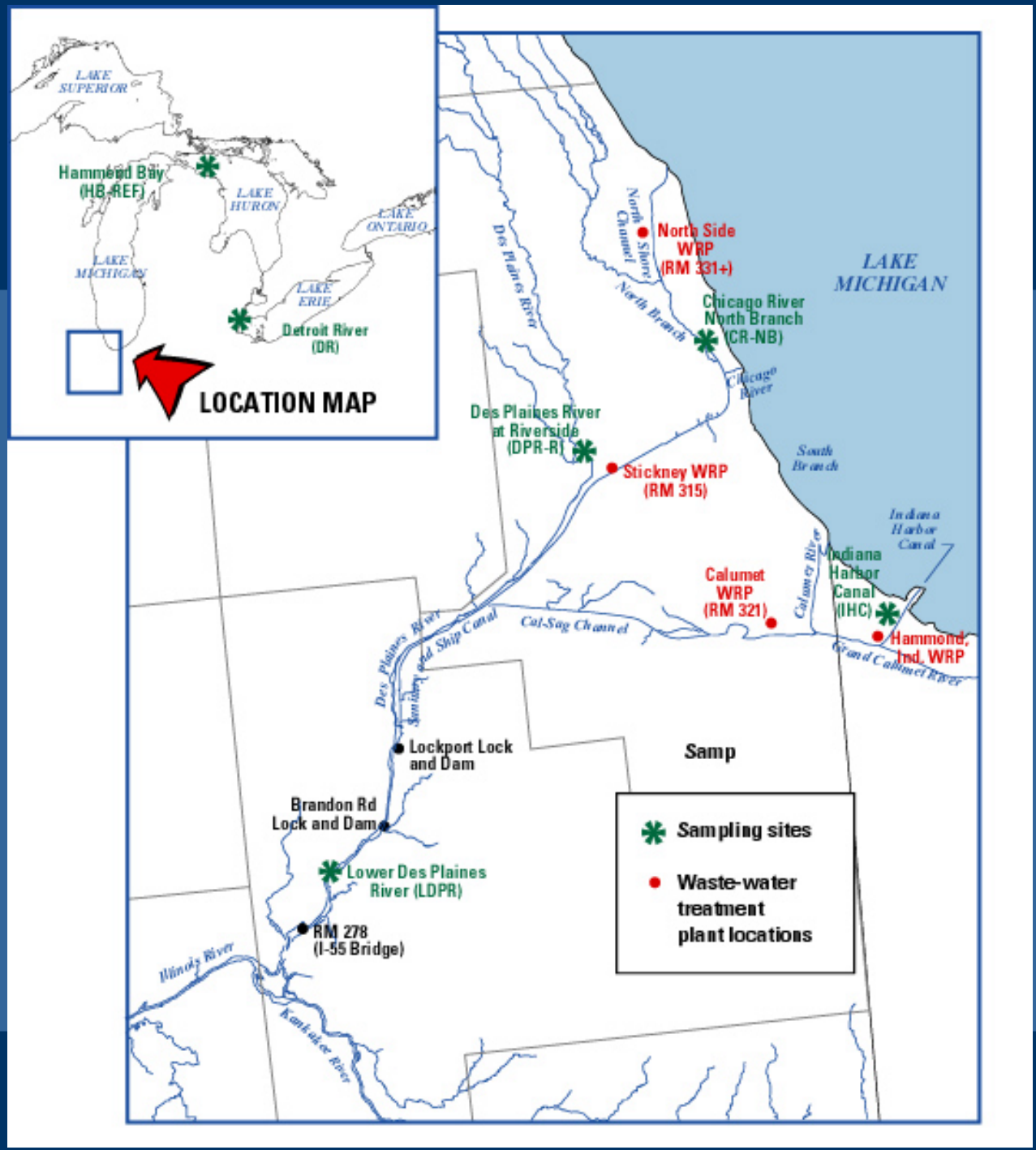

30 Most Frequently Detected Compounds
Concentration (µg/L)
100
10
1
0.1
0.01
0.001
70 70 54 85 85 85 85 85 85 85 84 85 54 85 84 85 84 85 85 85 104 85 70 104 84 85 85
84.3 84.3 74.1 71.8 57.6 57.6 50.6 45.9 44.7 43.5 41.2 38.1 36.5 31.5 29.4 28.6 28.2 27.4 25.9 25.9 24.7 23.8 23.5 23.5 21.5 21.4 19.2 19.0 17.6 16.5
cholesterol (5)
coprostanol (5)
N-N-diethyltoluamide (4)
caffeine (4)
tri(2-chloroethyl) phosphate (4)
triclosan (4)
4-nonylphenol (4)
4-nonylphenol monoethoxylate (4)
ethanol,2-butoxy-phosphate (4)
4-octylphenol monoethoxylate (4)
bisphenol A (4)
cotinine (3)
4-nonylphenol diethoxylate (4)
5-methyl-1H-benzotriazole (4)
fluoranthene (4)
1,7-dimethylxanthine (3)
pyrene (4)
trimethoprim (3)
1,4-dichlorobenzene (4)
diazinon (4)
4-methyl phenol (4)
acetaminophen (3)
tetrachloroethylene (4)
4-octylphenol diethoxylate (4)
erythromycin-H2O (1)
estriol (5)
lincomycin (1)
sulfamethoxazole (3)
phthalic anhydride (4)
carbaryl (4)



Study Sites

- Akron
- Chicago
- Detroit
- Duluth
- Indianapolis
- Minneapolis
- Calumet River
- Chicago Ship and Sanitary Canal
- Cuyahoga River
- Mississippi River

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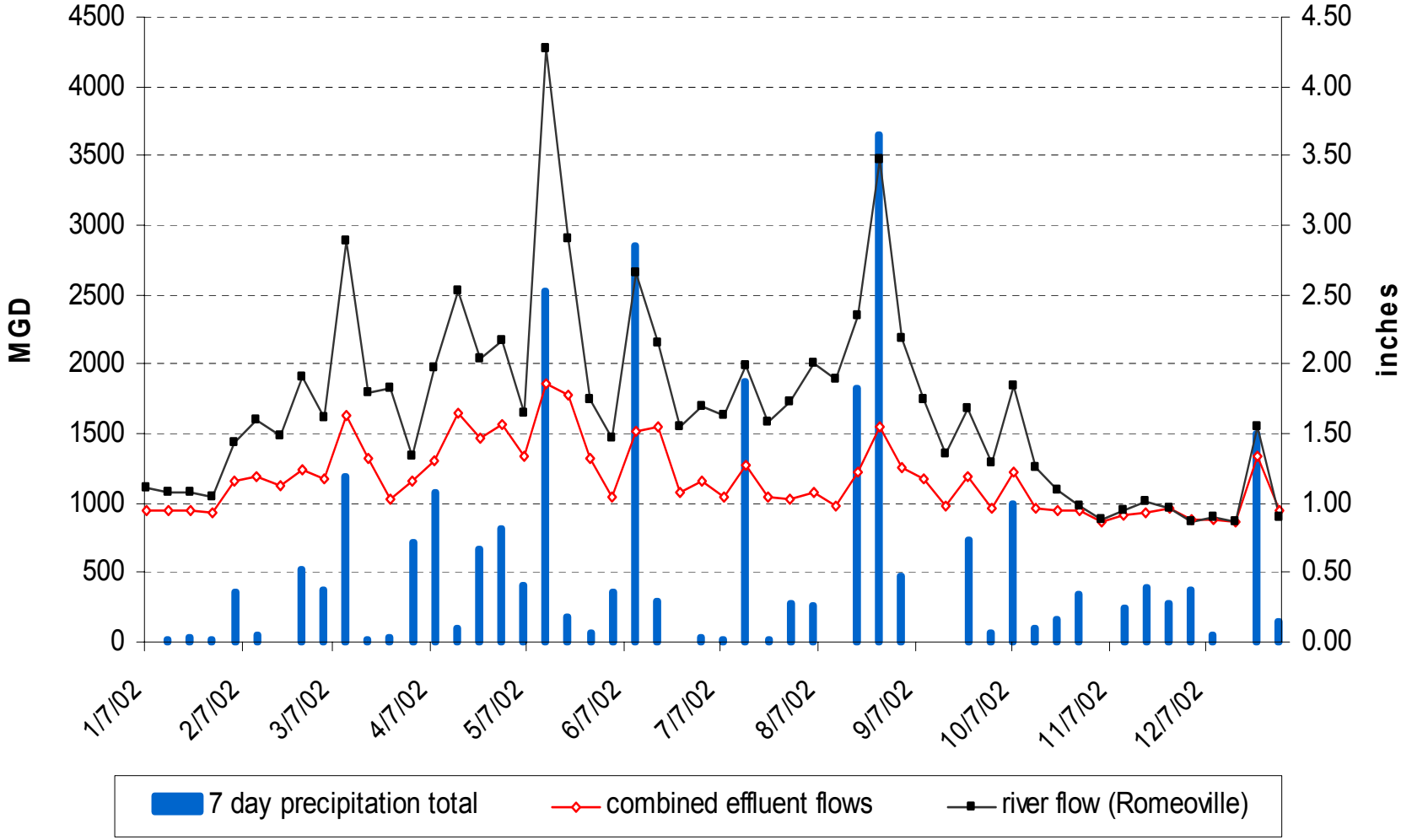
Effluent Contribution to Des Plaines River



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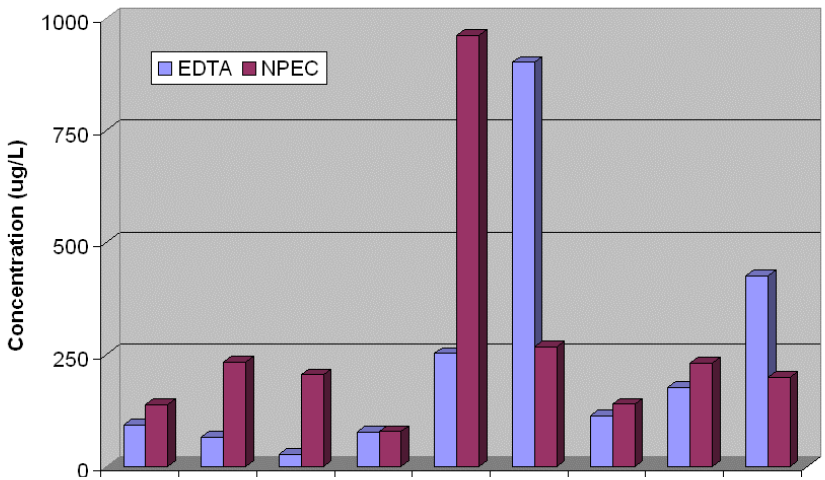
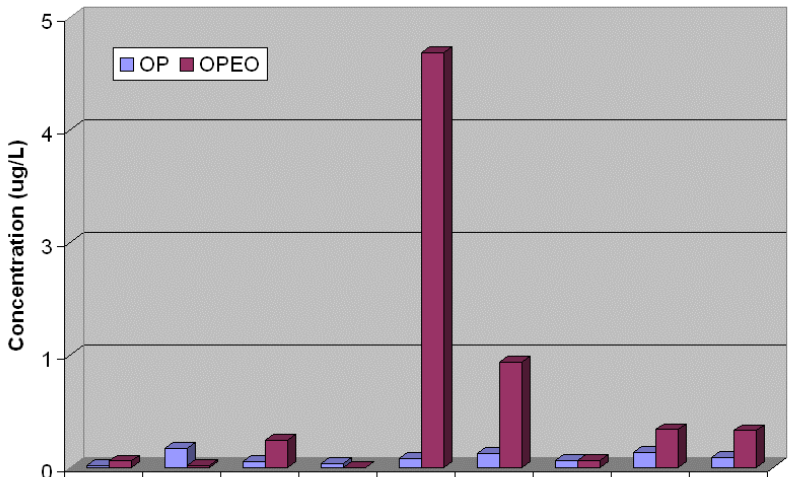
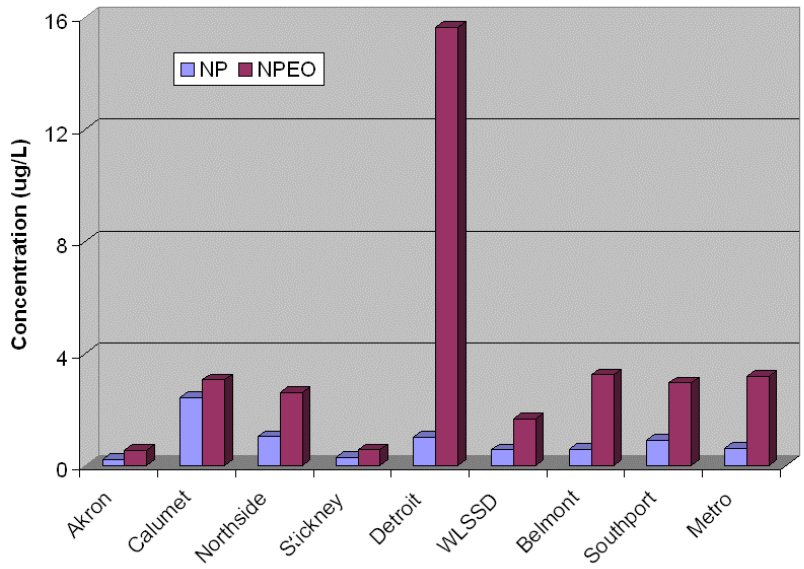
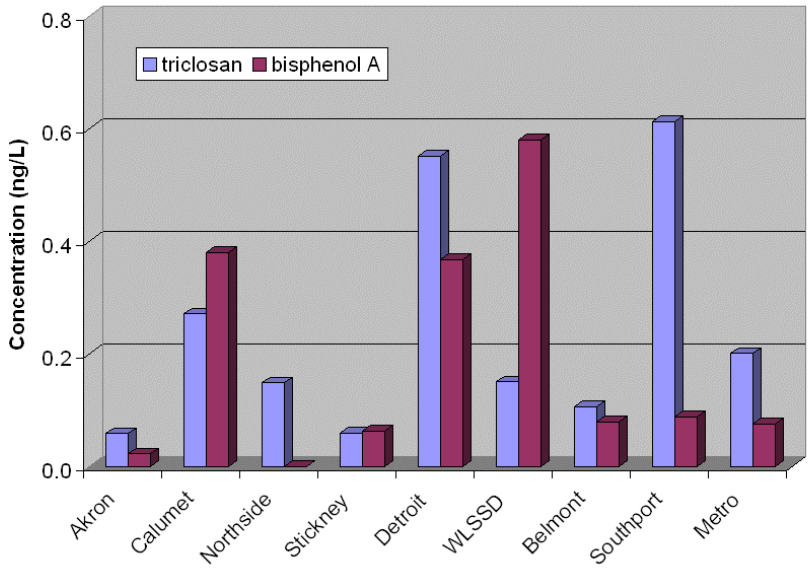
OWCs in WWTP Effluents









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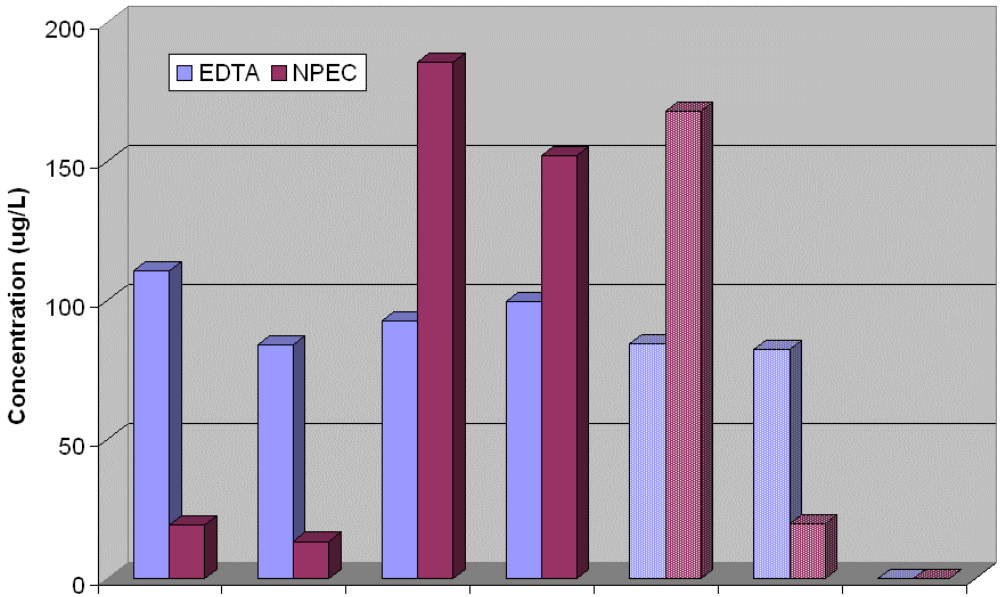
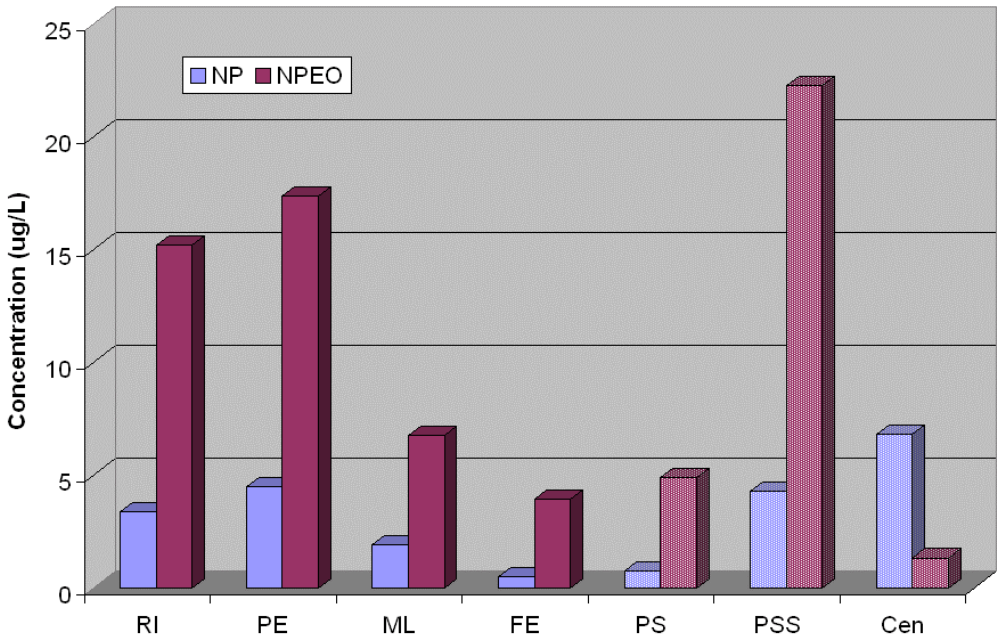
Fate of OWCs in Calumet WRP





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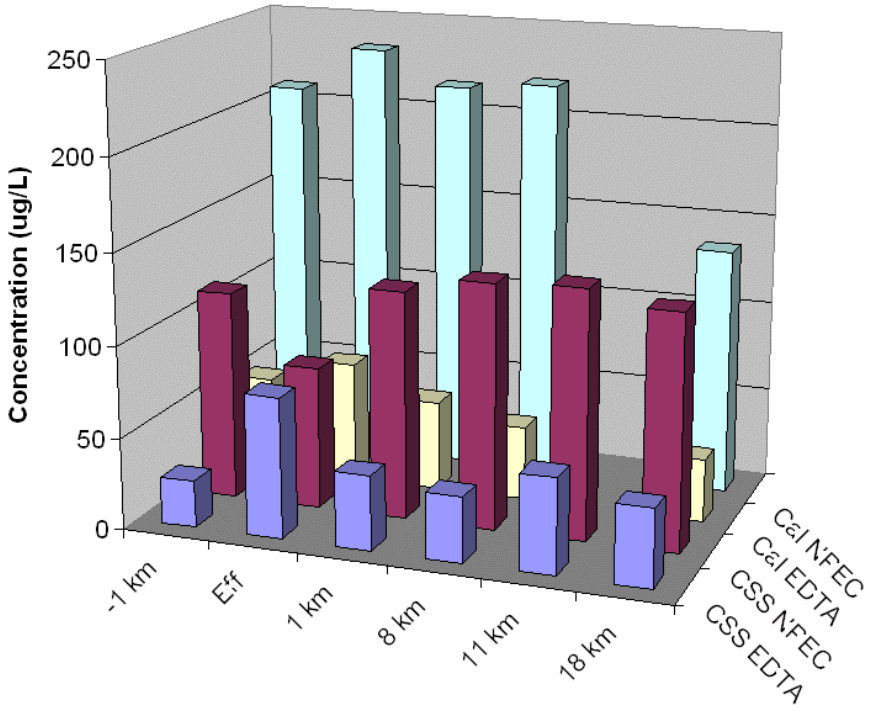
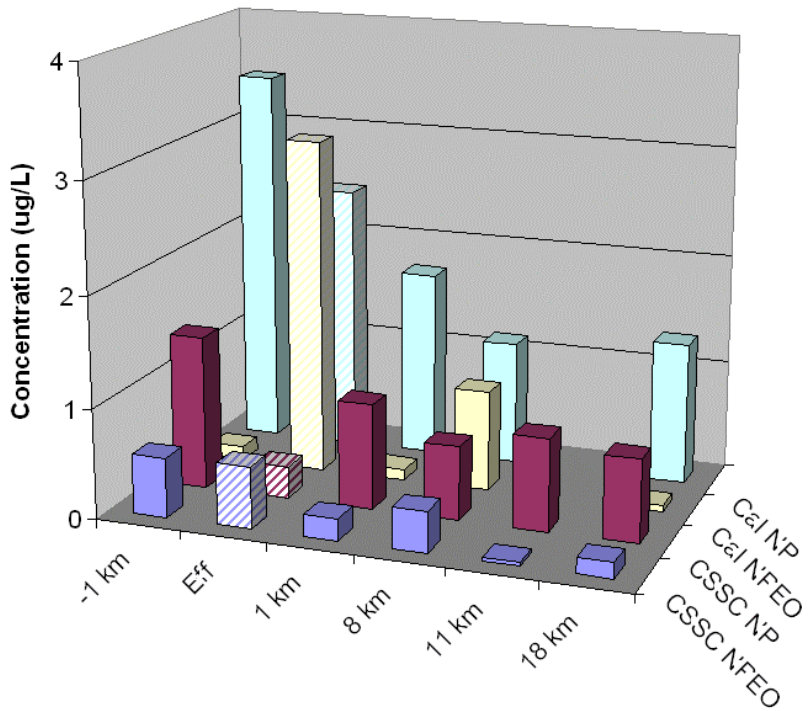
OWCs in Chicago Waterways





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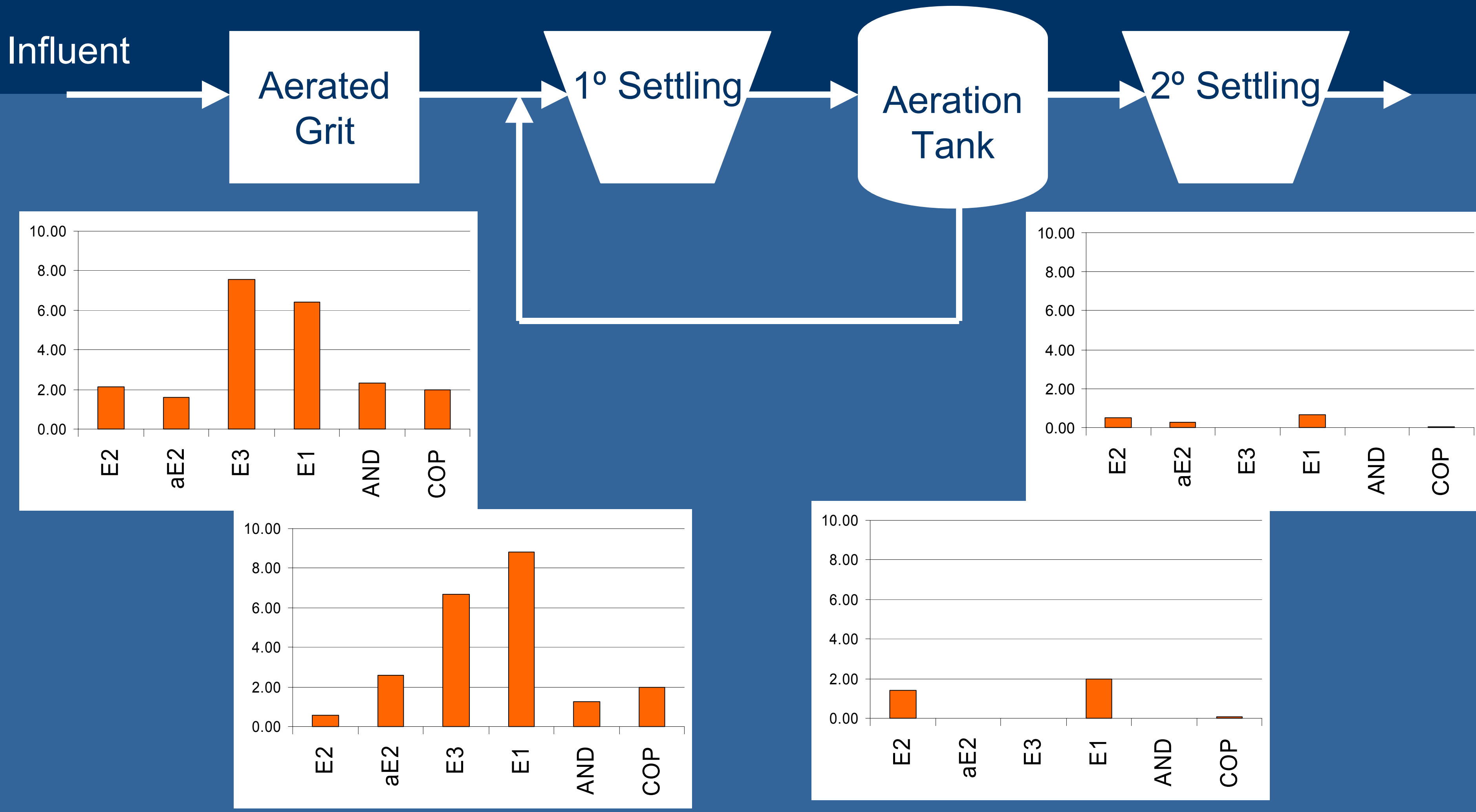
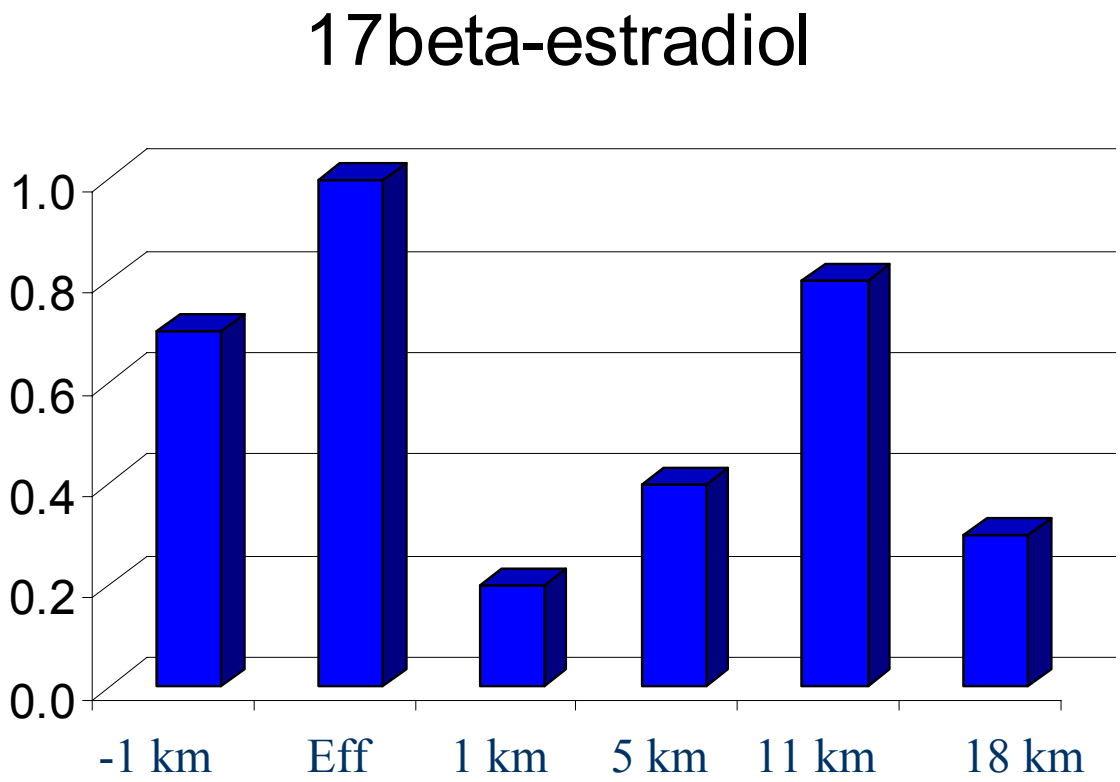
Hormones in CWRP Aqueous Streams



Hormone Occurrence in Cal Sag



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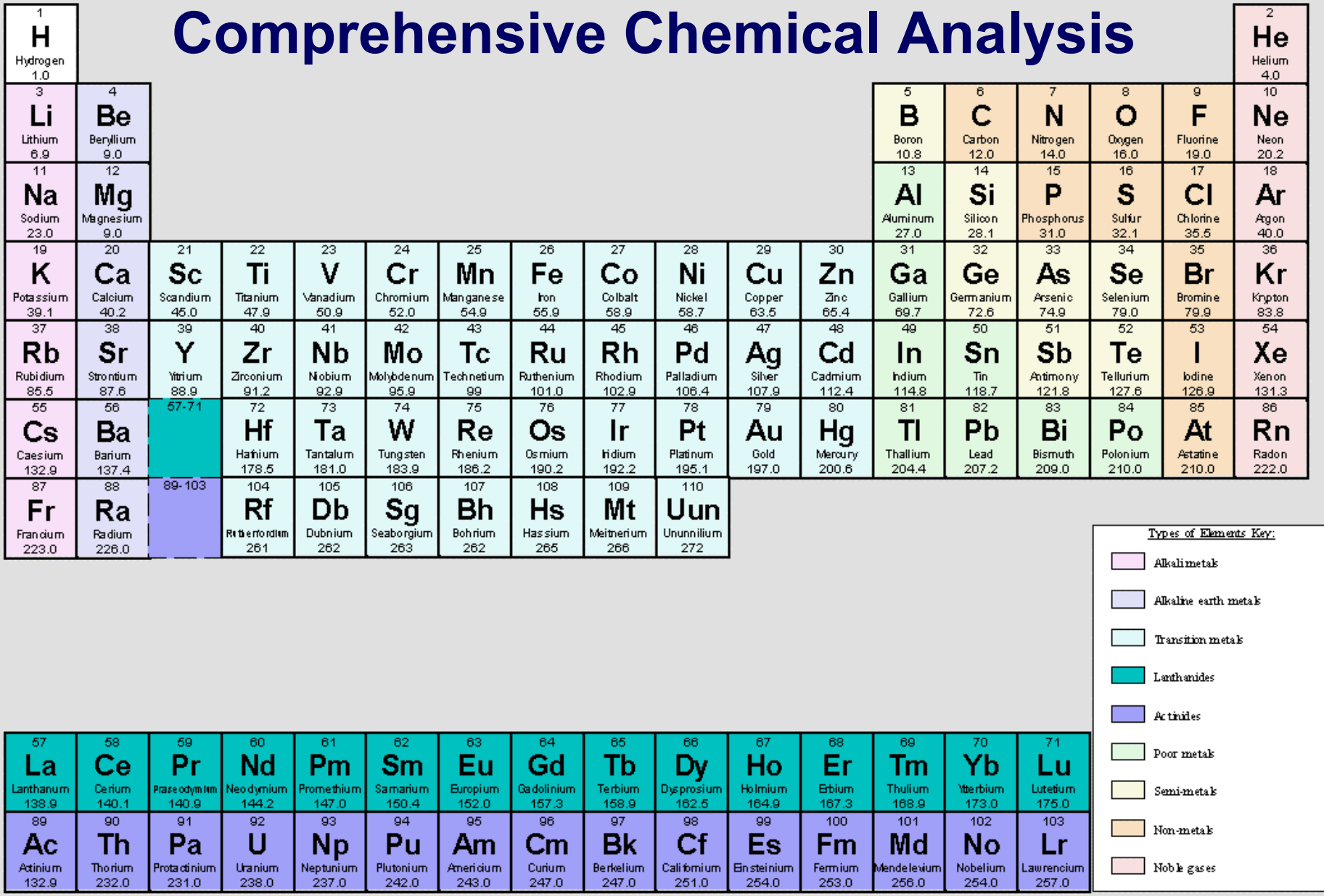
Comprehensive Chemical Analysis



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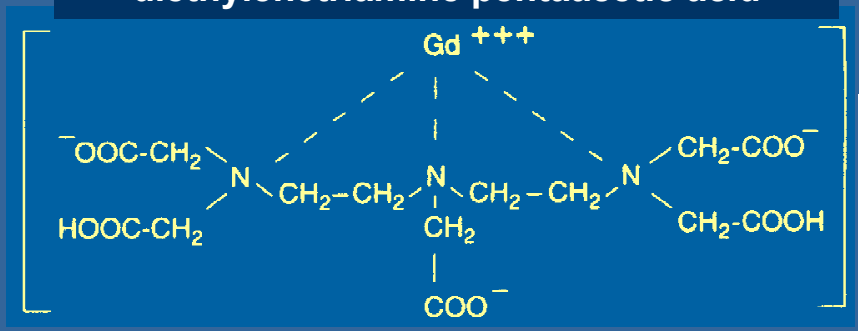
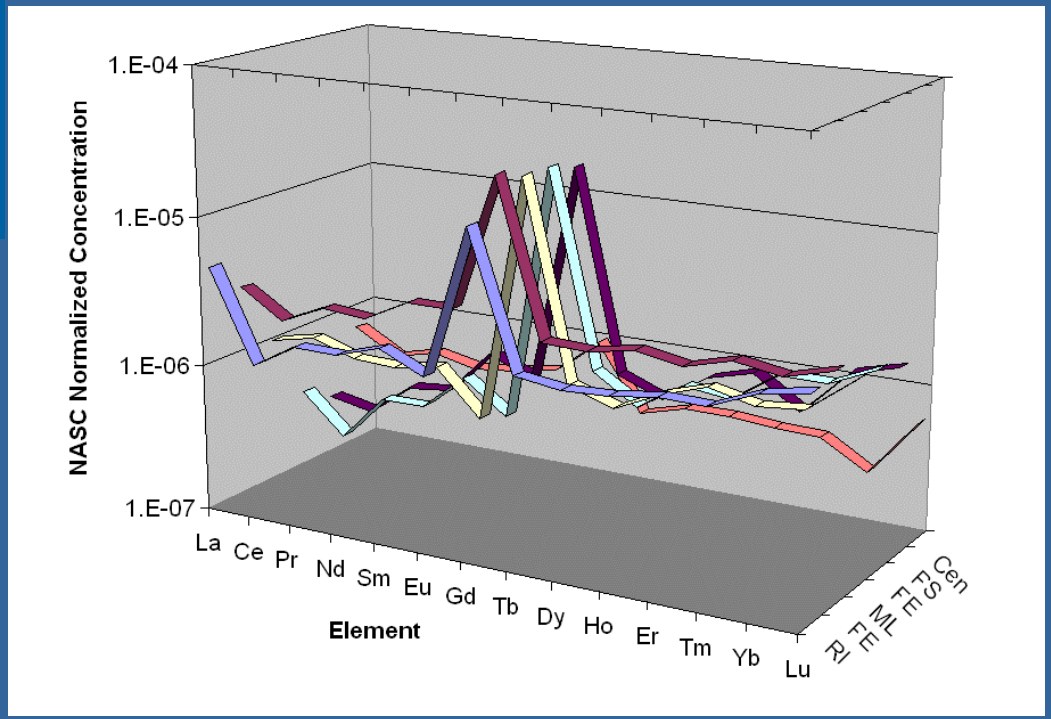
Rare Earth Element Distributions

The Gadolinium Anomaly

Gadolinium complex of diethylenetriamine pentaacetic acid



MRI Contrast Agent



Verplanck and others, 2005, Aqueous stability of gadolinium in surface waters receiving sewage treatment plant effluent, Boulder Creek, Colorado: Environ. Sci. Technol., v. 39

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The Link to Biology?

All life depends on water

Molecular, Cellular, and Developmental

in vitro

in vivo

Environmental, Population, and Organismic

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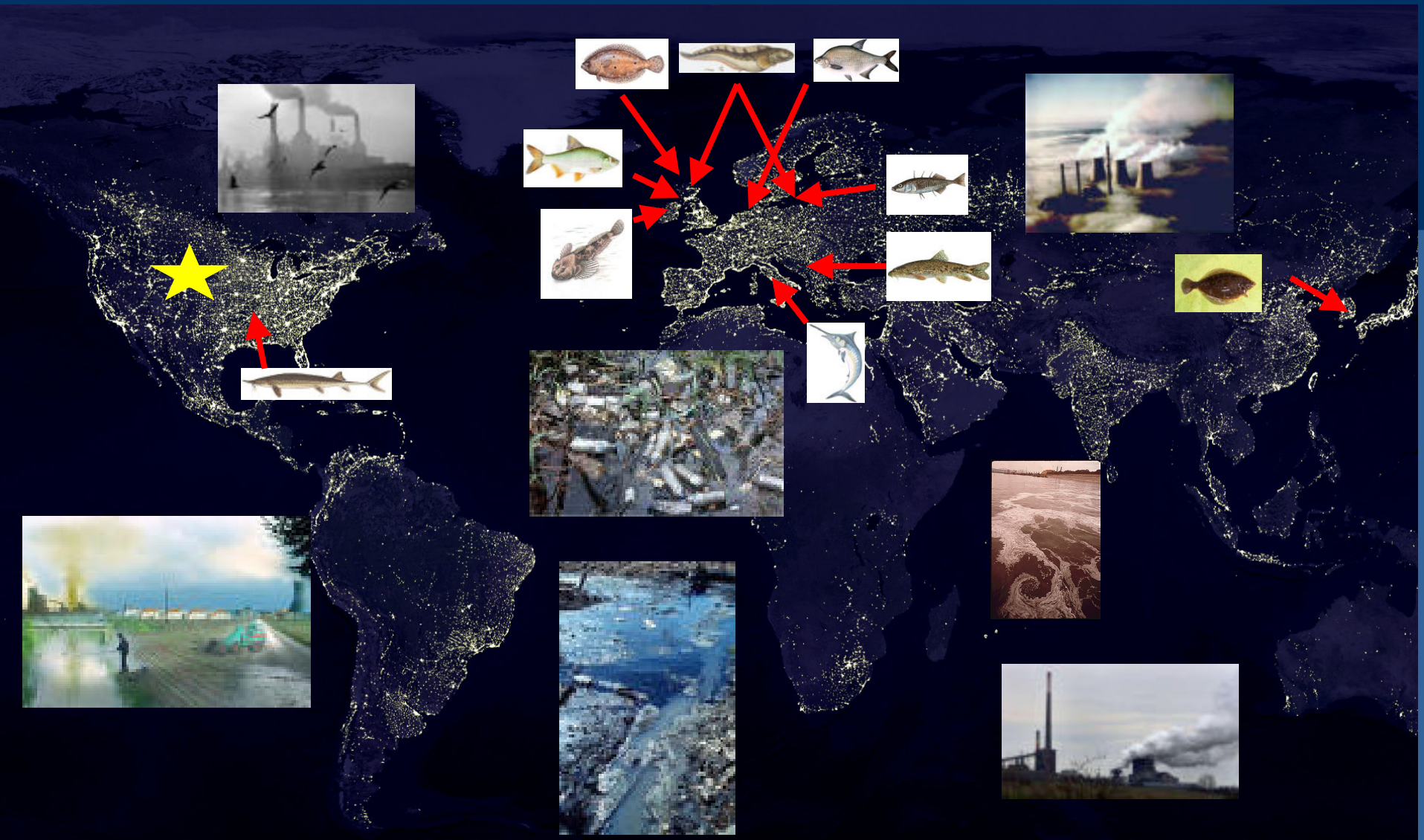
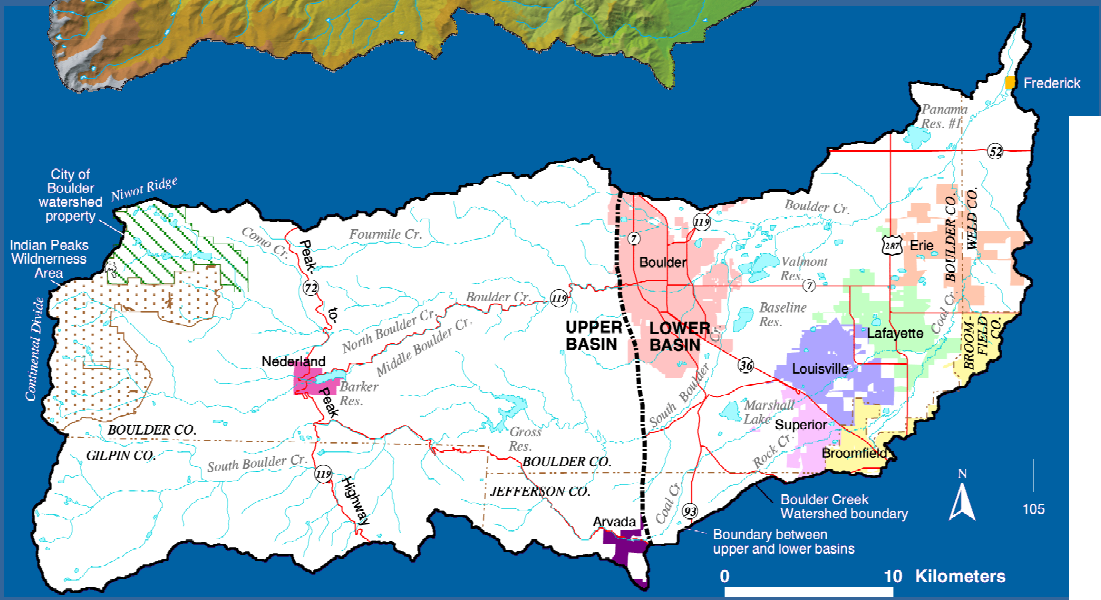
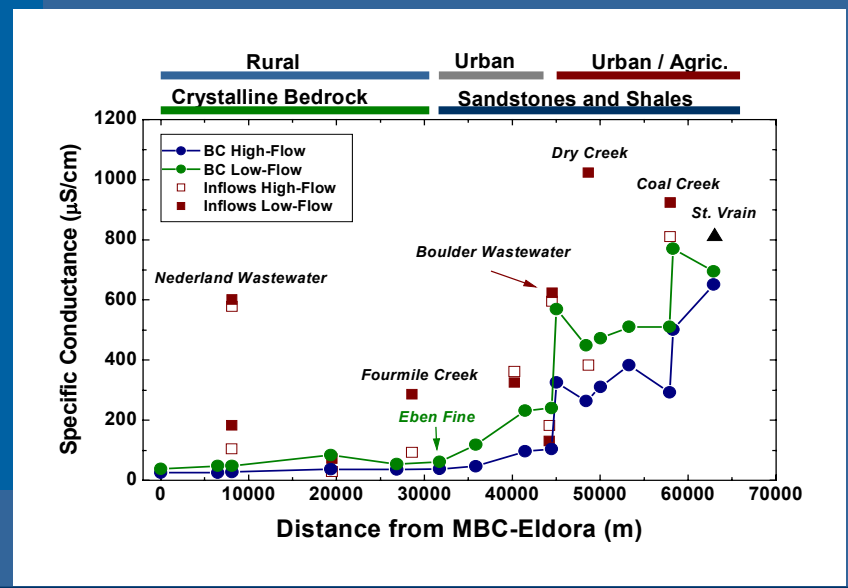


Since the Early 1980s Endocrine Disruption in Wild Fish Has Been Shown to be an Issue of Global Concern

Boulder Creek Watershed





Barber and others, 2006, Chemical loading into surface water along a hydrological, biogeochemical, and land use gradient - A holistic watershed approach: Environ. Sci.Technol., v. 40,

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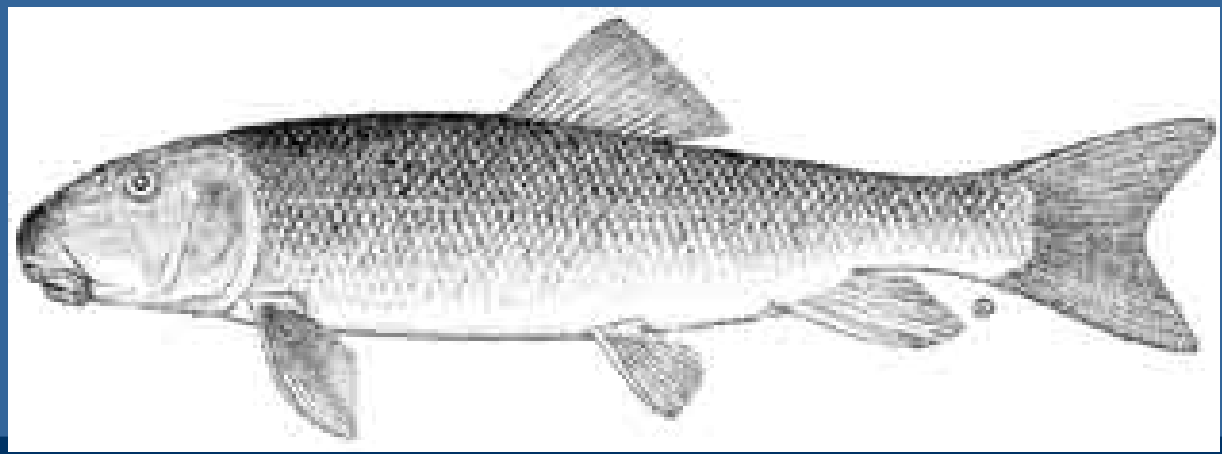
Evidence of Reproductive Disruption in Boulder Creek



White Sucker (*Catostomus commersoni*)

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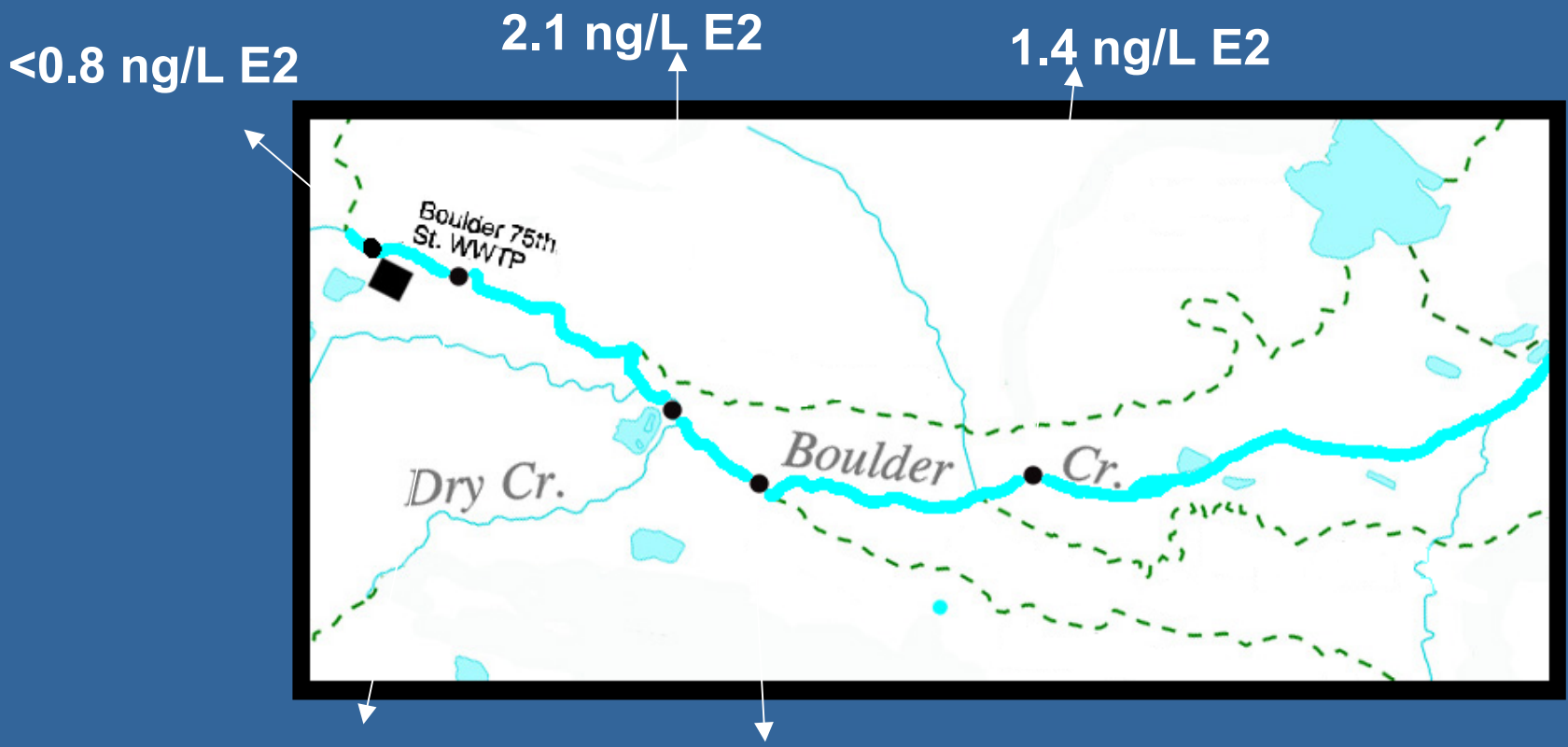
Estradiol in Boulder Creek



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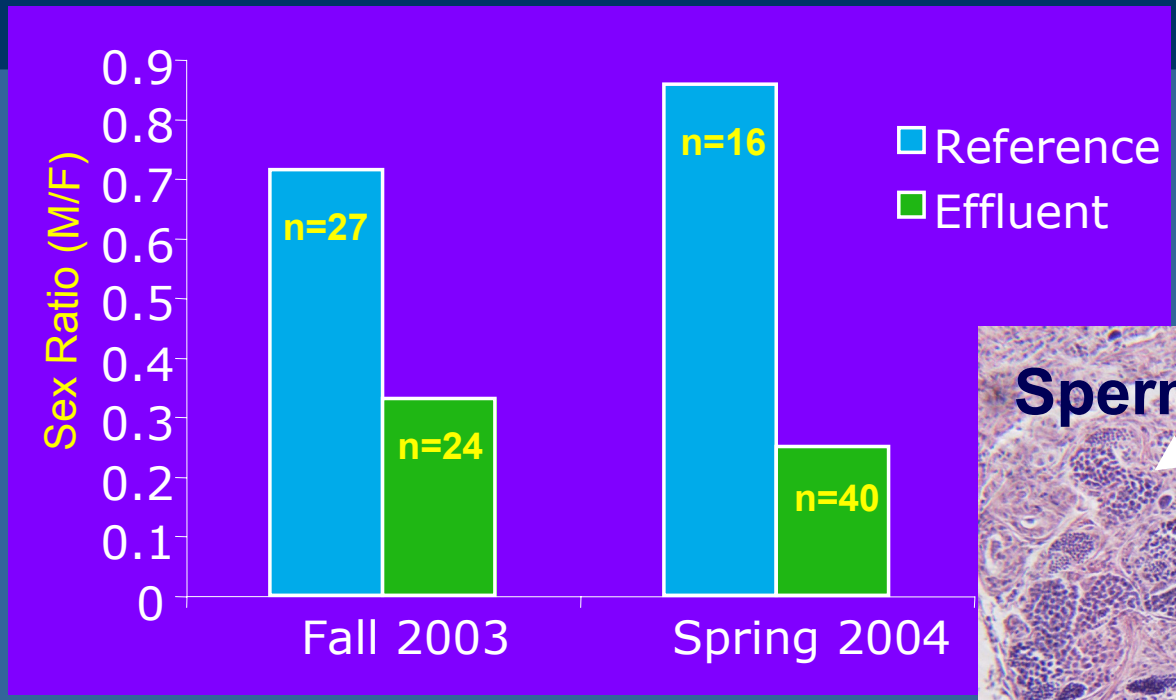
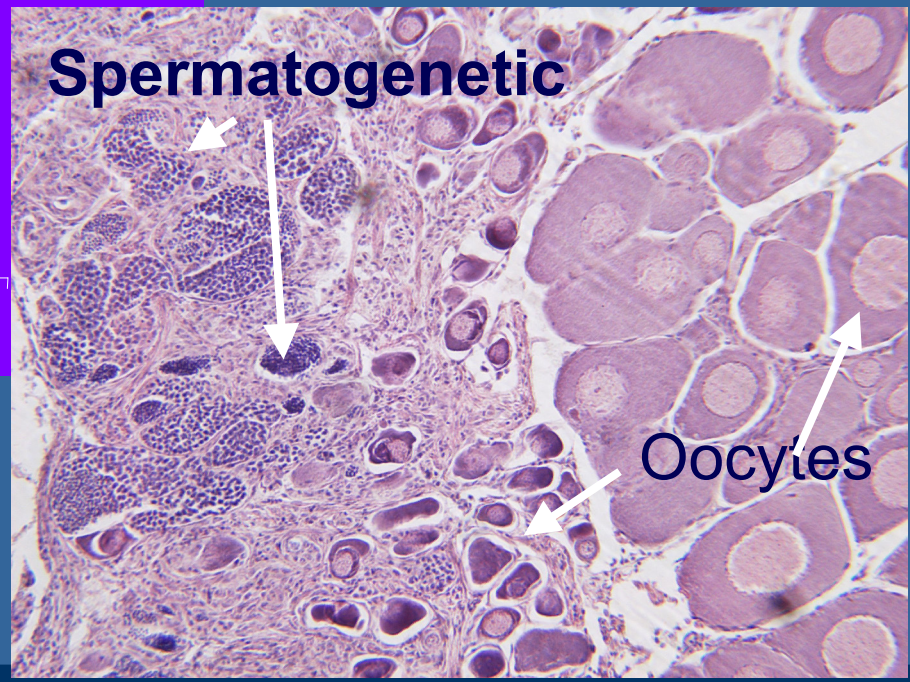
Shift in Sex Ratio



Intersex in Downstream Fish



Vajda and others, 2006

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Exposure Conditions

- 5 adult males per tank
- equal length and weight
- temperature = 21°C ±1
- photoperiod 16:8 L:D
- fed frozen brine shrimp
- Flow = 200 mL/min
- Aeration

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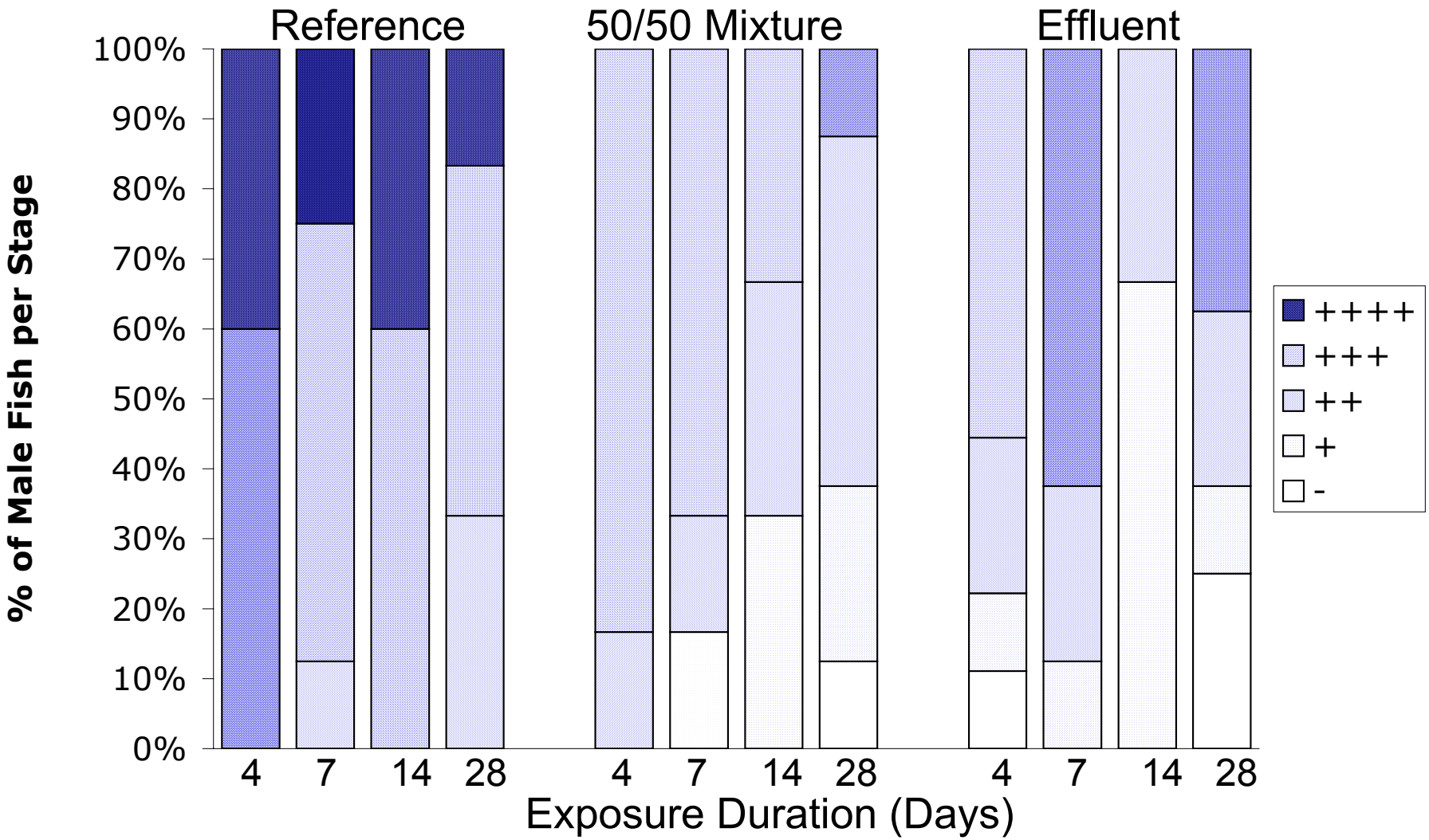
Effluent Inhibits Spermatogenesis



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“Lessons from Endocrine Disruption and Their Application to Other Issues Concerning Trace Organics in the Aquatic Environment “

Sumpter and Johnson, 2005, ES&T, v. 39

- Pay attention to unusual biological observations.
- What is normal?
- One animal’s poison may not be another’s.
- Potency is a key factor.
- Degradation products may bite!
- Beware of continual exposure to low concentrations and mixtures.
- Beware of nontraditional pollutants from unexpected sources.
- Acute toxicity tests may not be very helpful.
- Central role played by sewage treatment.
- Hydrology will tell you where to look!

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