Northwest **Power** and **Conservation** Council

August 8, 2017

MEMORANDUM

TO: **Committee Members**

FROM: **Leslie Bach**

SUBJECT: **Presentation on effects of Toxic contaminants on fish**

BACKGROUND:

Presenter: Nat Scholz and Jessica Lundin, NOAA Fisheries

Summary: Toxic chemical contaminants are a form of habitat degradation, and thus a limiting factor for salmon recovery in many areas of the Columbia River Basin. This presentation will briefly discuss major threats to salmon health and survival, ongoing efforts to improve water and sediment quality, likely benefits for threatened and endangered populations, and key information gaps. The discussion will also identify situations in which toxics, if unaddressed, can undermine the recovery goals of conventional physical habitat restoration efforts.

Relevance: The Fish and Wildlife Program Water Quality sub-strategy includes a provision for the Council to "…assist regional parties in advancing public education and information on toxics issues" (page 55, Water Quality Strategy). The emerging program priorities section calls for the Council to preserve program effectiveness by supporting "mapping and determining hotspots for toxic contaminants" (page 116, Investment Strategy – Emerging Program Priorities).

Background: Council staff have been hosting a regional workgroup consisting of staff from NOAA, CRITFC, Washington Ecology, ODEQ, LCEP, UCUTs, Yakama Nation, USGS, EPA and others. The basis for the group is to raise

awareness of the issue of toxic contaminant impacts on native fish and wildlife. This presentation is part of that effort, along with a pilot mapping exercise to demonstrate tools for identifying and displaying toxic contaminant issues in the Columbia River Basin.

Toxics and Pacific salmon conservation

Nat Scholz

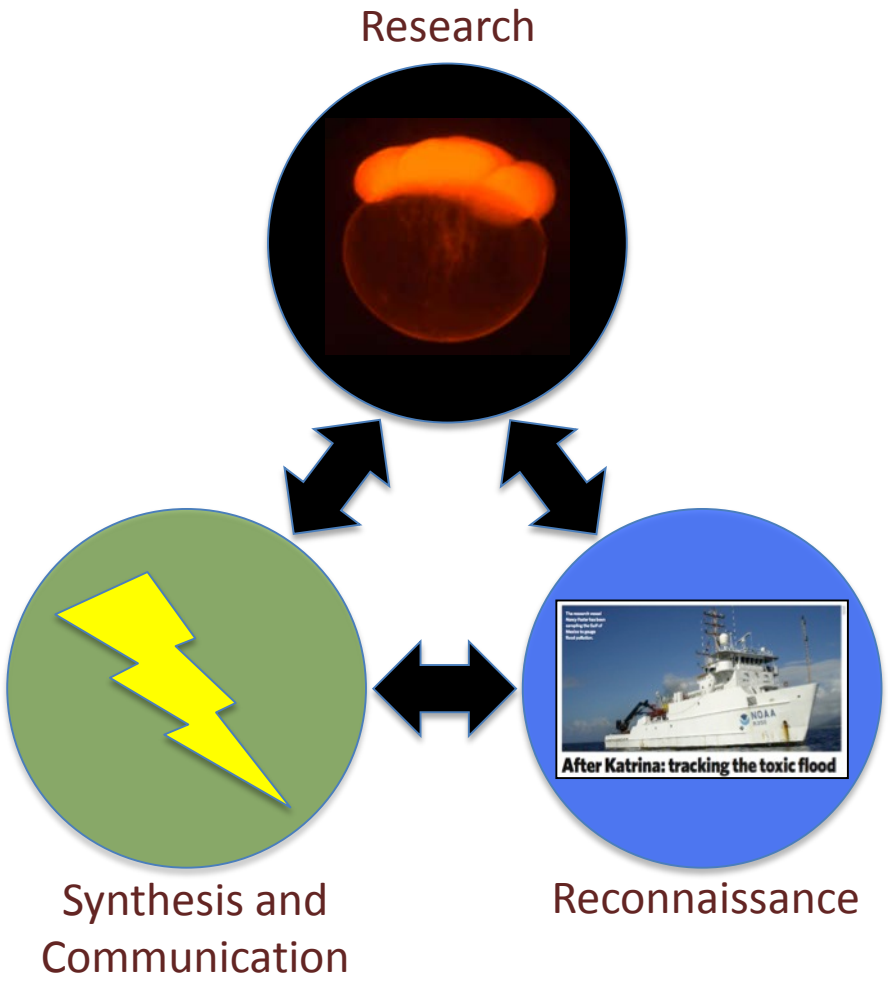
NOAA Fisheries, Northwest Fisheries Science Center, Seattle

NWFSC NORTHWEST FISHERIES SCIENCE CENTER

NWPCC, Portland - August 15th, 2017

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

Ecotoxicology Program: Core Competencies



Research

- Injury thresholds
- Toxic mechanisms/pathways
- Controlled experimental field studies
- Mixtures and multiple stressors
- Next generation biomarkers

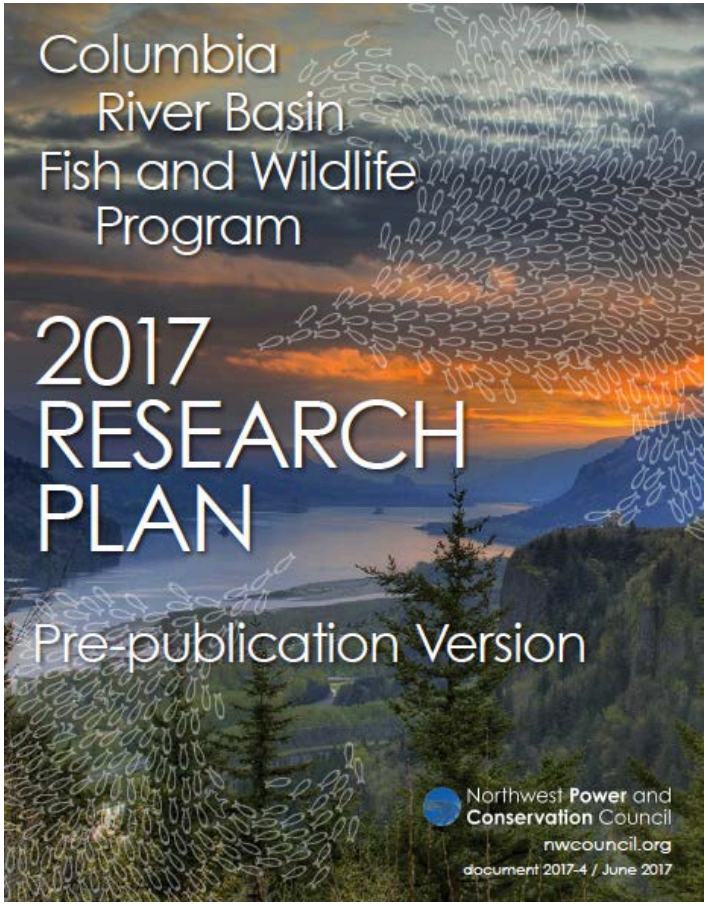
Reconnaissance

- Habitat restoration effectiveness
- Seafood safety/surveillance
- Environmental status and trends
- Chemicals of emerging concern
- Sentinels for ecological/human health

Synthesis and Communication

- Risk characterization and assessment
- Ecological modeling
- Resiliency forecasting
- Science communication
- Science-to-NOAA decisionmaking

A focus on Pacific salmon, degraded habitats, and the conservation of threatened and endangered species



Critical uncertainties

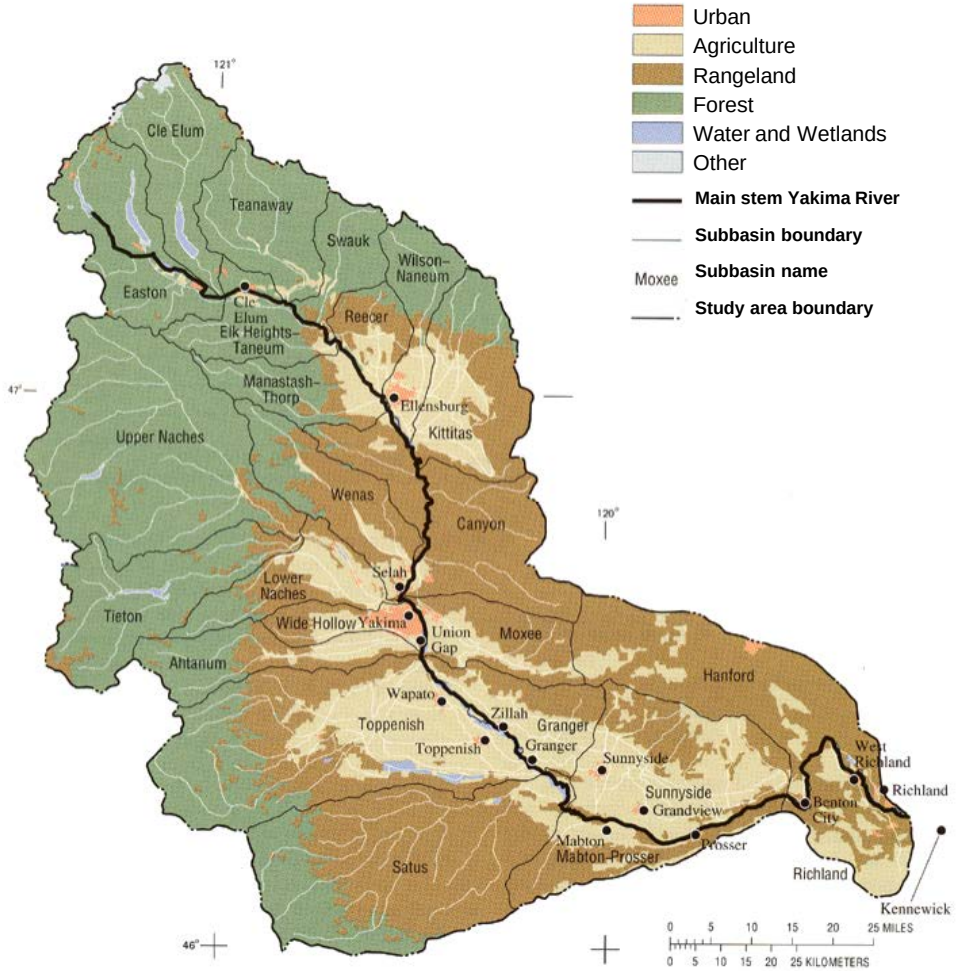
1.3. How do toxic substances, alone and in combination, affect fish and wildlife distribution and abundance, survival and fitness, and productivity in the Columbia River Basin?

1.4. What are the cumulative and/or synergistic effects of multiple toxic contaminants, particularly pesticides, on [food webs], as well as interactions between these chemicals and non-chemical stressors?

1.5. How do food web transfer, sediment transport, and biological effects of emerging and legacy organic contaminants under current management regimes affect key Columbia River species, the success of restoration projects within the basin, and human health (i.e., the success of harvest mitigation)?

1.6. What levels of chemicals of emerging concern (CECs) impact the health of focal species including Pacific Lamprey, White Sturgeon, and salmonids?

Surface water quality in the Yakima River Basin, 1990s



USGS surface water pesticide detections

(Modified from Rinella et al., 1999)

2,4-D		Methidathion
Atrazine		Methomyl
Bromacil		Methyl parathion
Butachlor		Methyl trithion
Cyanazine		Mevinphos
Dicamba		Parathion
EPTC		Permethrin
Fenoprop		Phorate
Hexazinone		Phosphamidon
		Propargite
	Isofenphos	Trithion
	Malathion	

= pesticides with EPA Aquatic Life Criteria

Land use and land cover for subbasins in the Yakima River Basin (from Rinella et al., 1999).

Exposures to pesticide mixtures is the norm and not the exception

Representative headlines, early 2000s

Pesticides enter salmon picture

Rivers: Scientists find 50 pesticides

Continued from Page One

West Coast basins are threatened with extinction.

The potential listings of the ... under the Endangered ... could bring ... trol of ...

...ed in the bottom ... the rivers ...

...ins impair ability of fish to smell

The suit was filed by the Washington Toxics Coalition, Northwest Coalition for Alterna... tives to Pesticides, Pacific ... Fisherm...

...ited the dis- ... but ...

agency — in this case the EPA must consult with the fisheries service — to make sure their actions do not harm endangered ...

"We see that ...

pesticides on salmon. Scholz has recently conducted experiments that show an additive effect when salmon brains are exposed to a mix of insecticides. He has also begun studies looking directly at the impact of pesticides on brain function. The question that needs to be answered, said Scholz, is "what's the link between the real world pesticide levels and the biology of the animal."

In the meantime, the lawsuit will begin winding its way through the courts. Patti Goldman, the attorney for the groups who filed the ...uit, said she expects it to be several months ...efore there is a ruling.

Yesterday's appointment of Christie Whitman as EPA administrator could also affect the ...ing ...ation ...

Pesticide promoters endanger Northwest salmon

...sticides are likely to be ... supply,

In our state, we can and should make up for EPA's lack of leadership. With the recent listings under the Endangered Species Act, we can no longer ignore the role of pesticides in the diminishing returns of salmon.

...e's what we need to do:

... should use alternatives ...den care.

By ERIKA SCHREDER

The Seattle Post-Intelligencer has done a tremendous public service with its reporting on how pesticides are winding up in Puget Sound streams and threatening salmon runs. ... 20 opinion piece written by ... the pro-pesticide

creasing number of studies hav... contrary to Hansen's assertions ... kill salmon directly and may ... factor in their decline.

Our region has already se... kills due to pesticides. In 19... used in an irrigation canal ... Bear Creek of the Rogue Ri... off thousands of steelhead ... ...lmon. When salr...

Skagit Valley Herald / www.skagitvalleyherald.com

NORTHWEST

Study explores pesticides and salmon

Pesticides wrongly blamed for salmon decline

By HEATHER HANSEN

A recent Post-Intelligencer editorial described pesticides as inherently dangerous to salmon. In March, the City of Seattle ran newspaper ads asking the public to help save salmon by avoiding t... weed killers and pesticides in the...

Whoa, stop the train!

While it is true that some pesti... levels well beyond safety standard... the Environmental Protection Ager... be harmful to salmon, others are reg... for controlling diseases on salmon in hatcheries.

Credible scientists assure me ... levels of pesticides currently being d... ...ed in regional streams and rivers ...

health and environmental tests, at least 20 of those involving fish, wildlife and ecosystem impacts.

All these tests can t... and cost $...

More pesticides mean more stream pollution

It shouldn't be surprising that there's a connection between the seasonal sale of pesticides in stores and the annual rise in pesticide contamination in Puget ... streams.

...prising is that it's taken ... officials this

The pesticide study by the U.S. Geological Survey, the state Department of Ecology and King County showed concentrations of pesticides rise to lethal levels for aquatic life.

In all, 23 pesticides were detected in 12 streams in King and south Snohomish counties. Five of the pesticides were found at levels above concentrations that are safe for ... ...ms. ...led containe...

Don't s... wash pest... streams. F... pesticides ... where th... rains. And ... rden. ... rs, o... face ... dr...

British and U.S. government scientists have found evidence that low levels of pesticides may impair the salmon's ...

...ble streams when washed away by rain. Levels of pesticide used in the tests were comparable to levels that the U.S. Geological Survey has routinely found in Western streams, Stein said.

...ell. ...as ...ter ...n- ... which can ...

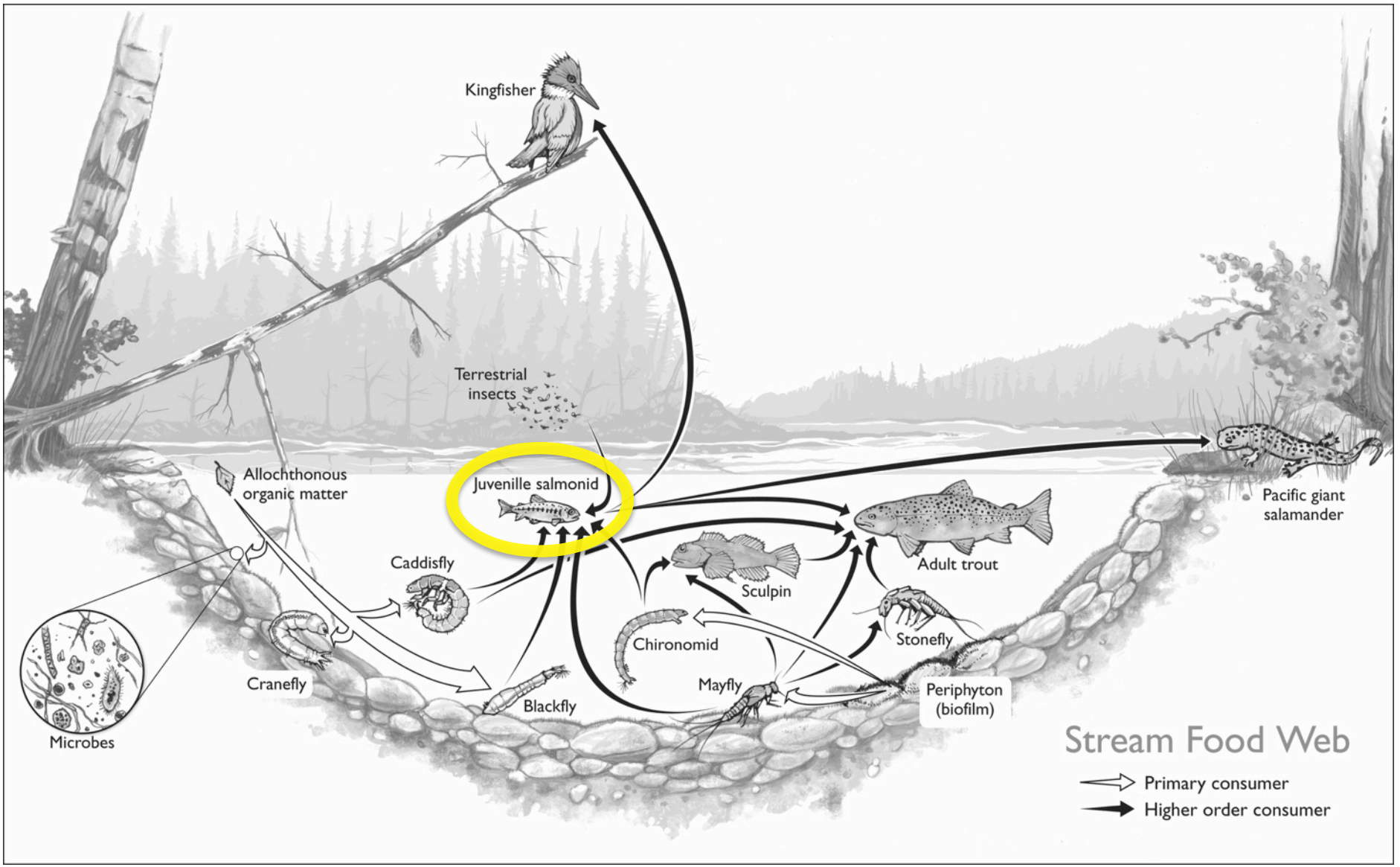
The Seattle-based researchers focused on salmon's antipredatory behavior, but the evidence also suggests pesticides could affect other sur... Stein said. The fish rely on their ... to find their way ...

EPA must act on pesticide findings

Research suggesting that salmon may be deprived of their sense of smell by a common insecticide has worrisome potential to torpedo efforts to restore the runs.

This region is spending billions of dollars on salmon restoration. That's why it's important that the Environmental Protection Agency quickly ... findings of the National ... Scientific ...

Indirect impacts on salmon prey species



Indirect impacts on salmon prey species

Developing a broader scientific foundation for river restoration: Columbia River food webs

Robert J. Naiman[a,b,1], J. Richard Alldredge[c], David A. Beauchamp[d], Peter A. Bisson[e], James Congleton[f], Charles J. Henny[g], Nancy Huntly[h], Roland Lamberson[i], Colin Levings[j,k], Erik N. Merrill[l], William G. Pearcy[m], Bruce E. Rieman[n,2], Gregory T. Ruggerone[o], Dennis Scarnecchia[p], Peter E. Smouse[q], and Chris C. Wood[r]

PNAS | December 26, 2012 | vol. 109 | no. 52 | 21201–21207

Independent Scientific Advisory Board

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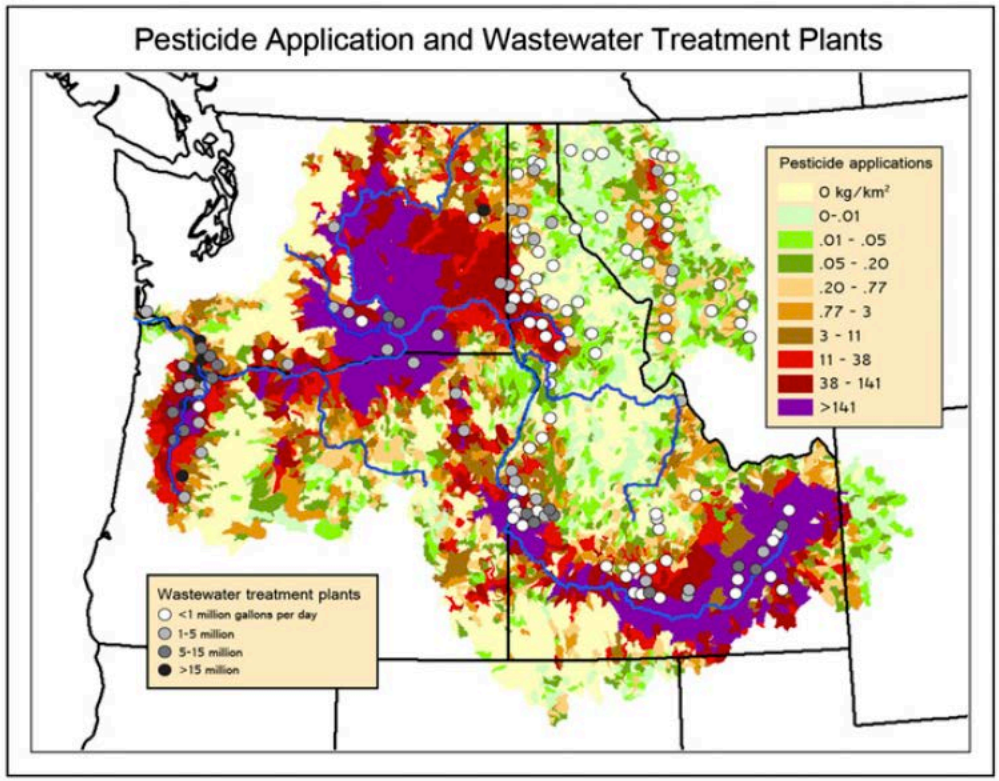

pesticides = hundreds of insecticides, herbicides, fungicides, etc.

wastewater = hundreds of pharmaceuticals and personal care products

Indirect impacts on salmon prey species

Developing a broader scientific foundation for river restoration: Columbia River food webs

Robert J. Naiman[a,b,1], J. Richard Alldredge[c], David A. Beauchamp[d], Peter A. Bisson[e], James Congleton[f], Charles J. Henny[g], Nancy Huntly[h], Roland Lamberson[i], Colin Levings[j,k], Erik N. Merrill[l], William G. Pearcy[m], Bruce E. Rieman[n,2], Gregory T. Ruggerone[o], Dennis Scarnecchia[p], Peter E. Smouse[q], and Chris C. Wood[r]

PNAS | December 26, 2012 | vol. 109 | no. 52 | 21201–21207

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"There is an urgent need to quantify and map the spatial patterns of these chemicals, assess their transfer and accumulation rates, and document the vulnerabilities of food webs to them."

"If the basal layers of food webs are being depleted by the rapidly expanding presence of contaminants, it could negate many ongoing restoration efforts."

Indirect effects

Pesticides, aquatic food webs, and the conservation of Pacific salmon

Kate H Macneale, Peter M Kiffney, and Nathaniel L Scholz*

Pesticides pose complex threats to the biological integrity of aquatic ecosystems. In the western US, pesticides have contaminated many surface waters that provide habitat for endangered salmon. These iconic species depend on the productivity of rivers, lakes, and estuaries to provide food for juvenile growth, a key determinant of subsequent marine survival. Despite extensive societal investments in salmon habitat restoration in recent years, the role of pesticides as a limiting factor for salmon recovery has received little attention. Pesticides can be toxic to primary producers and macroinvertebrates, thereby limiting salmon population recovery through adverse, bottom-up impacts on aquatic food webs. The integration of toxicology, environmental chemistry, population biology, community ecology, landscape ecology, conservation biology, and environmental policy is needed to better understand these indirect effects of pesticides on endangered species. We highlight key information gaps and discuss how future research on pesticides and food webs can most effectively guide the long-term conservation of imperiled fish species.

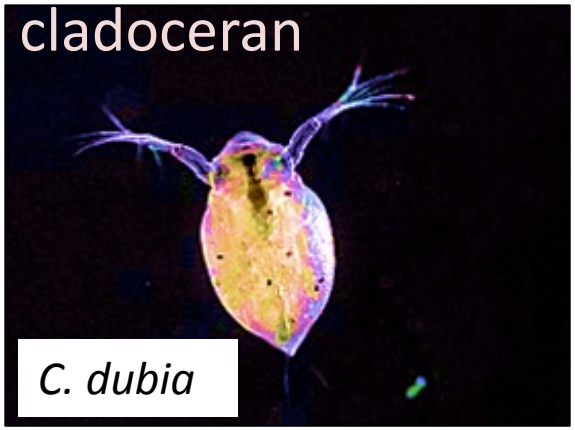
Front Ecol Environ 2010; 8(9): 475–482, doi:10.1890/090142 (published online 4 Jun 2010)

mayfly nymph

Baetis sp.

BioScience • *April 2012 / Vol. 62 No. 4*

cladoceran



C. dubia

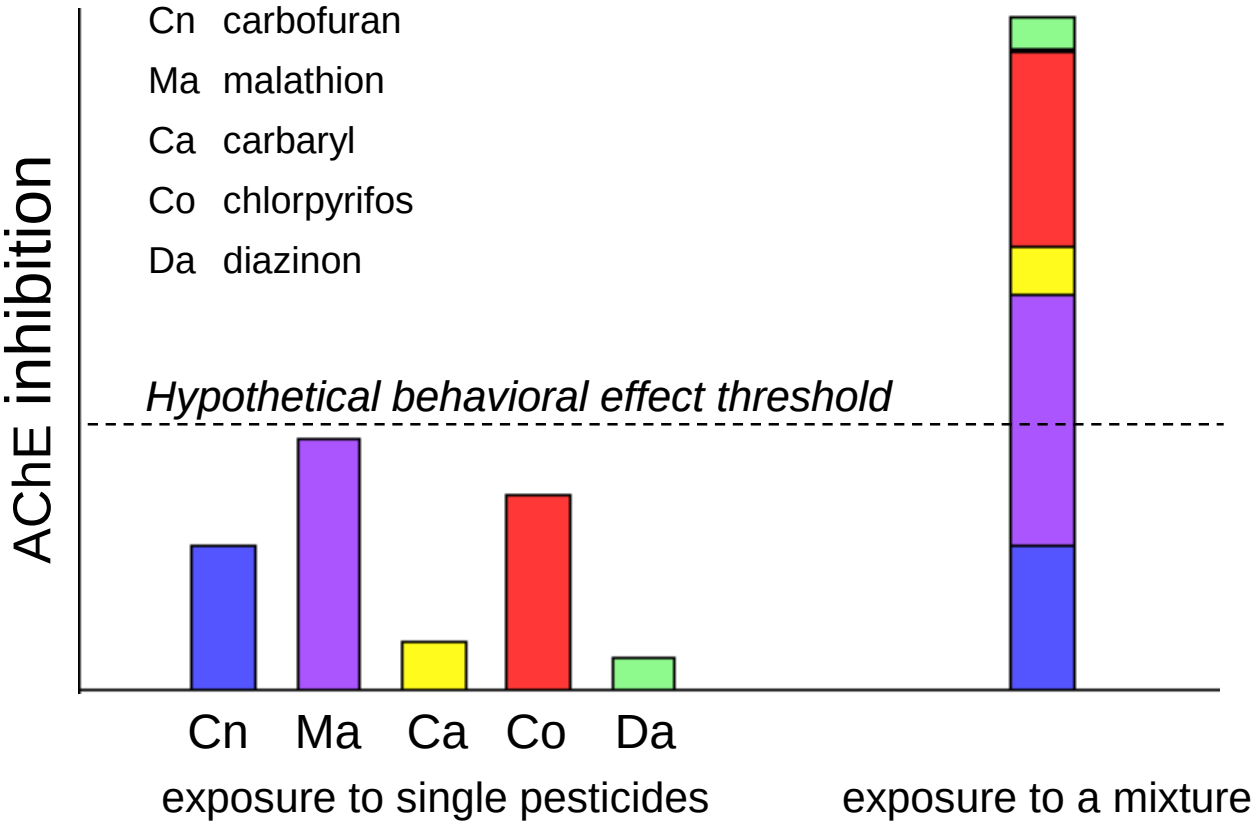
Forum

A Perspective on Modern Pesticides, Pelagic Fish Declines, and Unknown Ecological Resilience in Highly Managed Ecosystems

NATHANIEL L. SCHOLZ, ERICA FLEISHMAN, LARRY BROWN, INGE WERNER, MICHAEL L. JOHNSON, MARJORIE L. BROOKS, CARYS L. MITCHELMORE, AND DANIEL SCHLENK

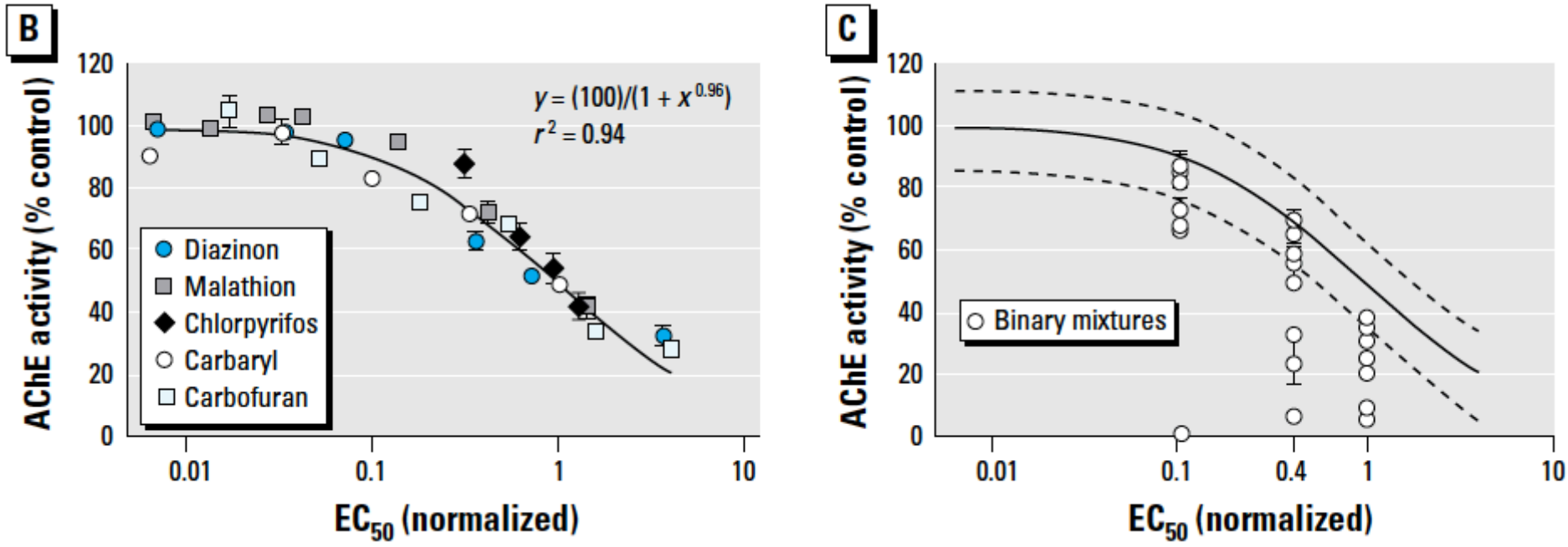
Pesticide mixture toxicity

Simple baseline assumption: additivity. This assumption is testable…



AChE is an enzyme in the salmon brain that is inhibited by neurotoxic insecticides commonly used in the CRB

Some combinations are highly synergistic



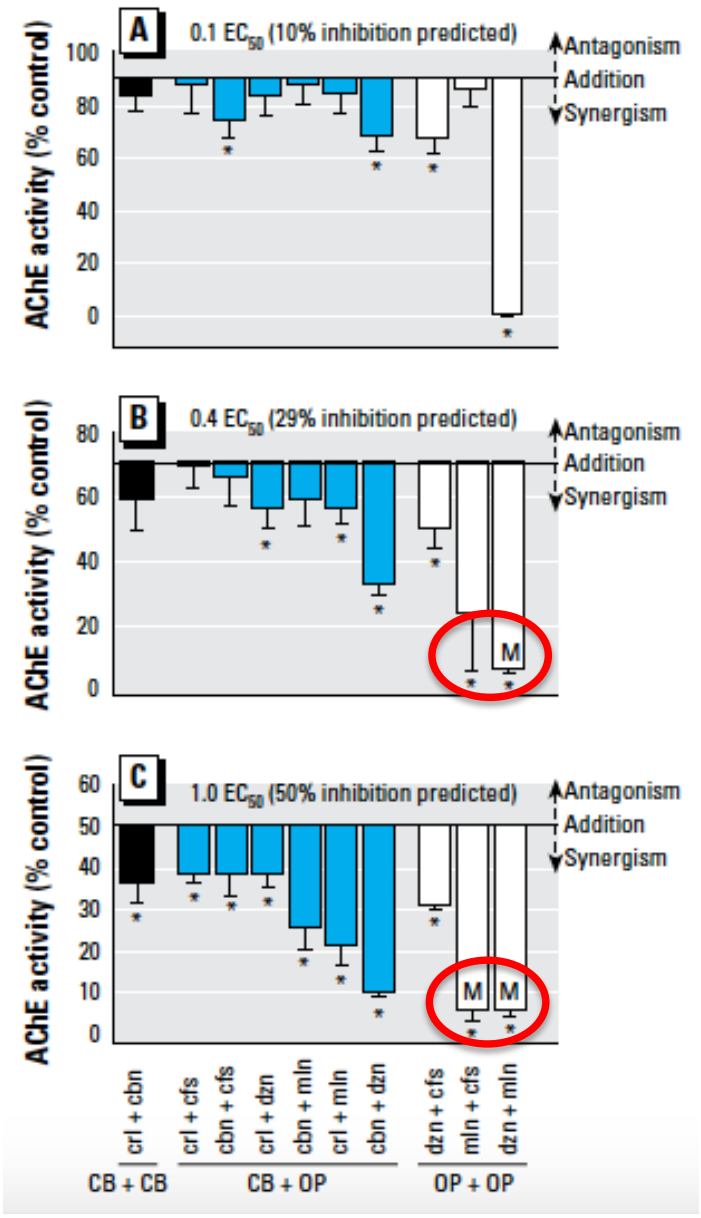
The Synergistic Toxicity of Pesticide Mixtures: Implications for Risk Assessment and the Conservation of Endangered Pacific Salmon

Cathy A. Laetz,[1] David H. Baldwin,[1] Tracy K. Collier,[1] Vincent Hebert,[2] John D. Stark,[3] and Nathaniel L. Scholz[1]

[1]NOAA (National Oceanic and Atmospheric Administration) Fisheries, Northwest Fisheries Science Center, Seattle, Washington, USA; [2]Food and Environmental Quality Laboratory, Washington State University, Richland, Washington, USA; [3]Department of Entomology, Ecotoxicology Program, Washington State University, Puyallup, Washington, USA

VOLUME 117 | NUMBER 3 | March 2009 · Environmental Health Perspectives

Sublethal toxicity becomes lethal



and…

Disrupted brain function extends to the behavioral level (reduced swimming)

Environmental Science & Technology

Article

pubs.acs.org/est

Interactive Neurobehavioral Toxicity of Diazinon, Malathion, and Ethoprop to Juvenile Coho Salmon

Cathy A. Laetz,*[,†] David H. Baldwin,[†] Vincent Hebert,[‡] John D. Stark,[§] and Nathaniel L. Scholz[†]

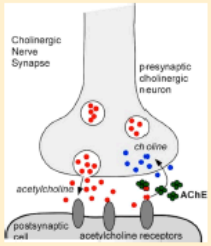
[†]Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Boulevard E., Seattle, Washington 98112, United States

[‡]Food and Environmental Quality Laboratory, Washington State University-TriCities, 2710 Crimson Way, Richland, Washington 99354, United States

[§]Department of Entomology, Ecotoxicology Program, Puyallup Research and Extension Center, Washington State University, 7612 Pioneer Way E, Puyallup, Washington 98371, United States

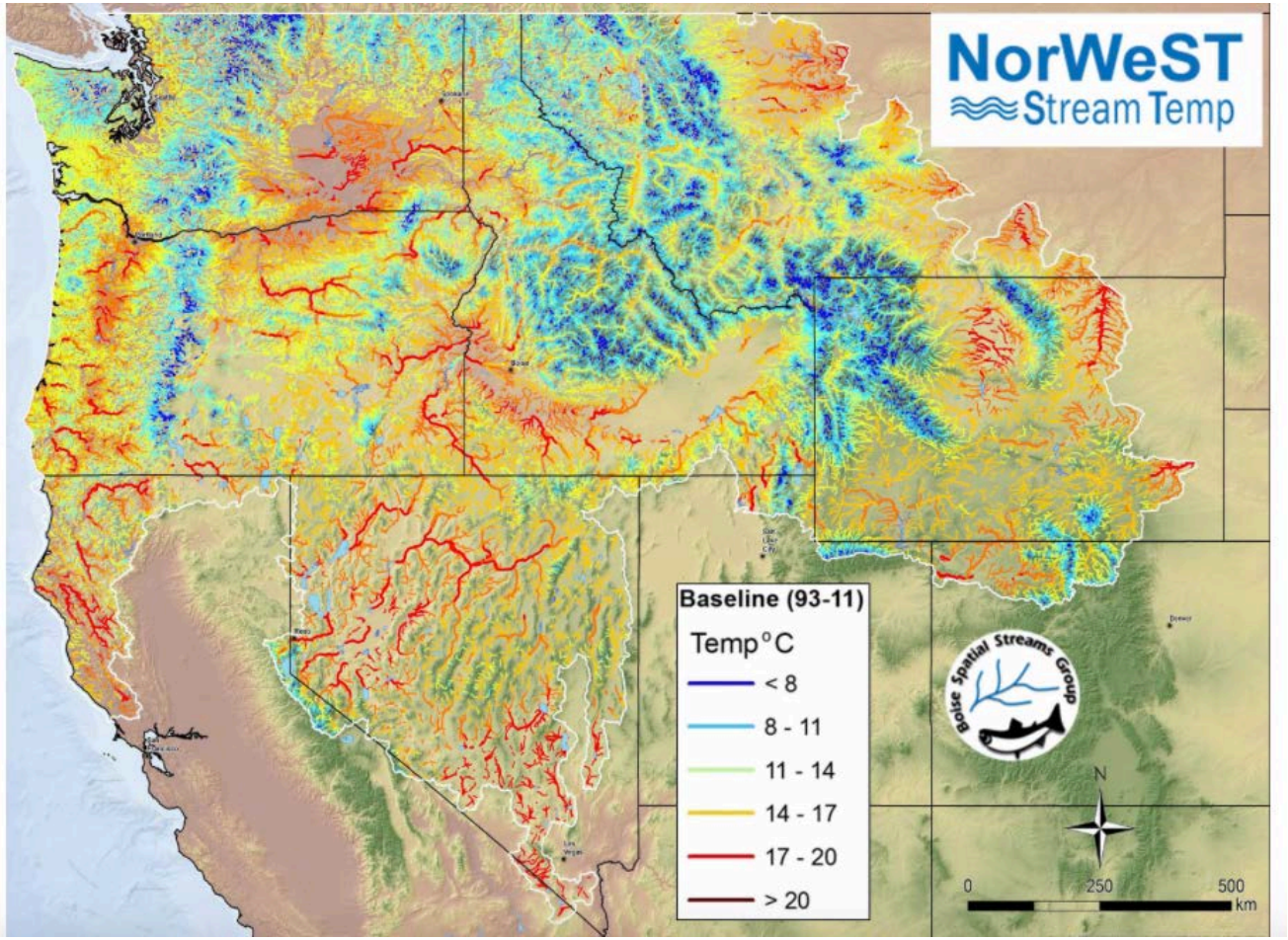
Supporting Information

ABSTRACT: In western North America, mixtures of current use pesticides have been widely detected in streams and other aquatic habitats for threatened and endangered Pacific salmon and steelhead (*Oncorhynchus* sp.). These include organophosphate insecticides that inhibit acetylcholinesterase (AChE) enzyme activity in the salmon nervous system, thereby disrupting swimming and feeding behaviors. Several organophosphates have been shown to interact as mixtures to produce synergistic AChE inhibition at concentrations near or above the upper range of surface water detections in freshwater systems. To evaluate potential synergism at lower concentrations (near or below 1 part per billion), juvenile coho (*Oncorhynchus kisutch*) were exposed to a range of mixtures of diazinon-malathion and ethoprop-malathion below a cumulative 0.05 of the predicted EC_{50} for AChE inhibition, as determined from single chemical concentration–response curves. Brain enzyme inhibition was concentration-dependent, with a 90% reduction and a significant decrease in spontaneous swimming speed at the highest binary mixture concentrations evaluated (diazinon-malathion at 2.6 and 1.1 μg/L, respectively; ethoprop-malathion at 2.8 and 1.2 μg/L, respectively). Brain enzyme activity gradually recovered over six weeks. Our findings extend earlier observations of organophosphate synergism in salmon and reveal an unusually steep concentration–response relationship across a mere 2-fold increase in mixture concentration.



Interactions between pesticide mixtures and non-chemical stressors

A focus on elevated surface water temperatures in freshwater habitats



Implications for current habitat conditions as well as future climate change

Source: U.S. Geological Survey

Mixture toxicity increases in warmer waters

Aquatic Toxicology 146 (2014) 38–44

Contents lists available at ScienceDirect

Aquatic Toxicology

journal homepage: www.elsevier.com/locate/aquatox

Elevated temperatures increase the toxicity of pesticide mixtures to juvenile coho salmon

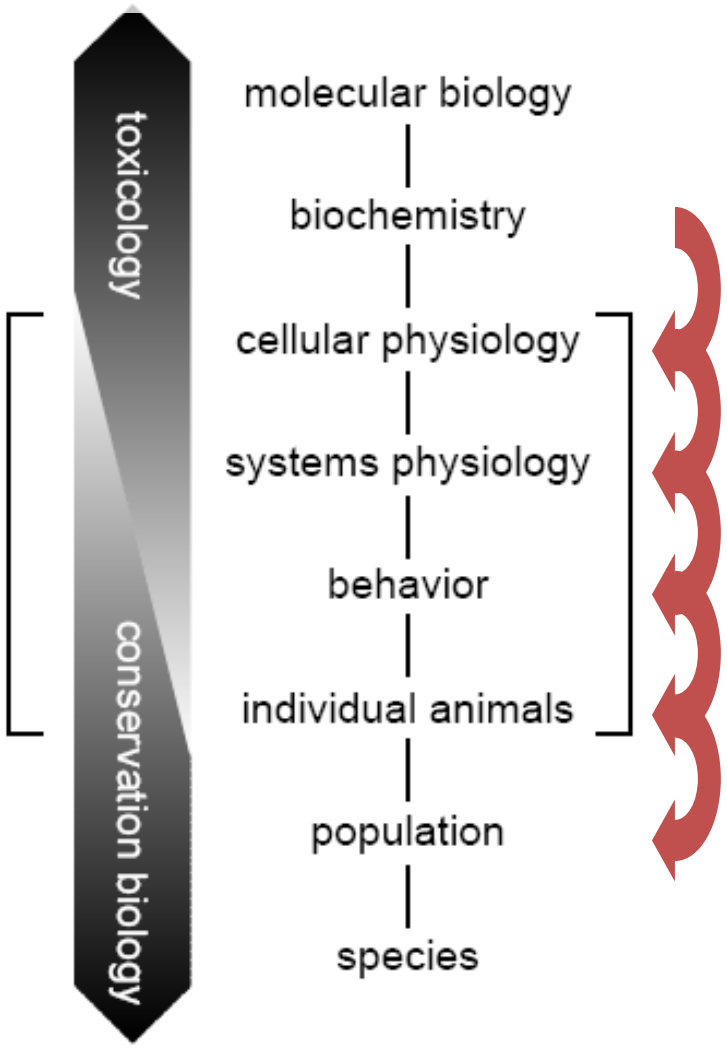
Cathy A. Laetz[a], David H. Baldwin[a], Vincent R. Hebert[b], John D. Stark[c], Nathaniel L. Scholz[a,*]

[a] *Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. E., Seattle, WA 98112, United States*
[b] *Food and Environmental Laboratory, Washington State University-TriCities, 2710 Crimson Way, Richland, WA 99354, United States*
[c] *Department of Entomology, Ecotoxicology Program, Puyallup Research and Extension Center, Washington State University, 7612 Pioneer Way E., Puyallup, WA 98371, United States*

(Experimental temperatures ranged from 12-21 ^{o}C)

Interpretation: higher surface water temperatures increase the rate of uptake and metabolic transformation to more toxic compounds

Biological scaling – population-level responses



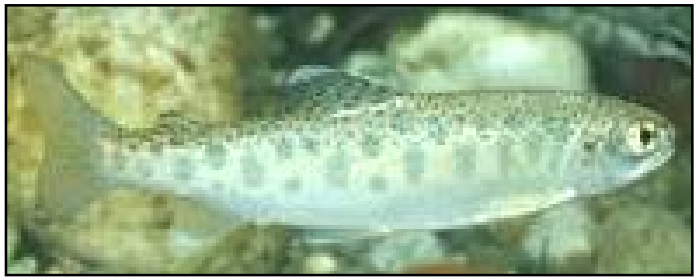
Ecological Applications, 19(8), 2009, pp. 2004–2015

A fish of many scales: extrapolating sublethal pesticide exposures to the productivity of wild salmon populations

DAVID H. BALDWIN,[1] JULANN A. SPROMBERG, TRACY K. COLLIER, AND NATHANIEL L. SCHOLZ

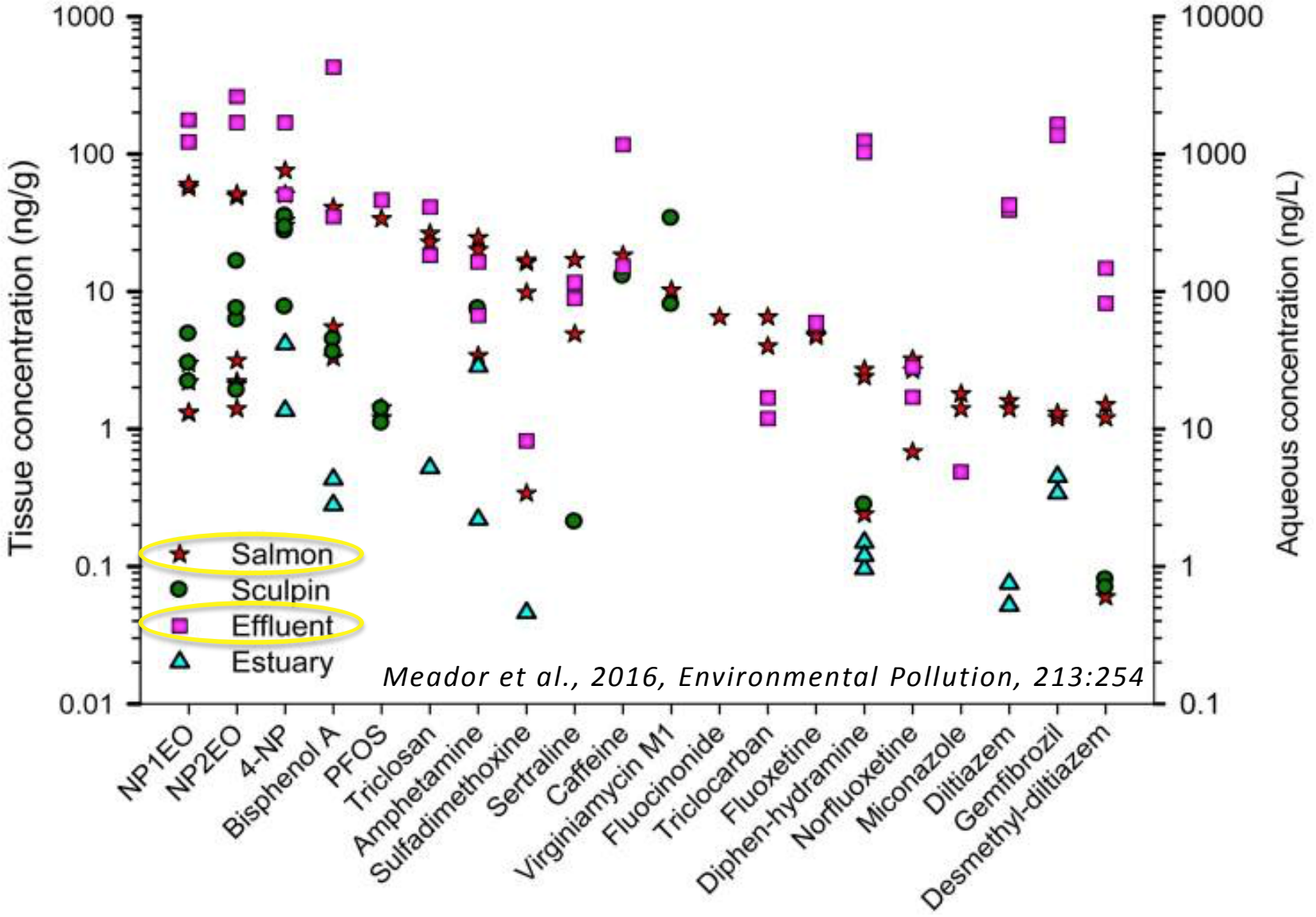
NOAA Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, Washington 98112 USA

Abstract. For more than a decade, numerous pesticides have been detected in river systems of the western United States that support anadromous species of Pacific salmon and steelhead. Over the same interval, several declining wild salmon populations have been listed as either threatened or endangered under the U.S. Endangered Species Act (ESA). Because pesticides occur in surface waters that provide critical habitat for ESA-listed stocks, they are an ongoing concern for salmon conservation and recovery throughout California and the Pacific Northwest. Because pesticide exposures are typically sublethal, a key question is whether toxicological effects at (or below) the scale of the individual animal ultimately reduce the productivity and recovery potential of wild populations. In this study we evaluate how the



Take home: environmentally-realistic seasonal pesticide exposures have the potential to limit juvenile growth, survival during migration, and population productivity and abundance over time.

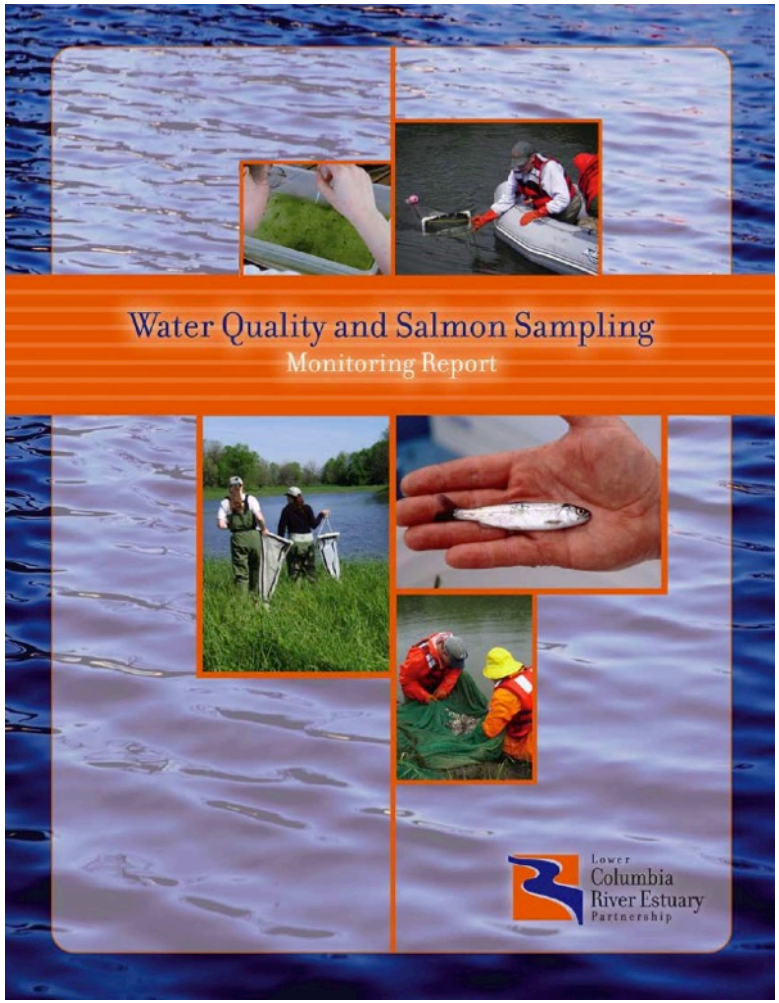
Measurable wastewater contaminants in salmon



Hormones, neuroactive drugs, antibiotics, plasticizers, etc.

Monitoring persistent contaminants in salmon

Persistent organic pollutants (POPs) bioaccumulate in aquatic food webs – juvenile salmon exposed primarily via diet



Lower Columbia River Estuary Partnership

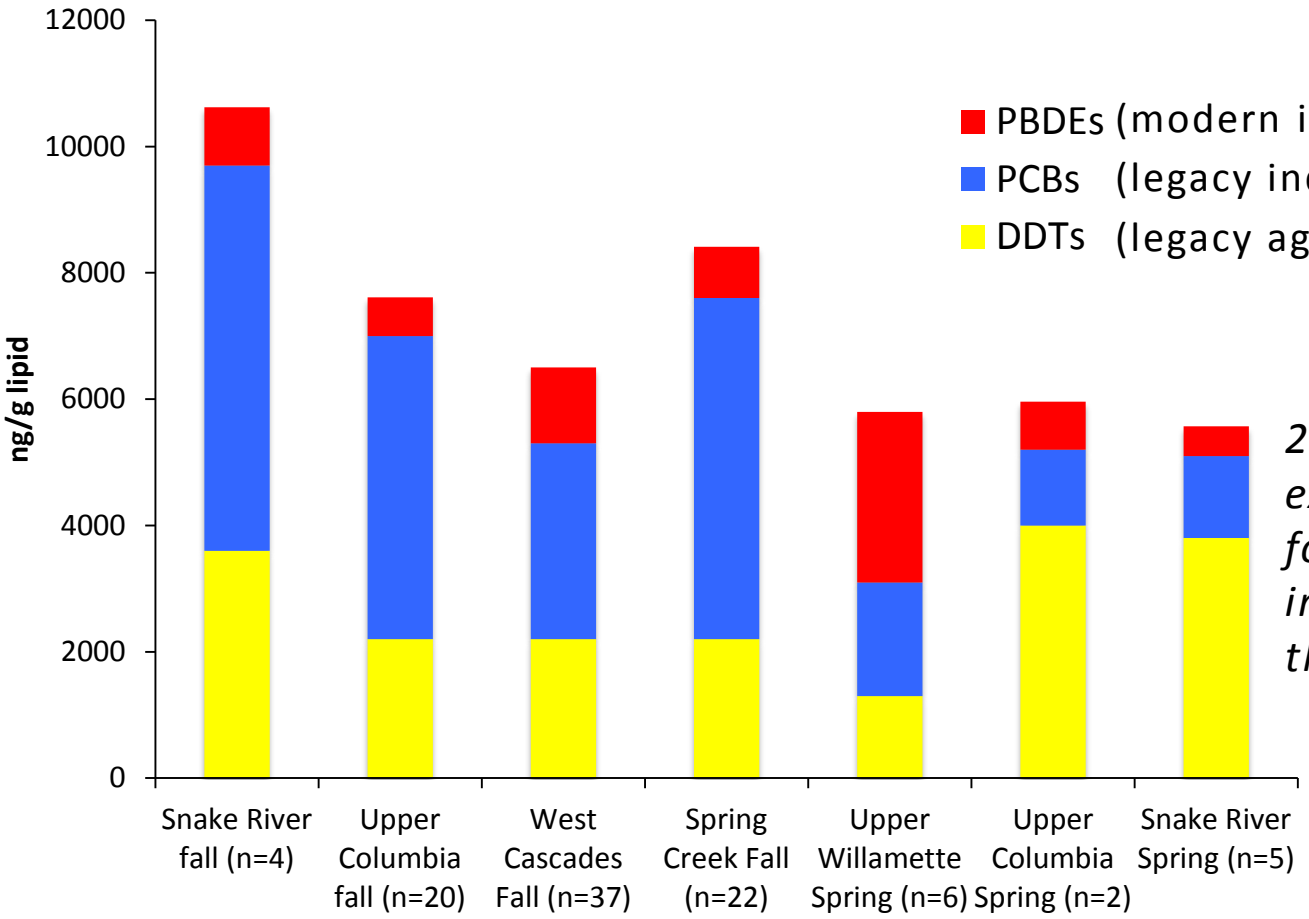
Polybrominated diphenyl ethers (PBDEs)
restricted

Polychlorinated biphenyls (PCBs)
banned (for most uses)

Dichlorodiphenyltrichloroethanes (DDTs)
banned

Focus on outmigrating juvenile Chinook salmon

Industrial versus legacy agricultural contaminants



20-80% of POP detections exceed toxicity threshold for adverse health effects in salmon, depending on the stock.

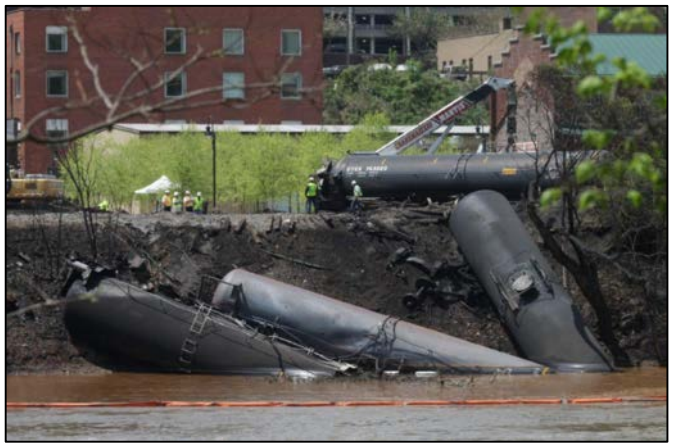
Fall Chinook stocks that rear and feed in the lower river and estuary have higher levels of industrial contaminants (PCBs and PBDEs).

Spring Chinook stocks that rear and feed more in the interior Basin have higher levels of legacy agricultural contaminants (DDTs).

Petroleum-derived hydrocarbons

Mosier, Oregon – June 3rd, 2016

Source: OPB



Source: OPB

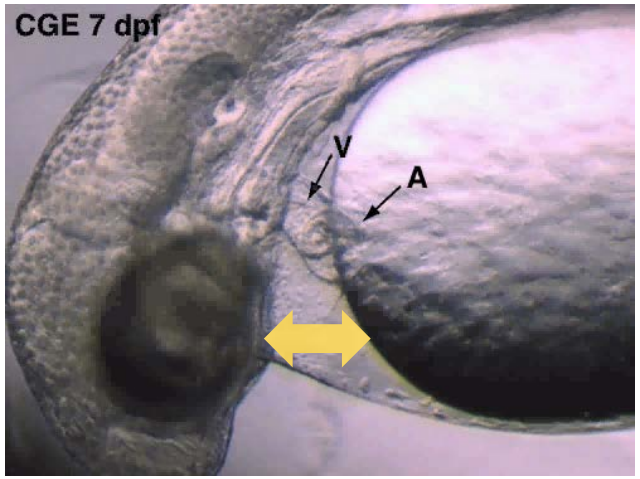
Source: US News

Petroleum-derived polycyclic aromatic hydrocarbons (PAHs) are common; oil spills, urban runoff, and industrial discharges are major sources.

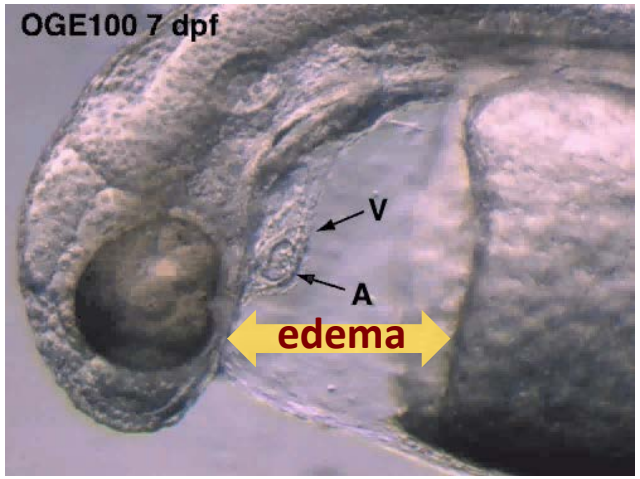
Juvenile salmon:

- reduced growth
- increased disease susceptibility

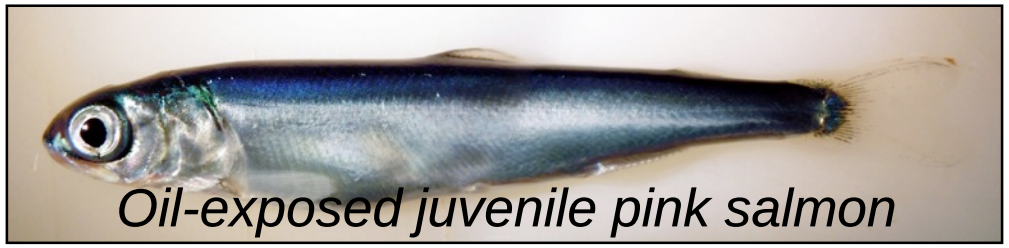
Unexposed



Crude oil-exposed



Delayed-in-time PAH cardiotoxicity



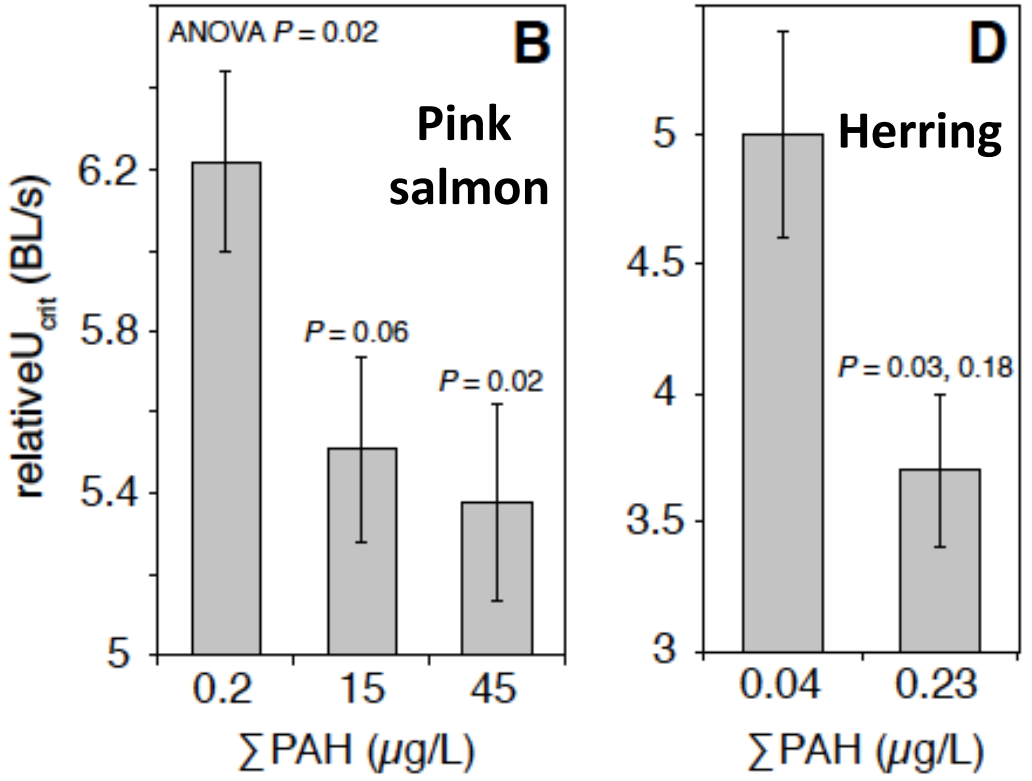
SCIENTIFIC REPORTS

OPEN

Received: 03 March 2015
Accepted: 28 July 2015
Published: 08 September 2015

Very low embryonic crude oil exposures cause lasting cardiac defects in salmon and herring

John P. Incardona[1], Mark G. Carls[2], Larry Holland[2], Tiffany L. Linbo[1], David H. Baldwin[1], Mark S. Myers[1], Karen A. Peck[1], Mark Tagal[1], Stanley D. Rice[2] & Nathaniel L. Scholz[1]



"Treadmill assays"

U_{crit} = swimming performance

BL/s = body lengths per second

Toxics can create ecological traps

OPEN ACCESS Freely available online

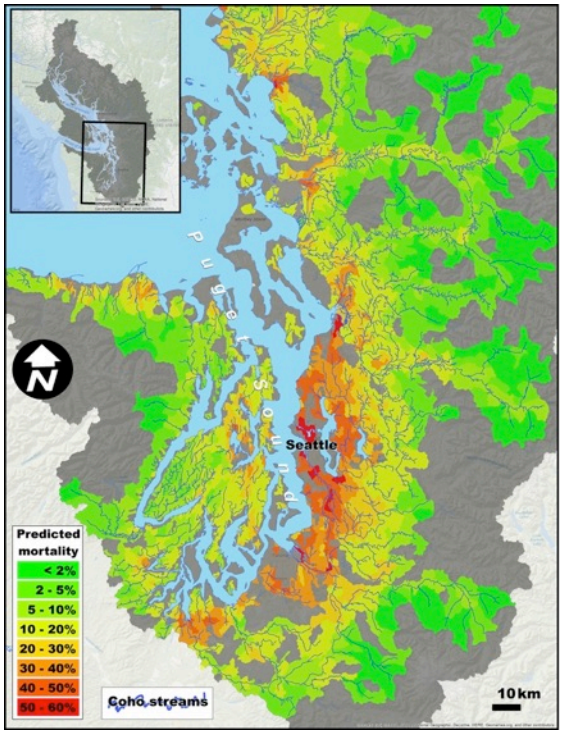
PLOS one

Recurrent Die-Offs of Adult Coho Salmon Returning to Spawn in Puget Sound Lowland Urban Streams

Nathaniel L. Scholz[1]*, Mark S. Myers[1], Sarah G. McCarthy[2], Jana S. Labenia[1], Jenifer K. McIntyre[1], Gina M. Ylitalo[1], Linda D. Rhodes[1], Cathy A. Laetz[1], Carla M. Stehr[1], Barbara L. French[1], Bill McMillan[3], Dean Wilson[2], Laura Reed[4], Katherine D. Lynch[4], Steve Damm[5], Jay W. Davis[5], Tracy K. Collier[1]

1 Northwest Fisheries Science Center, NOAA Fisheries, Seattle, Washington, United States of America, 2 Department of Natural Resources and Parks, King County, Seattle, Washington, United States of America, 3 Wild Fish Conservancy, Duvall, Washington, United States of America, 4 Seattle Public Utilities, City of Seattle, Seattle, Washington, United States of America, 5 Washington Fish and Wildlife Office, U.S. Fish and Wildlife Service, Lacey, Washington, United States of America

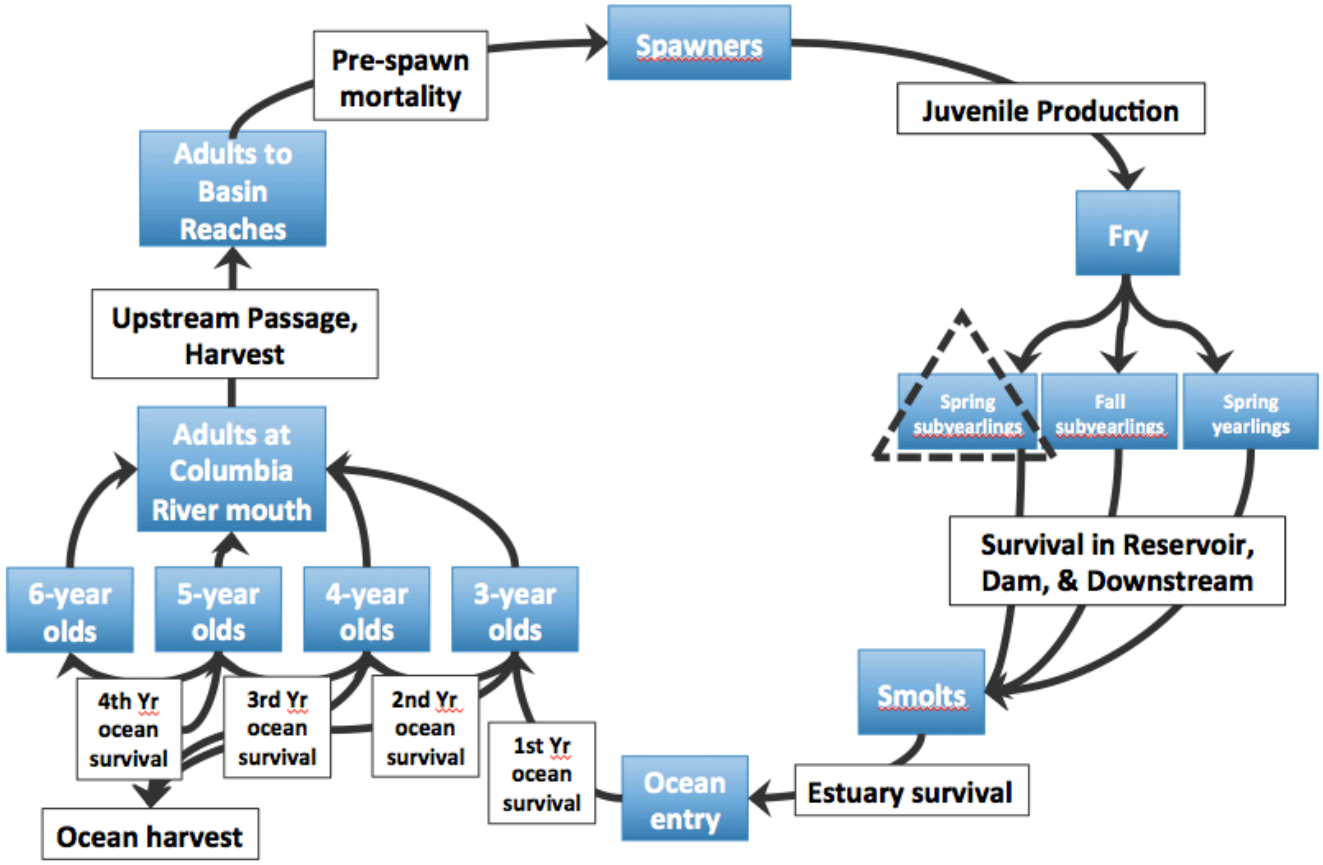
Basin-scale hotspot mapping



Feist et al., 2017,

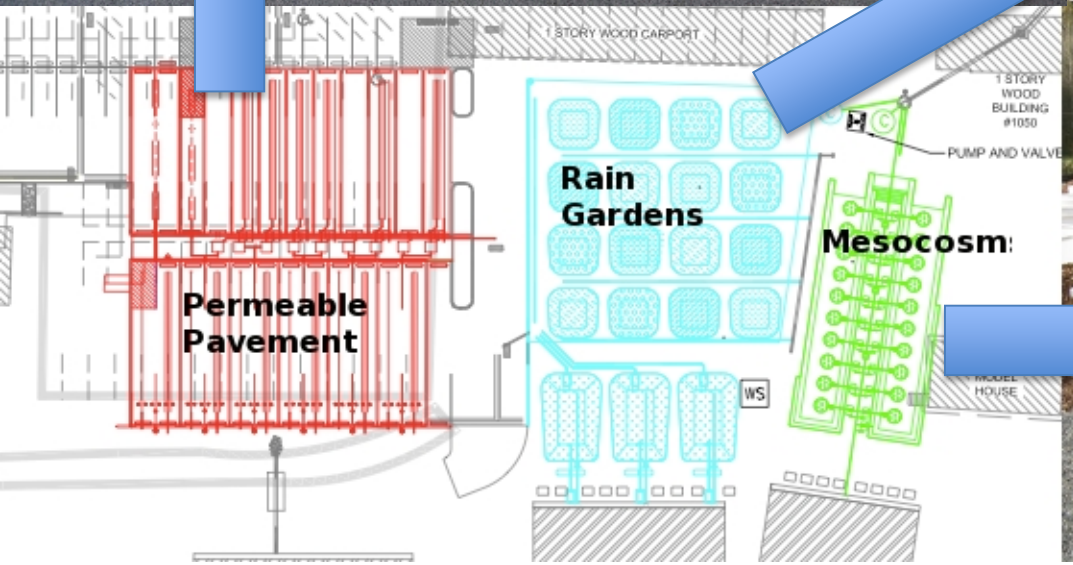
Ecological Applications, in press

Incorporating toxics into life cycle models



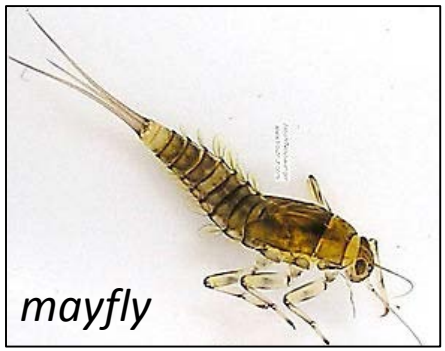
The goal is to create a framework wherein efforts to improve water and sediment quality can be evaluated alongside other restoration actions in terms of increasing salmon population growth and abundance.

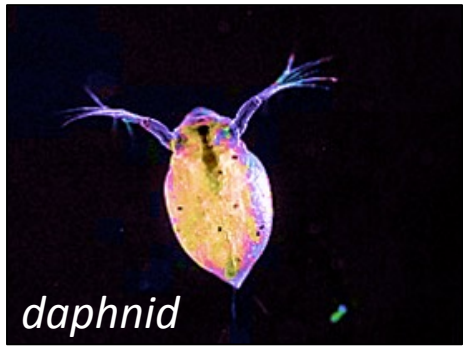
Solutions-oriented clean water research



WASHINGTON STATE UNIVERSITY

Inexpensive pollutant removal methods can protect salmon and their prey





% MORTALITY

100% → 0%

85% → 4%

100% → 0%

Result: lethality largely eliminated

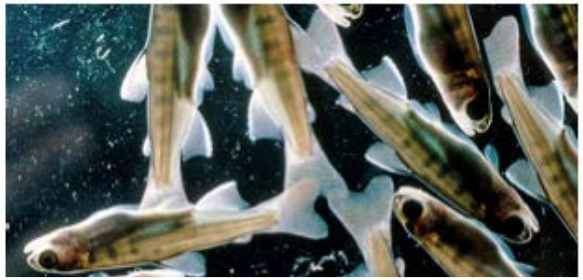
Moving the science towards mitigation effectiveness

SECTIONS HOME SEARCH The New York Times The New York Times

SCIENCE

Cleaning Up Water by Running It Through Dirt

JAN. 26, 2015



KPLU 88.5 News for Seattle and the Northwest

New Study Suggests Rain Gardens Can Save Salmon

Science of the Total Environment 500–501 (2014) 173–180

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Zebrafish and clean water technology: Assessing soil bioretention as a protective treatment for toxic urban runoff

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ARTICLE IN PRESS

Chemosphere xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Soil bioretention protects juvenile salmon and their prey from the toxic impacts of urban stormwater runoff

J.K. McIntyre [a,*], J.W. Davis [b], C. Hinman [a], K.H. Macneale [c], B.F. Anulacion [c], N.L. Scholz [c], J.D. Stark [a]

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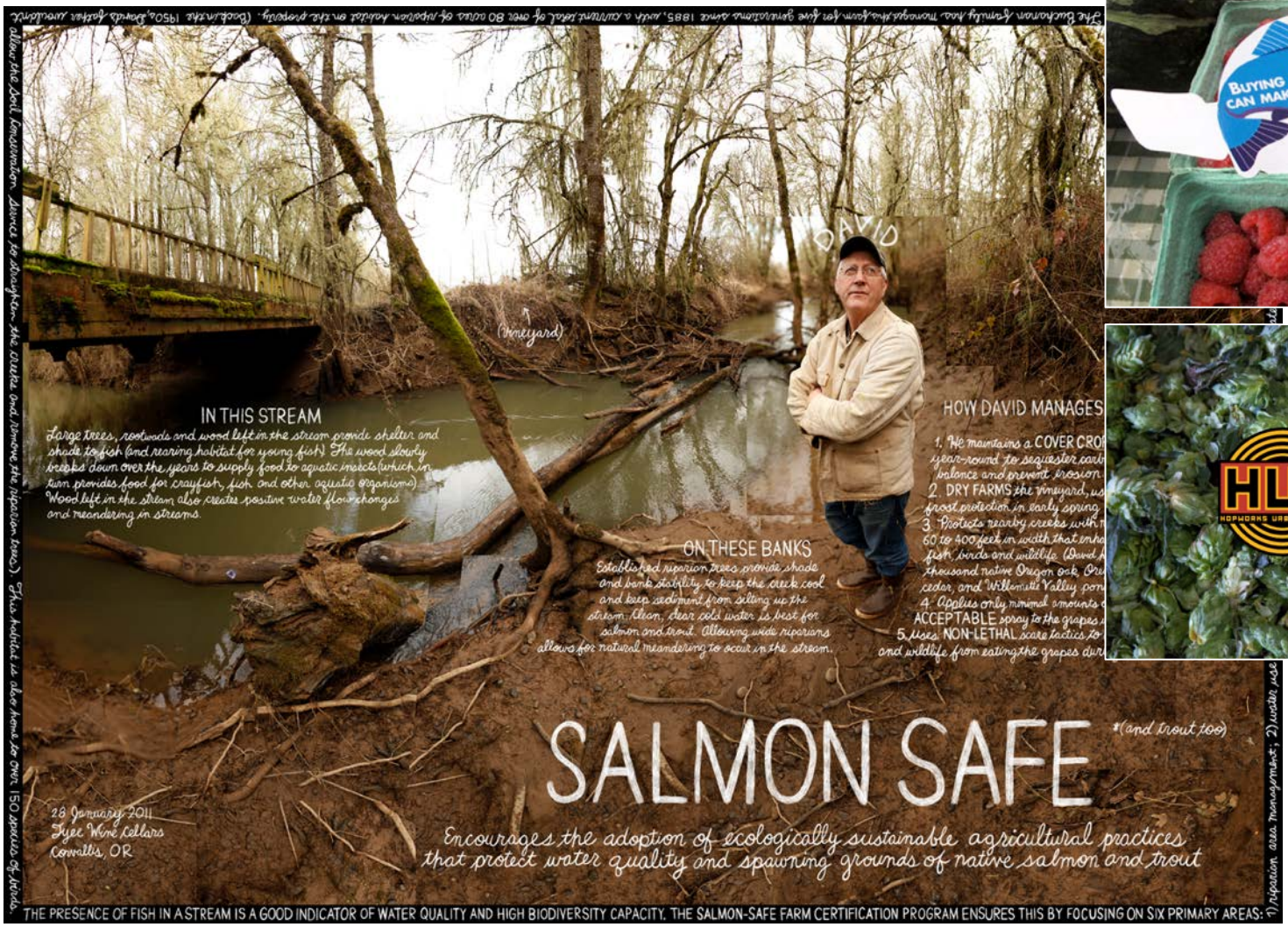
Much of the progress on toxics will be local

Ongoing science is informing local, landowner-led efforts to reduce pollution and improve salmon habitats in the Basin and beyond



Closing considerations for toxics and Pacific salmon conservation

- Toxic chemical contamination is a form of salmon habitat degradation
- Monitoring studies, while limited, suggest that water and sediment quality are degraded in many habitats
- Toxics pose a threat to salmon and their food webs
- Most effects on salmon health are sublethal and delayed in time

Closing considerations for toxics and Pacific salmon conservation

- Toxics can interact with other habitat stressors
- Individual-based effects on growth, reproduction, and survival have consequences for wild populations
- Clean water and sediment mitigation strategies to reduce pollution exposure can be very effective
- *The extent to which these efforts can improve the recovery trajectory for ESA-listed species is not currently known*