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Spatial and Temporal Quantification of Pesticide Loadings to the Sacramento River, San Joaquin River, and Bay-Delta to Guide Risk Assessment for Sensitive Species

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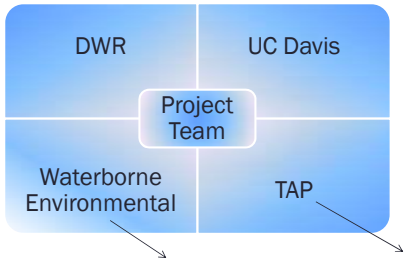
Key Objectives

- Identify the potential spatial and temporal co-occurrence of 40 pesticides with 12 threatened and endangered species to guide future risk assessments
  - Provide further knowledge of the fate and transport of pesticides in the study area
  - Provide further knowledge of species presence /life cycle in the study area
  - Identify and rank areas of highest potential risk to prioritize future initiatives

Project Team

Funded by CA Bay-Delta Science Program (CALFED)



US EPA Region 9
CDPR
CVRWQCB
NOAA-NMFS
TDC Environmental
USDA–ARS
USDA-NRCS
USGS

Study Area

Sacramento River
27,000 sq mi (69,930 km²)

Bay-Delta Estuary
4,500 sq mi (11,691 km²)

San Joaquin River
32,000 sq mi (83,000 km²)

The magic hat (pulling it together)

Pesticide Loadings

1. Runoff from fields
2. Drift from spray
3. Discharges from rice paddies
4. Runoff from urban settings

Species of Interest

1. Ecotoxicological benchmarks
2. Life history assessment
3. Species distribution

Watershed Characteristics

1. Landscape patterns
2. Soils
3. Climate Conditions

Water Quality Monitoring

Spatial-Temporal Co-occurrence

Visualizations

1. Species Distributions
2. Pesticide Loadings
3. Hotspots

Reporting

1. Species Distributions
2. Pesticide Loadings
3. Hotspots
4. Areas of Concern
5. Recommendations

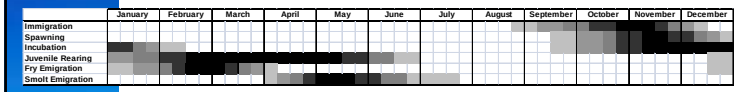
Species List

- Chinook Salmon (*Oncorhynchus tshawytscha*)
  - Sacramento River winter-run
  - Central Valley spring-run
  - Central Valley fall/late fall run
- Central Valley steelhead (*O. mykiss*)
- Southern North American Green Sturgeon (*Acipenser medirostris*)
- Delta Smelt (*Hypomesus transpacificus*)
- Striped Bass (*Morone saxatilis*)
- San Francisco Longfin Smelt (*Spirinchus thaleichthys*)
- Threadfin Shad (*Dorosoma petenense*)
- California Red-legged Frog (*Rana draytonii*)
- California Freshwater Shrimp (*Syncaris pacifica*)

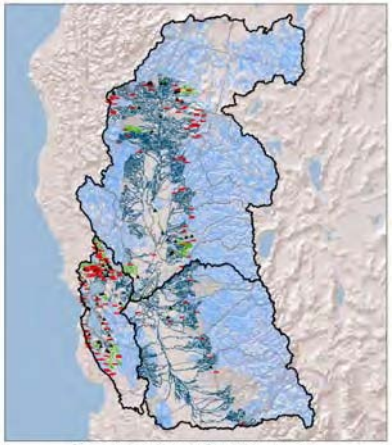
Longfin smelt photo by René Reyes, US Bureau of Reclamation. http://calfish.ucdavis.edu/index.cfm

Species Life Cycle / Species Distribution

- Fall Run Chinook Salmon



Species Distribution (by month)



Presence of Central Valley Steelhead

Reach is above a Barrier with Unknown Status
Reach is above a Total Barrier
Total Barriers
Partial Barriers
Reach is above a Partial Barrier
Reach has no Barrier Limiting Range

Pesticide List

(s)-Metolachlor	Herbicide	Imidacloprid	Insecticide
Abamectin	Insecticide	Indoxacarb	Insecticide
Bifenthrin	Insecticide	Lamda cyhalothrin	Insecticide
Bromacil	Herbicide	Malathion	Insecticide
Captan	Fungicide	Mancozeb	Fungicide
Carbaryl	Insecticide	Maneb	Fungicide
Chlomazone	Herbicide	Methomyl	Insecticide
Chlorothalonil	Fungicide	Naled	Insecticide
Chlorpyrifos	Insecticide	Oxyflurofen	Herbicide
Copper Sulphate	Fungicide	Paraquat dichloride	Herbicide
Copper Hydroxide	Fungicide	Pendimethalin	Herbicide
Cyfluthrin	Insecticide	Permethrin	Insecticide
Cyhalofop-butyl	Herbicide	Propanil	Herbicide
Cypermethrin	Insecticide	Propargite	Insecticide
Deltamethrin	Insecticide	Pyraclostrobin	Fungicide
Diazinon	Insecticide	Simazine	Herbicide
Dimethoate	Insecticide	Trifluralin	Herbicide
Diuron	Herbicide	Ziram	Fungicide
Esfenvalerate	Insecticide	Thiobencarb	Herbicide
Hexazinone	Herbicide	Tralomethrin	Insecticide

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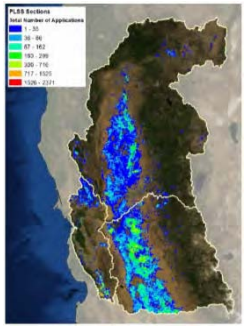
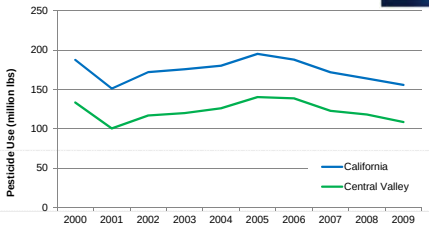
Pesticide Applications

- California Pesticide Use Reporting (PUR) database
  - PLSS section level data for agricultural applications
    - Date, rate, method (air/ground) area treated, pesticide, and crop
  - County level data for urban applications
    - Month and application site
    - Home owner use is not included





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Context

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Urban Pesticide Use

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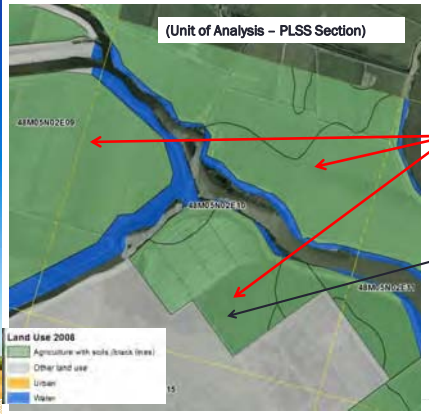
Urban Use Studies

Challenge–Where was it applied?



X acres were treated
But where?

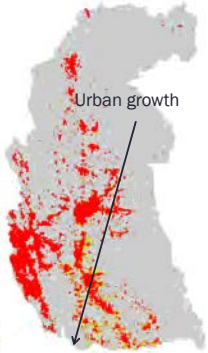
Soil represents y% of the agricultural areas

Challenge–A Changing Landscape

- Crop location and acreage changes annually
- Used the FMMP, which is mapped every 2 years, to "fill in" between years

Example: Fraction agricultural lands in a PLSS section

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Known	0.52		0.48				0.40		0.36	
"Fill in"	0.52 →		0.48	→		→	0.40	→	0.36	→
Our use	0.52	0.52	0.48	0.48	0.48	0.40	0.40	0.36	0.36	



Role of Modeling

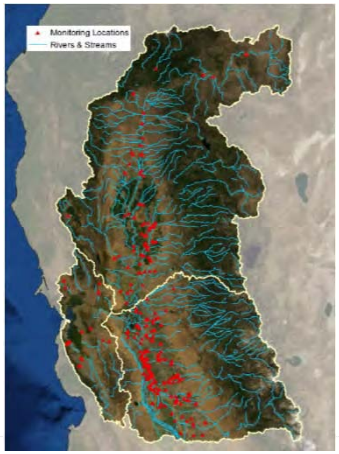
- Estimate potential pesticide loadings into nearby water bodies considering important factors in chemical fate and transport:
  - Application location, date, rate, method
  - Pesticide mobility / persistence
  - Site conditions – crop (land use), irrigation, soil properties, weather

Models

- Agricultural modeling
  - Pesticide Root Zone Model (PRZM)
  - Adapted for furrow irrigation runoff
  - Edge-of-field mass
- Rice modeling
  - Rice water quality model (RICEWQ)
  - Water management /release
- Urban modeling
  - Pervious and impervious areas with PRZM
  - Pyrethroid "Kd "calibrated to hard surface washoff studies
- Drift estimates

Role of Monitoring Data

- Monitoring results from federal, state, and regional monitoring programs
- "Real" concentrations esp. larger water bodies



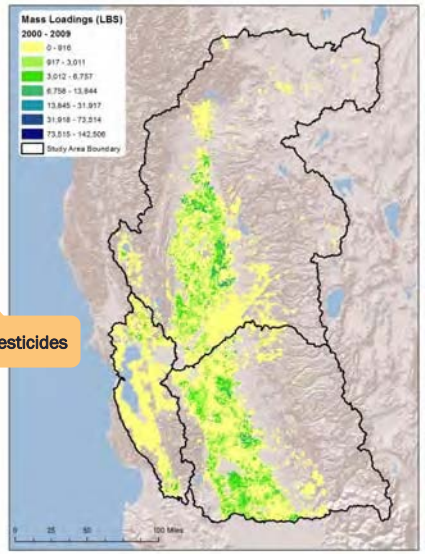
Results

Total mass loading

Drift 4.98%
Erosion 4.43%
Rice 4.34%
Runoff 86.22%
Urban 0.03%

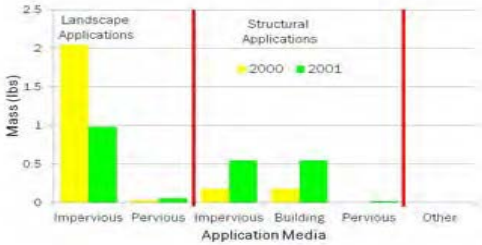
4 Pesticides only!

40 Pesticides

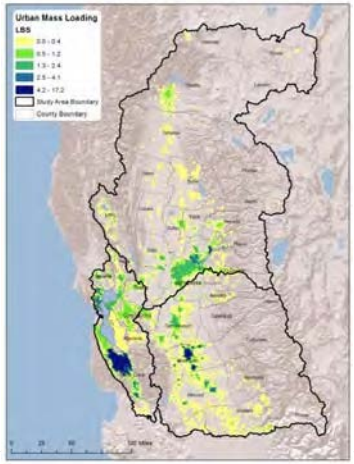


Urban Conclusions

- Annual predicted runoff losses were <0.1% of applied a.i.
  - Study area as a whole, all years, all pyrethroids
  - Varies with individual areas, years, and chemicals
- Applications to impervious areas were predicted to be the primary source of pyrethroid runoff
- Very little loss from pervious areas
- Higher losses associated with rainy season compared to irrigation season



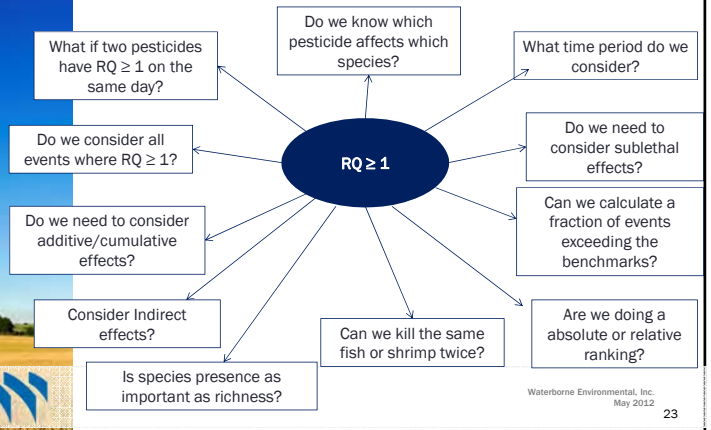
Spatial Distribution of Urban Pyrethroid "Loads"



Co-occurrence

- What is co-occurring?
  - Species of concern
  - Pesticides in surface water
- Requirement for co-occurrence
  - Same location (PLSS section level)
  - Same time (monthly)
- *Goal is to develop an scalable index that takes into account available species and pesticide information*

Questions to consider when developing a Co-occurrence Index

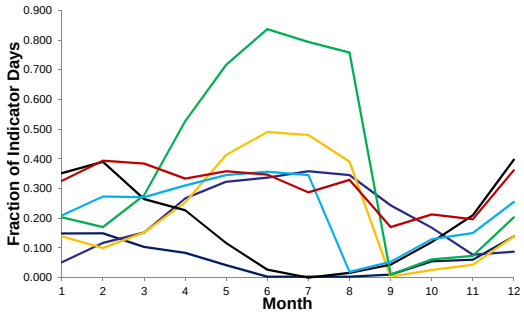


Co-occurrence Index

- Indicator days - day that one or more pesticides exceed the toxicity threshold
  - On monthly basis compute the number of indicator days within a PLSS
  - Determine the percentile points from all PLSS (10th, 20th, … 90th, 100th)
- Species richness – the number of species present in a given area
  - On a monthly basis compute the number of species present within a PLSS
  - Determine the percentile points from all PLSS (10th, 20th, … 90th, 100th)
- Flexible and scalable to the questions be asked

Indicator Days

Distribution of Indicator Days for randomly selected PLSS Sections



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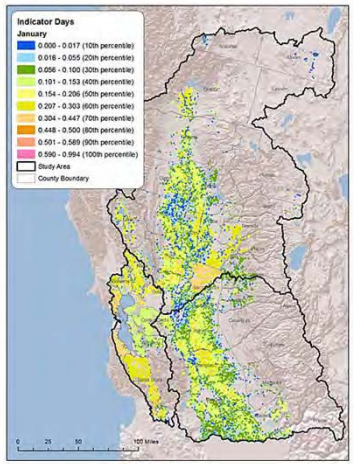
Indicator Days by Month



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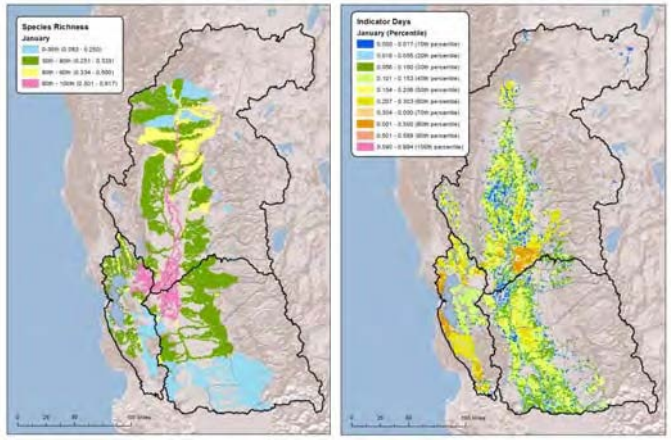
Species Richness / Indicator Days



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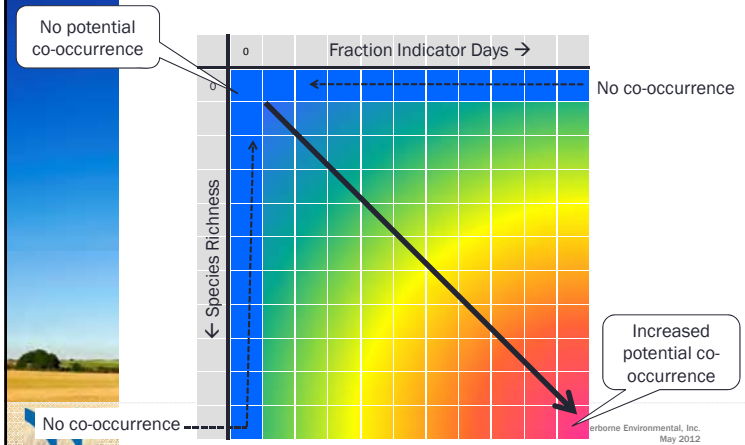
Multi-dimensional Index



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Multi-dimensional Index

Indicator Days →

← Species

	0	1	2	3	4	5	6	7	8	9	10
0	00	01	02	03	04	05	06	07	08	09	010
1	10	11	12	13	14	15	16	17	18	19	110
2	20	21	22	23	24	25	26	27	28	29	[illegible]
3	30	31	32	33	34	35	36	37	38	39	310
4	40	41	42	43	44	45	46	47	48	49	410
5	50	51	52	53	54	55	56	57	58	59	510
6	60	[illegible]	62	63	64	65	66	67	68	69	610
7	70	71	72	73	74	75	76	77	78	79	710
8	80	81	82	83	84	85	86	87	88	89	810
9	90	91	92	93	94	95	96	97	98	99	910
10	100	101	102	103	104	105	106	107	108	109	1010

What does 73 mean?

73 means that at least 70% of the species are present and the top 70 percentile of the indicator events. Emphasis would be on the species

What does 37 mean?

37 means that top 70 percentile of the indicator events are considered and at least 30% of the species are present. Emphasis would be on the pesticides.

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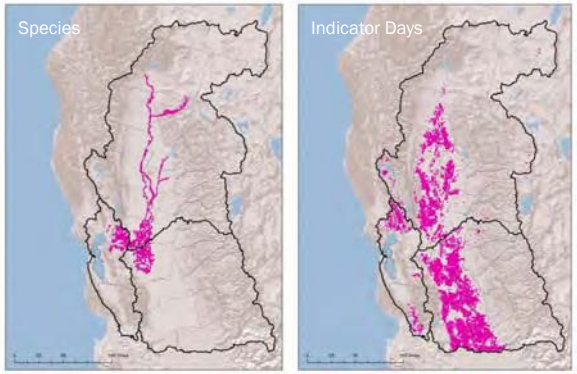
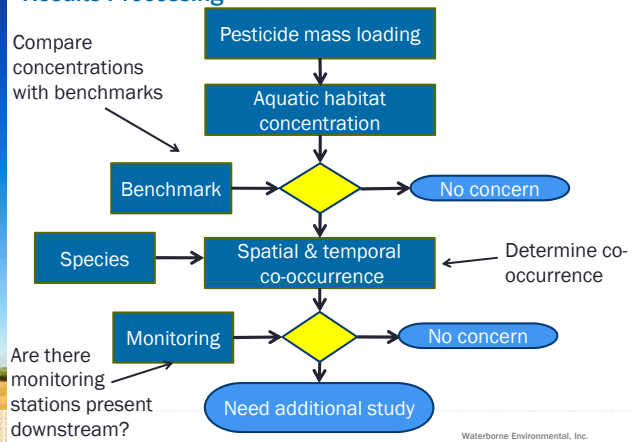
Implementation

- Q: Show all areas with at least half the species present and 50th percentile indicator events for the month of July?



Results Processing



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Caveats based on data limitations and uncertainty

- PUR precision / accuracy
- Pesticide properties
- Field-specific characteristics
- Hydrography
- Hydrology / hydraulics
- Species distributions
- Dissipation processes not represented
- Standardized assumptions

Co-occurrence predictions do not indicate adverse effects

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Use of Results

- Relative risk
- Prioritize research
- Where to focus refined risk assessments
- Support future monitoring programs (strategic locations, sampling frequency)
- Aid in developing plans to improve ecosystem quality and water quality (e.g., BMPs, hydrologic operations)

Data and Framework Retained for Future Analysis

- GIS products
  - Species of concern maps – by species by month
  - Land use changes
  - Mass loadings – by pesticide by source by day
  - Indicator days – by pesticide by day
  - Etc
- Model ready input
  - Cropping parameters
  - Soil properties
  - Weather data
  - Pesticide properties
  - Etc.

Next steps

- Where to house data?
- Development of GIS user interface?
- Data mining
  - Causal assessment
  - BMP assessments
  - Other "what-if" scenarios
- Refine data gaps and areas of uncertainty
  - Upgrade components
  - Extend species further upstream
  - Link to routing models
- Foundation for other initiatives
  - Address additional pesticides and/or other constituents
  - Future trends
    - climate change
    - land use change
  - Link with population models
- Program specific needs

Urban Approach

- Bifenthrin, cypermethrin, and cyfluthrin
  - Highest urban uses (DPR-PUR) and most often contributing to toxicity (Moran, 2010)
- Permethrin
  - Highest urban use (DPR-PUR)
- Professional pest control operator (PCO) use from PUR
  - Structural, landscape, other (right-of-way, uncultivated non-ag, turf/sod)
- Homeowner use
  - Bifenthrin only - assume 0.25 x PCO use (Moran, 2010)

Contact Information

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To download report and see overview of project:

http://www.waterborne-env.com/projects_featured.asp