How evaluations of low concentrations of organic chemical contaminants are important in managing lake ecosystems: An example from Lake Mead NRA

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Presentation Outline

- What are Endocrine Disrupting Compounds (EDCs)?
- Why are EDCs important?
- Why use Lake Mead as an example?
- History of EDC Work at Lake Mead
- Has this work been important for management of Lake Mead and other lakes?

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Endocrine Disruption

Process by which a chemical from outside an organism causes ADVERSE health effects by changing the endocrine function of the organism

For more about endocrine disruption:

Sumpter and Johnson (2005) ES&T,v39, pp 4321- 4332

Jobling and Tyler (2006) EHP, v 114, supplement 1

http://www.tmc.tulane.edu/ecme/eehome/

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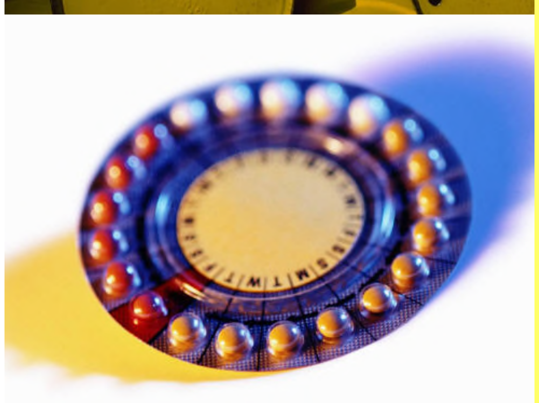
Classes of EDCs

Effluents	STW, pulp & paper mills
Flame Retardants	PBDEs
Fungicides	Vinclozolin
Herbicides	Atrazine
Insecticides	Methoxychlor
Metals	Tributyltin
Pharmaceuticals	Ethinyl Estradiol
Phenols	Bisphenol A
Plasticizers	Phthalates
Industry	PCBs, dioxin
Soy Products	Genistein
Surfactants	Alkylphenol Ethoxylates



Why are EDCs Important?

- Since the 1990's there has been evidence that synthetic organic compounds cause disruption to the endocrine system of fish and other aquatic organisms
- These finding were controversial, but were substantiated in multiple studies over many years and different locations
- This then led to the controversy of whether EDCs released to the environment affect Human health
- There is still controversy about whether there is an affect on Human health through water

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Chronic Exposures of Aquatic Wildlife to EDCs

- Wildlife do not have the benefit of analyzing and treating their food and water prior to consumption
- Aquatic organisms are particularly susceptible to pollutants in the water: They are exposed constantly
- Fetal development is regulated by the endocrine system
- Low doses of ECs at critical points during fetal development may have profound impacts on the development which may last through maturation

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Why Study Lake Mead

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CSI: Las Vegas – “The case of the cross-dressing carp”

Broadcast 18 Oct. 2007

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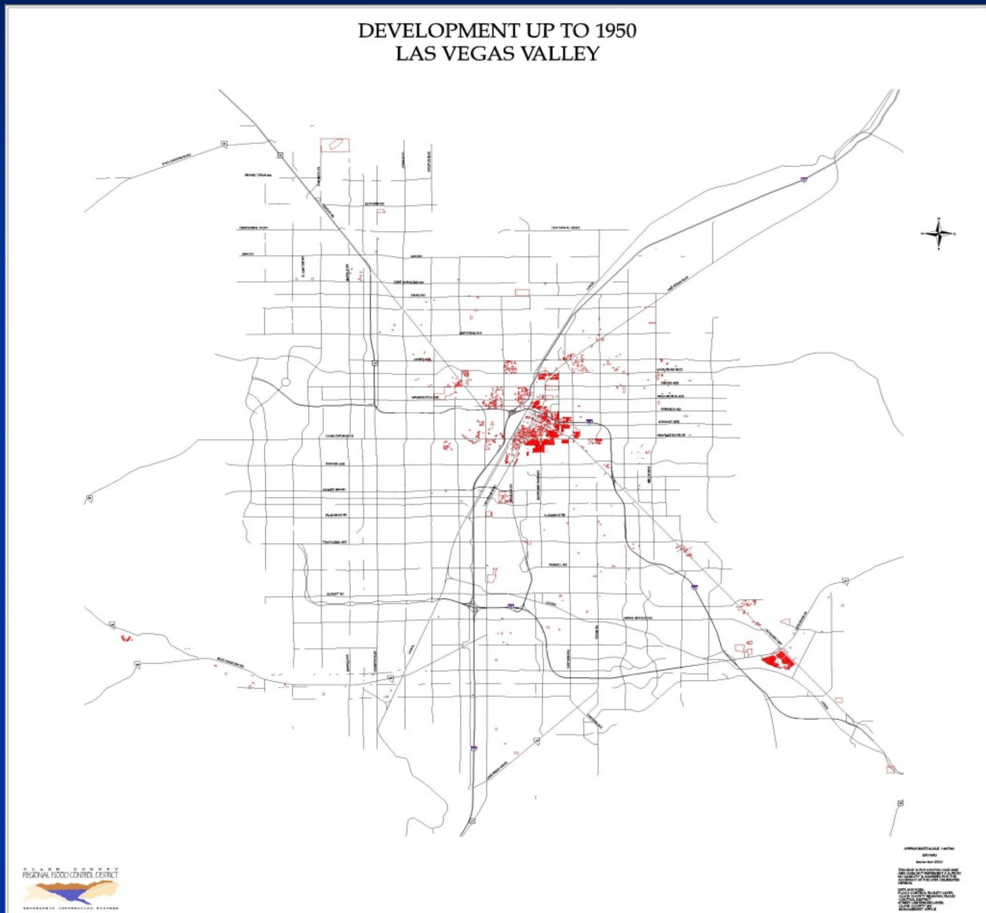
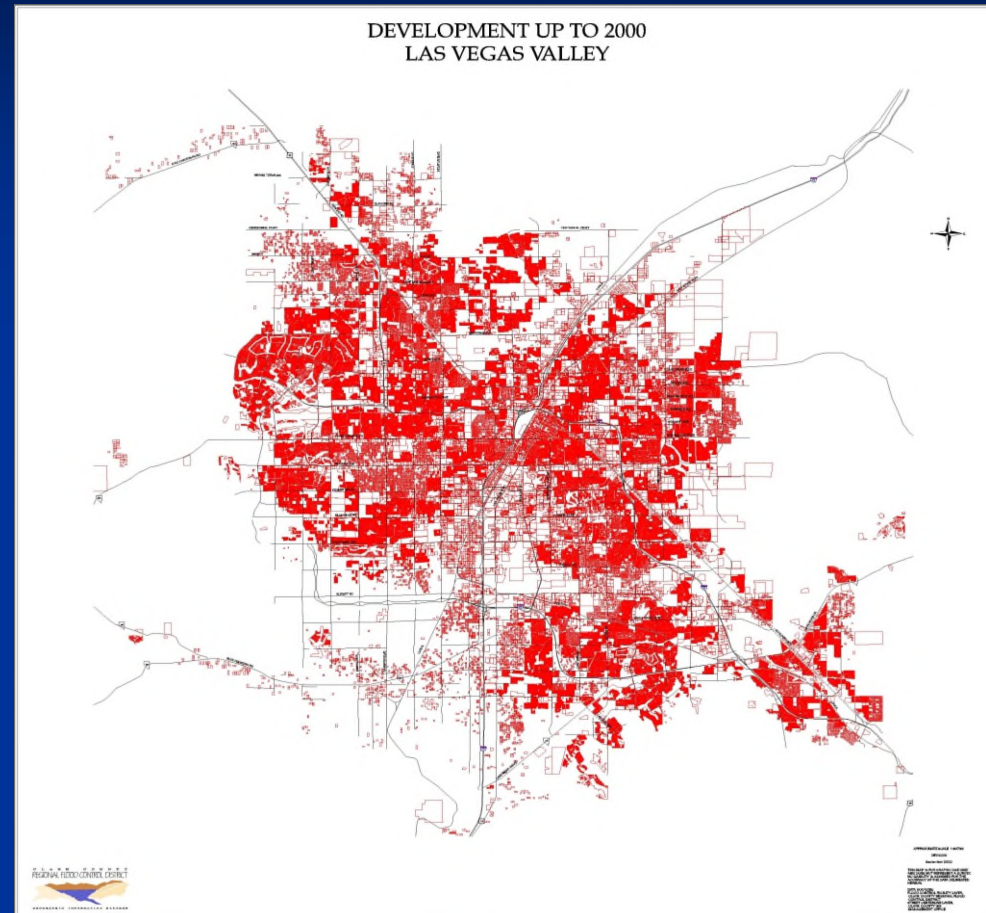
Population Growth in Las Vegas Valley





1950

Pop 47,000

2000

Pop 1,300,000

2014 population 2.1 million

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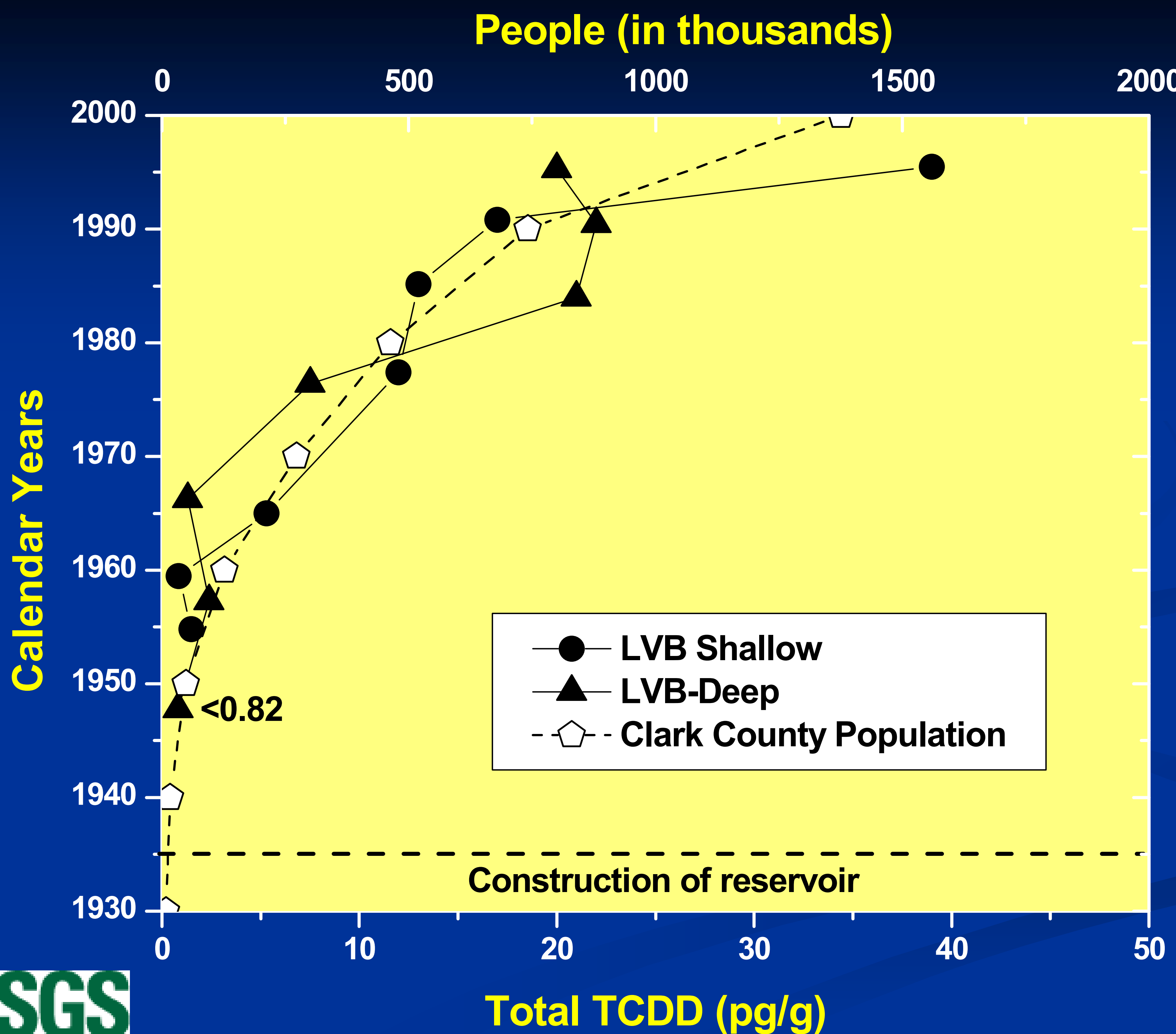

From Rosen and Van Metre (2010)

How did the USGS get involved

- As part of the National Water Quality Assessment (NAWQA) program Lake Mead was studied for water quality
- Relatively new types of fish tissue research was also included in the water quality sampling
- Results were published in a USGS report in 1996
- Results were not met with overwhelming enthusiasm….

U.S. Department of the Interior—U.S. Geological Survey

SYNTHETIC ORGANIC COMPOUNDS AND CARP ENDOCRINOLOGY AND HISTOLOGY IN LAS VEGAS WASH AND LAS VEGAS AND CALLVILLE BAYS OF LAKE MEAD, NEVADA, 1992 AND 1995

Water-Resources Investigations Report 96-4266

Nevada Basin and Range Study Unit
National Water-Quality Assessment Program

By Hugh E. Bevans[1], Steven L. Goodbred[2], John F. Miesner[3], Sharon A. Watkins[1], Timothy S. Gross[4], Nancy D. Denslow[4], *and* Trenton Schoeb[4]

ABSTRACT

The Nevada Basin and Range study unit of the National Water-Quality Assessment Program, U.S. Geological Survey, in cooperation with the National Park Service, National Biological Service, and U.S. Fish and Wildlife Service, investigated the occurrence of organochlorines and semivolatile industrial compounds in the water column, bottom sediment, and carp (*Cyprinus carpio*) tissue at five sites in Las Vegas Wash and Lake Mead. Endocrine systems of carp were assessed by analyzing concentrations of female and male sex-steroid hormones, 17β-estradiol and 11-ketotestosterone, and vitellogenin (an estrogen-controlled egg protein) in blood-plasma samples. The histology of carp gonads, hepatopancreas, kidney, gill, and lower intestine were analyzed for effects that can result from endocrine disruption or exposure to toxicants.

Organochlorines (pesticides and industrial compounds) and semivolatile industrial compounds were detected in semipermeable membrane devices and bottom-sediment samples; only organochlorines were detected in carp-tissue samples. Concentrations of organochlorines were higher in Las Vegas Wash and Bay than in Callville Bay (the reference site) for the three media that were sampled. Results of a carp-tissue bioassay indicated the presence of dioxins or furans with low toxic-equivalent factors relative to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in Las Vegas Wash and Las Vegas and Callville Bays. Patterns of necrosis observed in hepatopancreas and kidney samples from carp are consistent with long-term subchronic exposure to toxicants. Polycyclic aromatic hydrocarbons, phthalates, and phenols also were detected at higher concentrations in bottom-sediment samples from Las Vegas Bay than in a comparable sample from Callville Bay. Polycyclic aromatic hydrocarbons were detected in samples from semipermeable membrane devices from all sites.

Endocrine disruption in carp from Las Vegas Wash and Bay, as compared to Callville Bay, is evidenced by high concentrations of 11-ketotestosterone levels in blood-plasma samples of female carp in Las Vegas Wash, low concentrations in male carp from Las Vegas Bay, and low 17β-estradiol concentrations in male carp from Las Vegas Bay. The most compelling evidence of endocrine disruption is the presence of vitellogenin in blood-plasma samples of male carp from Las Vegas Wash and Bay and elevated concentrations in female carp from Las Vegas Bay.

Many of the organochlorines and semivolatile industrial compounds detected in semipermeable membrane devices, bottom sediment, and carp tissue from Las Vegas Wash and Bay have been linked to endocrine disruption in fish by previous investigations of other areas. The endocrine disruption observed in carp from Las Vegas Wash and Bay could be due to the presence of these compounds.

Aerial view of lower Las Vegas Wash and Las Vegas Bay of Lake Mead. View to the northwest, Oct. 12, 1995. Photograph by A.S. VanDenburgh.

[1]U.S. Geological Survey, Carson City, Nev.
[2]U.S. Geological Survey (formerly National Biological Service), Sacramento, Calif.
[3]U.S. Fish and Wildlife Service, Reno, Nev.
[4]University of Florida, Gainesville (Biotechnology for Evolutionary, Ecological, and Conservation Services Program).

Possible EDC Effects seen at Lake Mead from 1996 USGS report

- Genital and gender characteristic abnormalities
  - Gonadal tissue irregularities ("intersex")
  - Vitellogenin induction in males
  - Skewed sex-ratios
- Bad Temper!

Cartoon from Las Vegas newspaper in 1996 when EDCs were first reported in Lake Mead

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Are EDCs important in Lake Mead?

- Associated Press article on pharmaceuticals in water supplies and their effect on aquatic organisms created quite a bit of interest in EDCs
- Senate hearing held in April 2008

Reno Gazette-Journal March 11, 2008

JAE C. HONG/ASSOCIATED PRESS

Carla Wieser, fishery biologist with the U.S. Geological Survey, takes a blood sample from a carp Nov. 5 in the Lake Mead National Recreation Area near Boulder City to study effects of pharmaceuticals in water on fish.

Drugs also harming fish

Unclean water causing reproduction problems

BY JEFF DONN, MARTHA MENDOZA AND JUSTIN PRITCHARD
ASSOCIATED PRESS

LAKE MEAD, Nev. — On this brisk, glittering morning, a flat-bottomed boat glides across the massive reservoir that provides Las Vegas its drinking water. An ominous rumble growls beneath the craft as its two long, electrified claws extend into the depths.

Moments later, dozens of stunned fish float to the surface.

Federal scientists scoop them up and transfer them into 50-quart Coleman ice chests for transport to a makeshift lab on the dusty lakeshore. Within the hour, the researchers will club the seven-pound common carps to death, draw their blood, snip out their gonads and pack them in aluminum foil and dry ice.

The specimens will be flown across the country to laboratories where aquatic toxicologists are studying what happens to fish that live in water contaminated with at least 13 different medications — from over-the-counter pain killers to prescription antibiotics and mood stabilizers.

More often than not these days, the laboratory tests bring unwelcome results.

A five-month Associated Press investigation has determined that trace amounts of many of the pharmaceuticals we take to stay healthy are seeping into drinking water supplies, and a growing body of research indicates that this could harm humans.

But people aren't the only ones who consume that water. There is more and more evidence that some animals that live in or drink from streams and lakes are seriously affected.

Pharmaceuticals in the water are being blamed for severe reproductive problems in many types of fish: The endangered razorback sucker and male fathead minnow have been found with lower sperm counts and damaged sperm; some walleyes and male carp have become what are called feminized fish, producing egg yolk proteins typically made only by females.

Meanwhile, female fish have developed male genital organs.

There are problems with other wildlife as well: kidney failure in vultures, impaired reproduction in mussels, inhibited growth in algae.

"We have no reason to think that this is a unique situation," said Erik Orsak, an environmental contaminants specialist with the U.S. Fish and Wildlife Service, pulling off rubber gloves splattered with fish blood at Lake Mead.

"We find pretty much anywhere we look, these compounds are ubiquitous."

In November, at the annual Society of Environmental Toxicology and Chemistry meeting in Milwaukee, 30 new studies related to pharmaceuticals in the environment were presented — hormones found in the Chicago River; abnormalities in Japanese zebra fish; ibuprofen, gemfibrozil, triclosan and naproxen in the lower Great Lakes.

Many of those studies refer to the heralded research at Lake Mead. There, on a recent morning, Steven Goodbred struggled to hold a large wriggling carp with both hands. On the outside, the carp looked fine, vibrant and strong, but the U.S. Geological Survey scientist assumed the worst.

"Typically, we see low levels of sex steroids, limited testicular function, low sperm count, that kind of thing," he said slipping the fish into a holding tank and closing the lid. "We'll have to wait and see about this fellow."

Many of those studies refer to the heralded research at Lake Mead. There, on a recent

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In 2009 the Center for Biological Diversity Petitioned NDEP to list some waters of Lake Mead

CENTER *for* BIOLOGICAL DIVERSITY

Because life is good.

For Immediate Release, November 16, 2009

Endocrine-disrupting Chemicals, Risk to Human Health and Wildlife Survival, are Polluting Lake Mead

CBD petitions Nevada Division of Environmental Protection to list Lake Mead, Las Vegas Wash and Bay on 303(d) list of impaired waters

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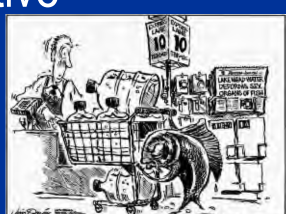
Improvements to waste water treatment plants

Lake Mead timeline of EDC understanding

1996

Publication of USGS WRIR on EDCs in Lake Mead

Media and local government reaction was not positive



2001

Snyder et al 2001, and other references indicates there is no toxicological relevance to organic chemicals in Lake Mead. One drop in a swimming pool analogy. Caged fish also show no effects.

2003

Publication of Patiño et al, 2003 showing histopathological effects on carp

2005

New USGS studies from 2005 to 2010 show continued effect on Lake Mead. But with smaller impact

2006

Recognition that aquatic wildlife may be at risk begins at Lake Mead

2009

CBD requests listing of LM to EPA 303d list

2012

Publication of USGS circular on Lakes Mead and Mohave – cooperation of all agencies involved in Lake Mead

2013

Publication of USGS Video >250,000 hits

2015

Two USGS journal articles show impacts on both Carp and Large Mouth Bass in Lake Mead

Total of 19 pubs by USGS on EDCs

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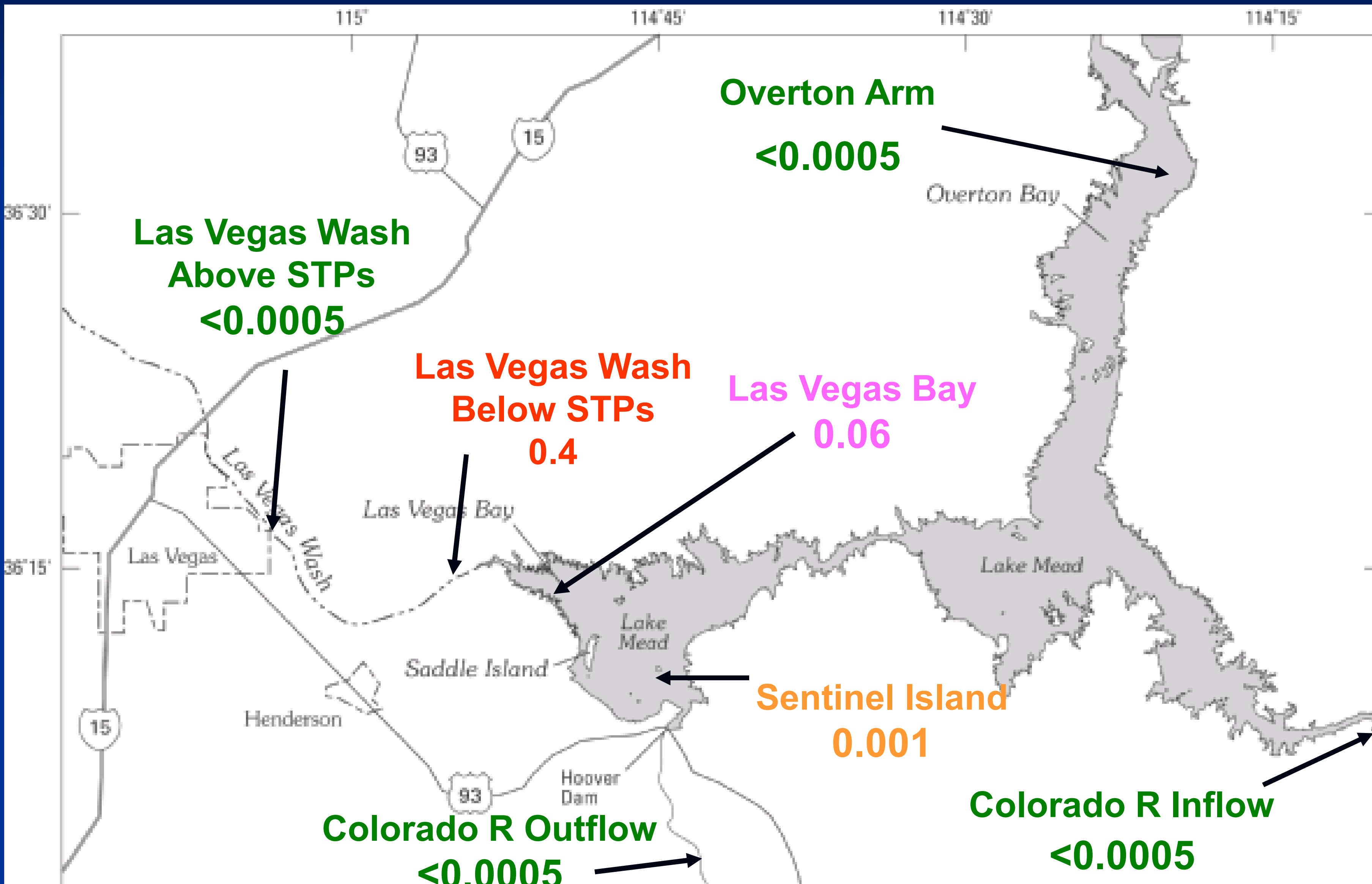
Where are EDCs Coming From?

Example of Galaxolide (µg/L) at 8 m depth in Lake Mead



Data on next three slides from Rosen et al. (2010)

Compounds Detected in Las Vegas Wash Upstream of WWTPs (21 different detections)

PCPs

- Caffeine
- 4-tert-octylphenol

PAHs

- Pyrene
- Various napthalene compounds
- Phenanthrene
- Benzo (a) pyrene

Pesticides/herbicides

- Chlorpyrifos
- Dacthal
- Trifluralin, Benfluralin
- Hexachlorobenzene – banned in 1966 in USA
- **Industrial**
- BDE (47,99)
- Pentachloroanisole (degradation of PCP)
- 5-methyl-1H-benzotriazole
- *para*-cresol
- Tris (2-butoxyethyl) phosphate

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Compounds Detected in Las Vegas Wash Downstream of WWTPs (35 different detections)

PCPs

- Galoxolide
- Tonalide
- 4-tert-octylphenol
- Triclosan

PAHs

- Pyrene
- Anthracene
- Phenanthrene
- Benzo (a) pyrene

Pesticides

- Chlorpyrifos
- o,p’ DDE
- Trifluralin
- HCB
- Trans & Cis Chlordane

Industrial

- BDE (47,99,100,138, 146,180)

And others

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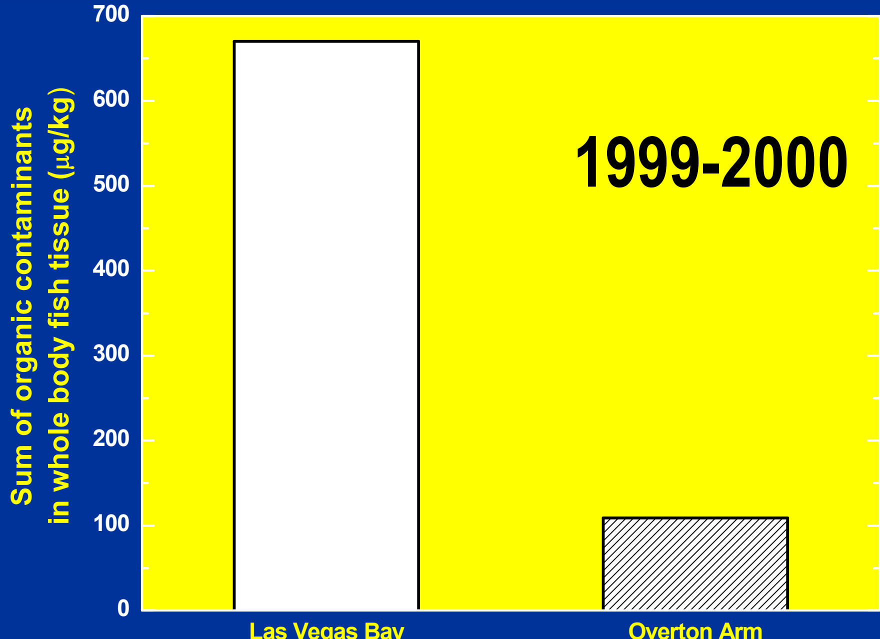
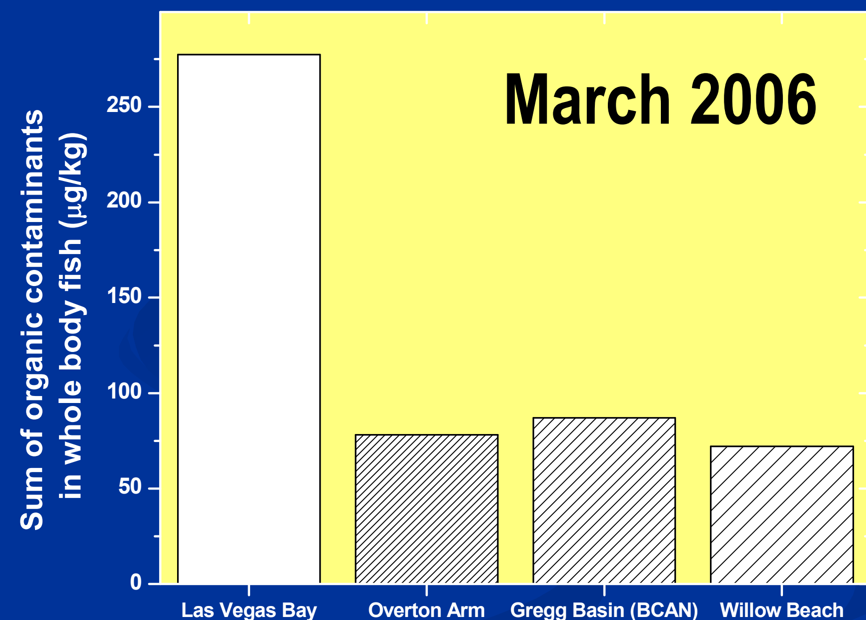
Effects in Male Carp

Tumors and Intersex fish found in Willow Beach Carp

EDCs found in carp include Methyl Triclosan,PBDEs, DDT (and metabolites), Fragrances



From Goodbred et al. (2007)



Derived from Patiño et al. (2015)

From high to low, reproductive condition by site can be classified as:

OA > LVB > LVW > WB

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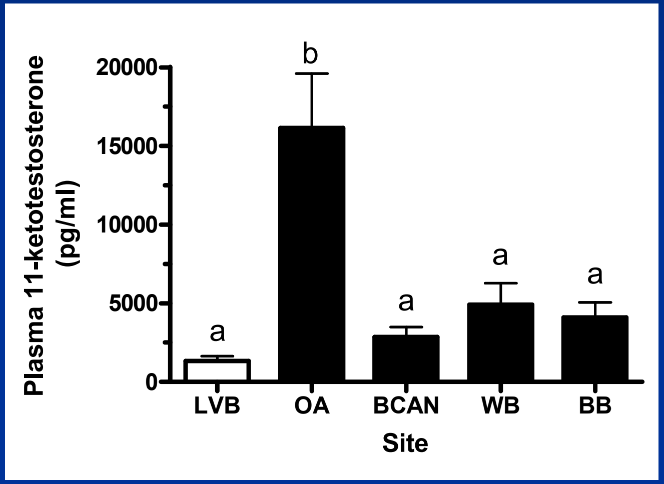
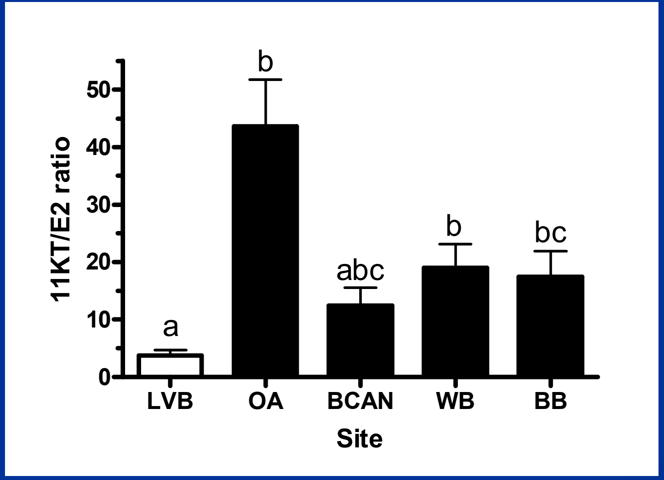
March 2006 Results – Males

Reproductive hormones

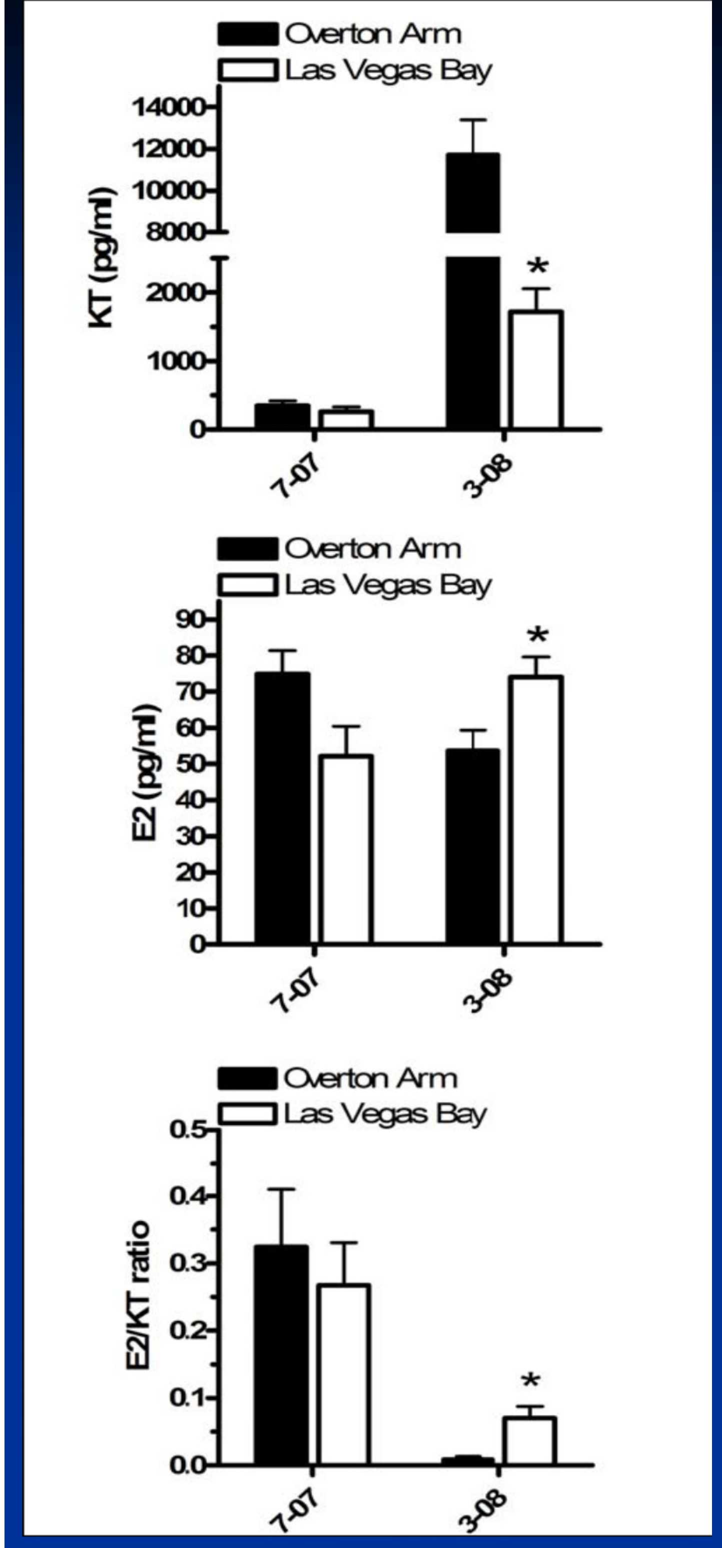




From data in Patiño et al. (2015)

Comments

- Highest levels of plasma 11KT and 11KT/E2 ratios found in OA males
- Lowest levels of plasma 11KT and 11KT/E2 ratios found in LVB males



Effects in Male Largemouth Bass

Only two sites have bass samples collected chemical data show similar trends to carp

The differences between sites were most evident just prior spawning period (March 2008)

Relatively low KT levels and high E2/KT ratios in Las Vegas Bay males are consistent with reduced health and reproductive condition

From Goodbred et al. (2015)

Motility of Endangered Razorback Sucker sperm

	Total (%)	Duration (s)
Las Vegas Bay	72.3 (4.1)	40.2 (1.1)
Reference Site	87.1 (1.4)	42.8 (1.6)

From data in Jenkins et al. (2011)

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Evolution of reaction to EDC studies

1990's when first studies came out saying EDCs present in aquatic ecosystems

REACTION: no effect on aquatic wildlife

Early 2000's when many studies showed effects of EDCs on aquatic ecosystems

REACTION: Well, there is some effect on wildlife, but not on humans

2010s: Studies are beginning to come out on EDC effects on Primates[1]

REACTION: ???? None yet, too early and not well publicized or replicated yet

[1]Sobolewski, M. et al, 2014. Sex-specific enhanced behavioral toxicity induced by maternal exposure to a mixture of low dose endocrine-disrupting chemicals. NeuroToxicology 45 121–130.

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Conclusions

- As more and more studies have been published since the 1990s, it became difficult to continue to assert that there was no affect on aquatic wildlife, even when chemical concentrations were at "low" levels
- Mixtures of EDCs at low concentrations may be important
- Affects on human health are less certain, but there is new evidence suggesting a link, although there is likely much more direct and concentrated routes of EDCs to human health
- Studies in Lake Mead and other places have shown that EDCs can affect aquatic wildlife, and these studies have helped to improve wastewater treatment in large cities, including Las Vegas

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Questions?

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