The Role of Modeling the Delta's Open Water's MeHg Supply—Insights and Knowledge Gaps

Delta Science Mercury Workshops

Workshop 1: Mercury Sources: January 26, 2016

Carol DiGiorgio,
Jamie Anderson,
DWR

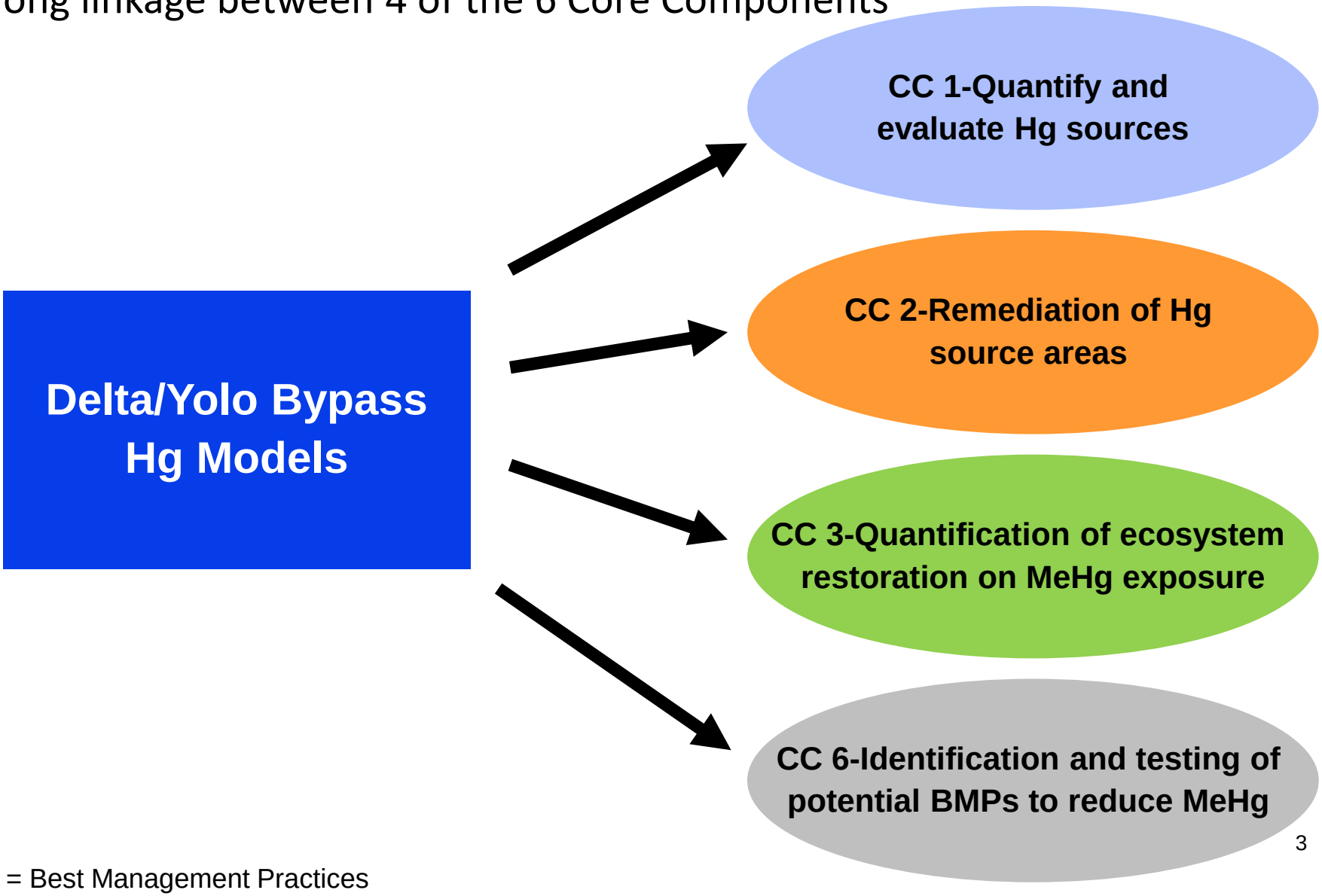
Reed Harris,
Reed Harris Environmental Ltd.

Outline

- Importance of a Hg model in the development of an updated Hg strategy
- Background on open water Hg modeling
  - Delta
  - Yolo Bypass
- Field data supporting modeling
- Insights and knowledge gaps
- Next steps

Utility of Delta/Yolo Bypass Hg Models

- Strong linkage between 4 of the 6 Core Components



BMPs = Best Management Practices

Hg Modeling and the Delta Mercury Control Program

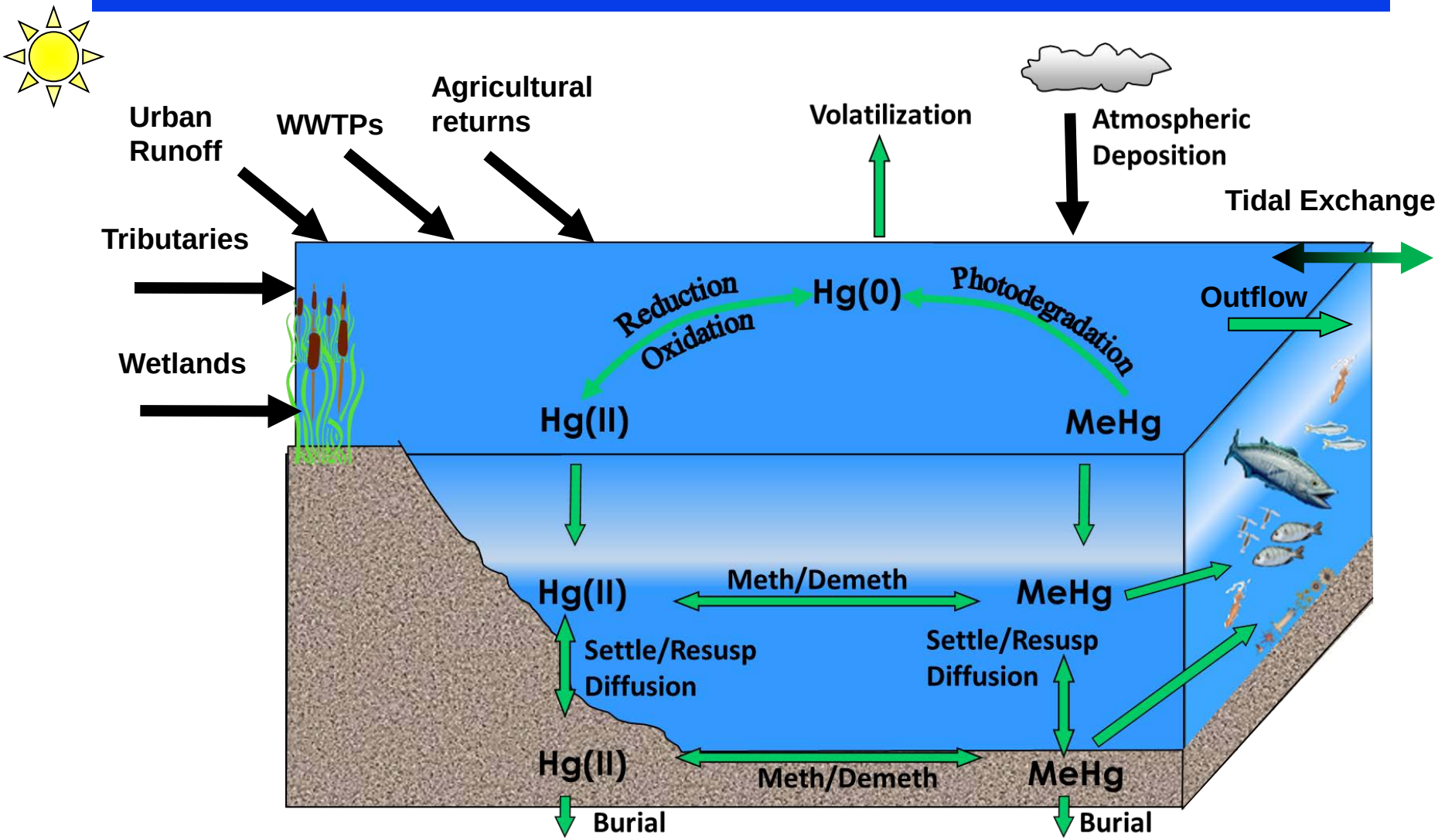
Delta Mercury Control Program & Open Water

- Driven by the Delta Mercury Control Program (DMCP) open water regulatory requirements placed on DWR and other open-water regulated entities that together make-up the open water workgroup
- Open water allocations apply to MeHg load fluxes from sediments to the water column
- Must evaluate activities (operational changes or other strategies) to reduce open water MeHg loads

Delta channels

Lands immersed by managed flood flows

Mercury Model Framework



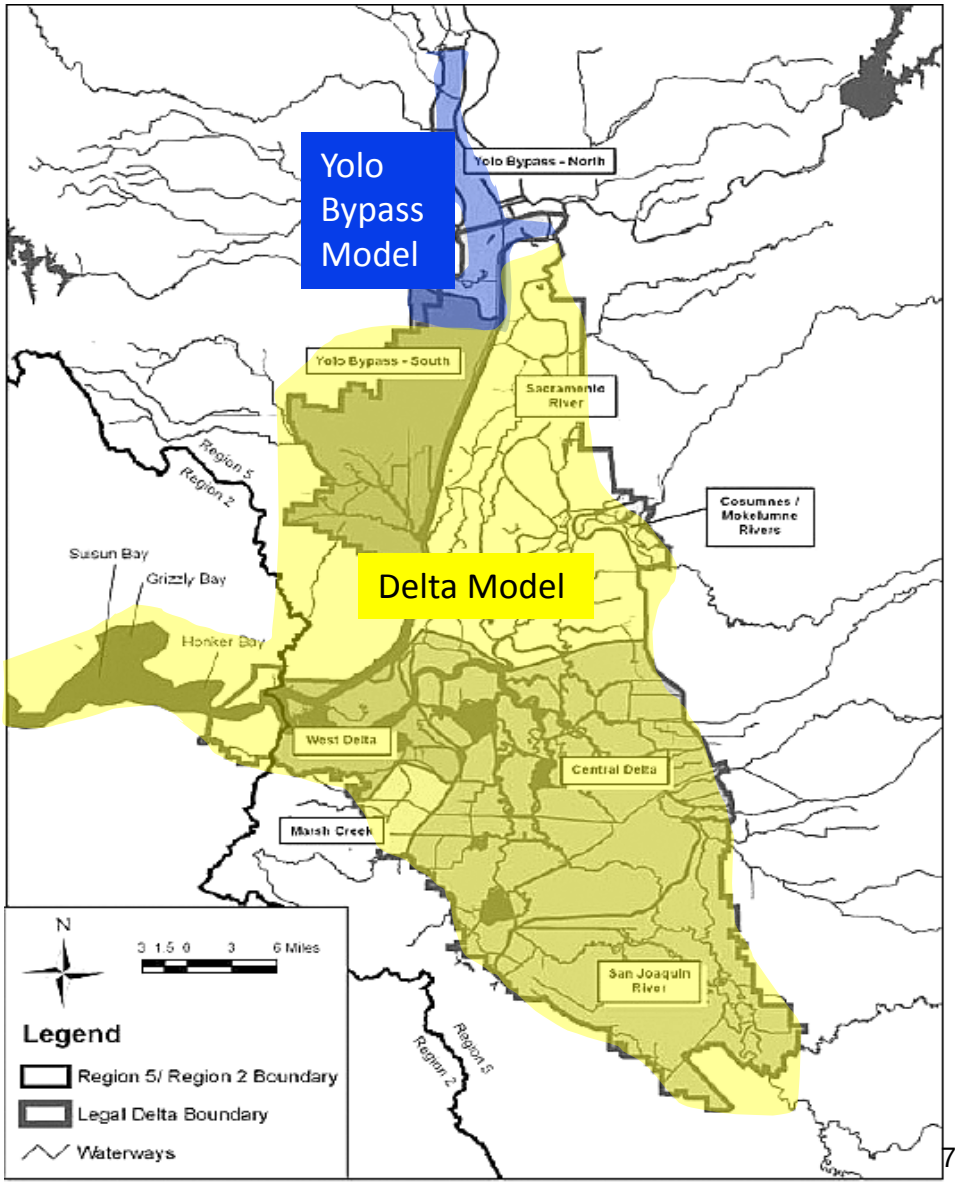
Legend

External sources of inorganic Hg and MeHg →

Modeled mercury fluxes →

Open Water Hg Models

- Delta
  - DSM2 + Hg algorithms
    - (DWR + Reed Harris Environmental, Ltd.)
- Yolo Bypass
  - Dynamic Mercury Cycling Model (D-MCM)
    - (Reed Harris Environmental, Ltd.)



Highlighted areas show approximate model boundaries. Base map from 2010 TMDL staff report.

Modeling Objectives

- Use modeling and field data to examine the effects of State Water Project operations and flooding on MeHg supply.
  - Provide working models of MeHg transport and fate
  - Literature, field and laboratory studies to provide info for the model
  - Determine most important drivers (Sensitivity analysis)
  - Scenario testing

Tasks and Timeline

Delta Mercury Model

Identify key processes → Develop Delta Hg Model & collate available data → Tune & Test Model → Final Report

Yolo Bypass Mercury Model

Identify key processes → Set-up Yolo Bypass Hg Model & collate available data. → Tune & Test Model → Final Report

Conduct Yolo Bypass Field Experiments

* Deadline subject to change pending discussion with Regional Board.

Delta Hg Modeling-DSM2

Delta Hg Modeling

DWR Delta Modeling Staff

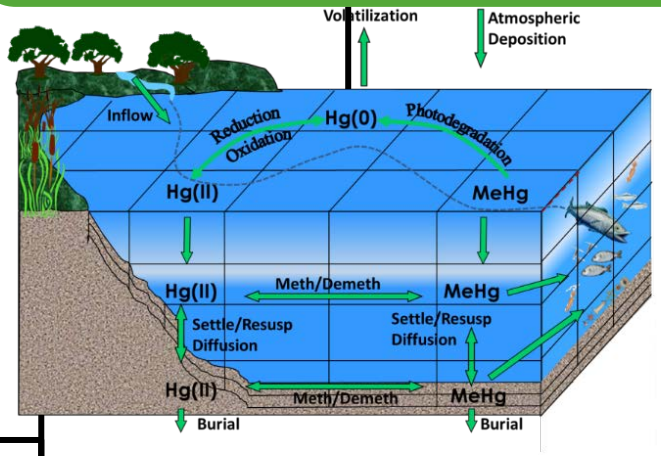
Reed Harris Environmental Ltd

Upgrade DSM2

Add Suspended and Bed Sediment Transport

Add new Water Quality constituents if needed

Develop Mercury Cycling Code



Incorporate Mercury into Model

Test
Calibrate
Apply

Solids are important for mercury…

Suspended Sediment Transport

Suspended sediment in the water column (sand, clay, organics)

Bed load

Mercury Cycling

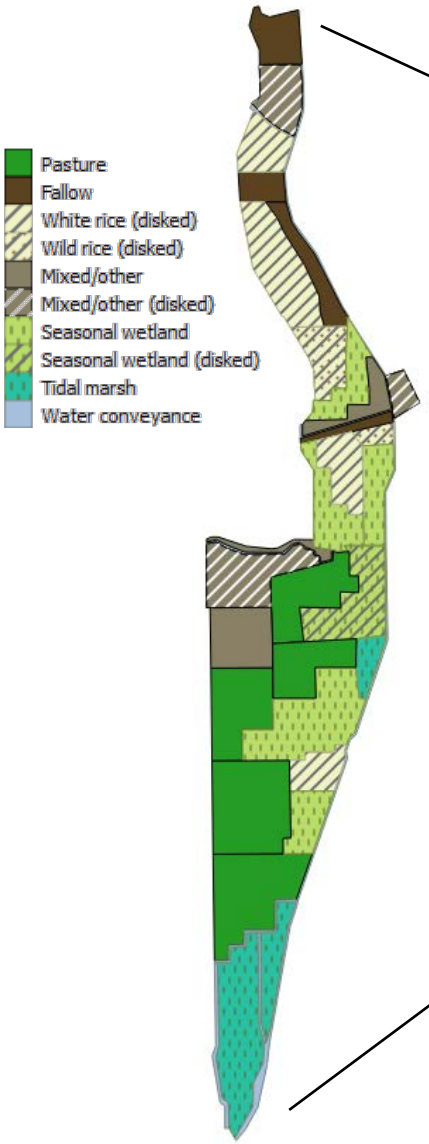
Mercury transport dissolved in water and on sediments, reactions including methylation, and dispersion

Sediment Bed

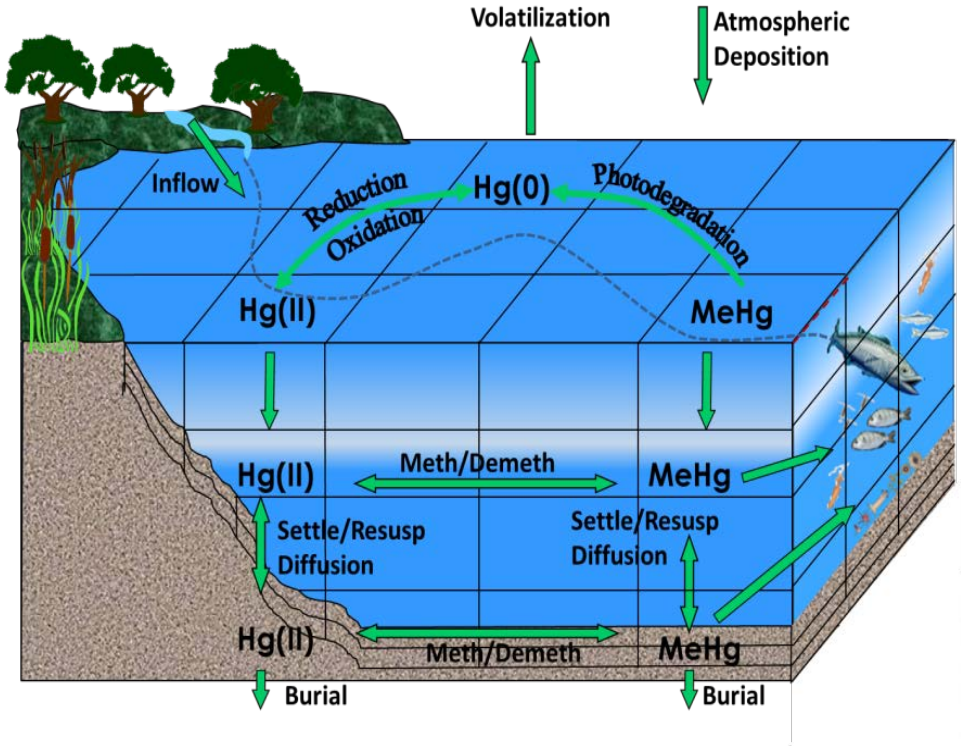
Deposition (settling), Erosion (re-suspension)
Anoxic conditions, MeHg production
Exchange MeHg with water column

Yolo Bypass Hg Modeling-D-MCM

Yolo Bypass Hg Modeling using D-MCM



Inputs and modeled or predicted outputs for each cell.



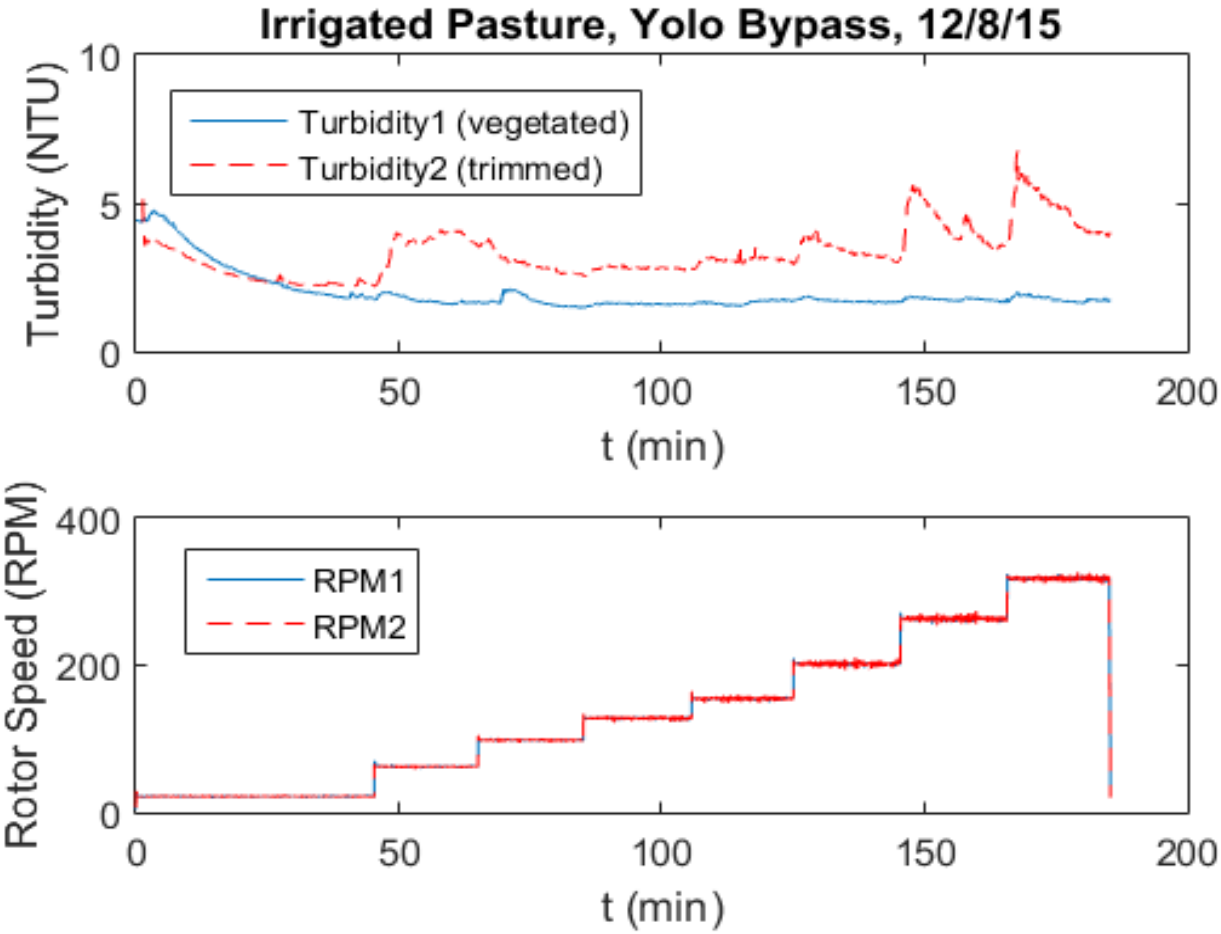
Yolo Bypass Field & Lab Studies to Support D-MCM

Yolo Bypass Field Studies

Study	Purpose
Gust Chamber	Sediment erosion
Spatial soil THg/MeHg	Quantify Hg/MeHg pools and identify hot spots to understand why some areas are high or low.
Temporal soil MeHg (to begin this spring)	Assessment of seasonal/flooding influences on MeHg production.
Pore water	Factors governing methylation and soil to water MeHg fluxes.
Vegetation senescence (first sample collected in Dec. 2015)	Vegetation related pools and fluxes of MeHg and carbon.
Inlet/Outlet	Particulate and filtered loads entering and leaving the Yolo Bypass. Under different flooding regimes, Is the YB a net source or sink for Hg?

Erosion Characteristics-Gust Chamber

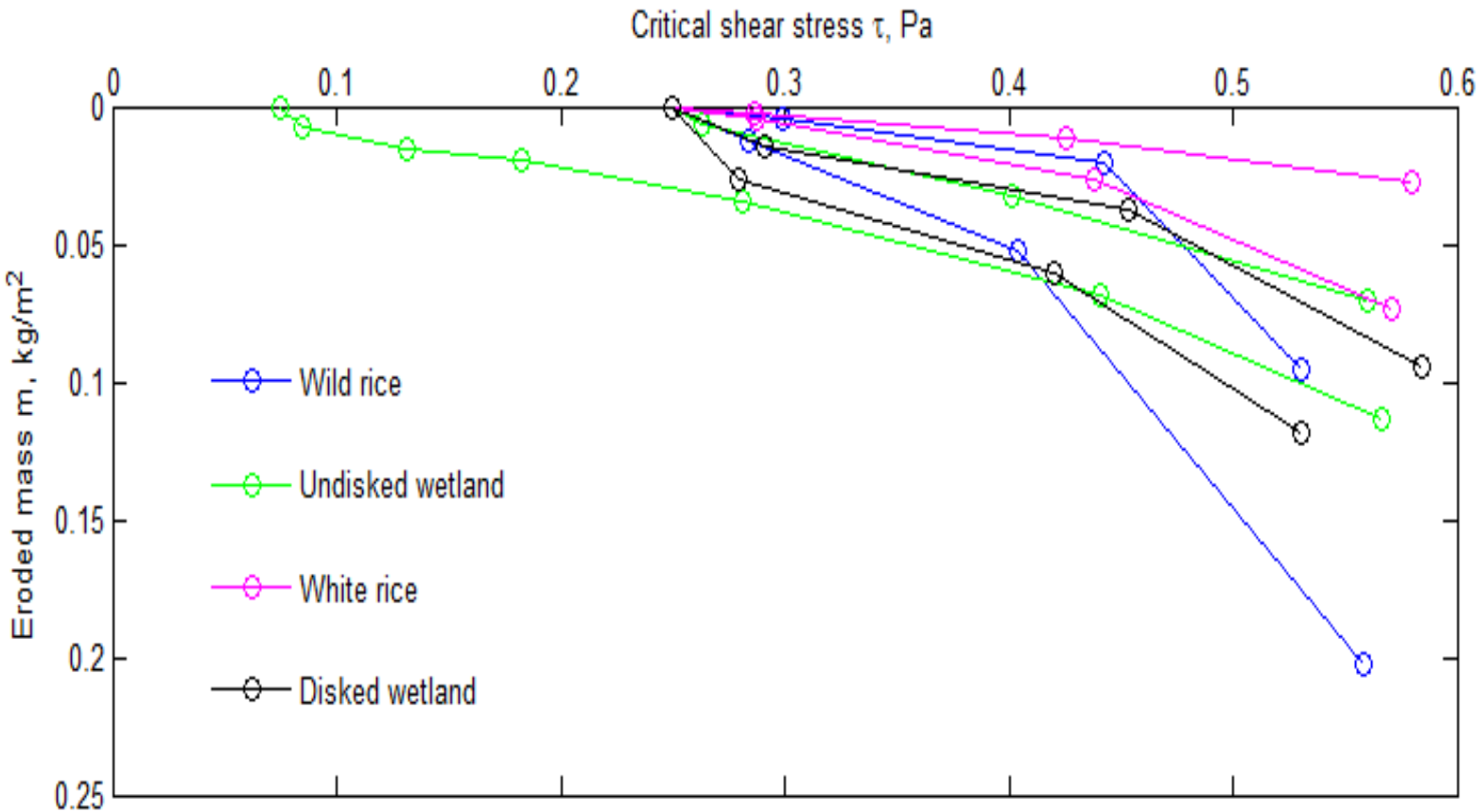
- Objectives: Determine erosional characteristics of most common land-uses in Yolo Bypass.
- Methods: 2 cores collected/land use. Gust Chamber used to determine erosion characteristics for a given shear strength.



- Very little erosion from irrigated pasture

Data and photos courtesy, D. Schoellhamer, P. Work, USGS

Erosion Characteristics



- Successfully estimated erosion for different land-uses
- White rice least erodible, wild rice the most erodible—but small dataset!!!!!!
- So far, erosion on irrigated pasture is ~3% of what we see for other land uses

Data courtesy of D. Schoellhamer, P. Work, USGS

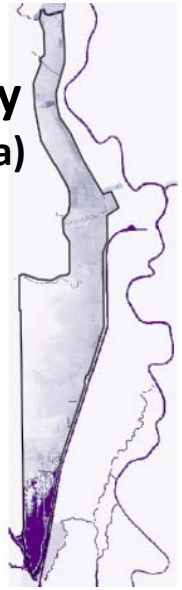
Using Spatial Data

Land use
(previous study)

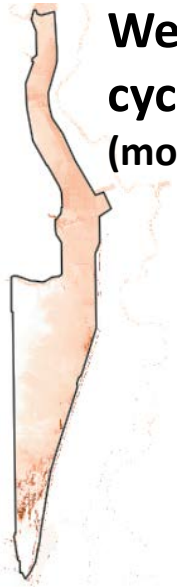
Sediment mercury
(field study)

Disked land
(previous study)

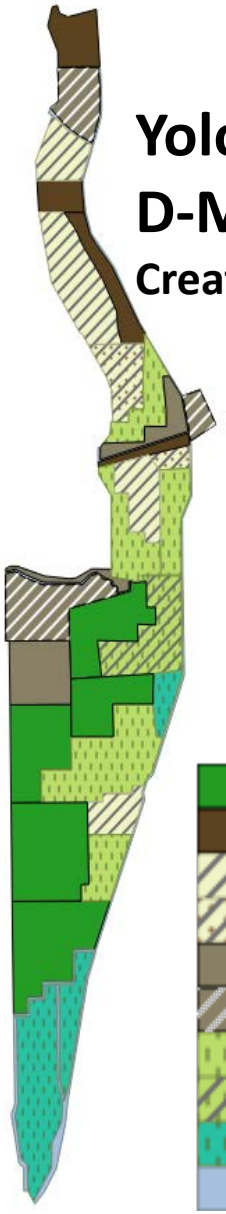
Wetting frequency
(model data)



Wet/dry cycling
(model data)

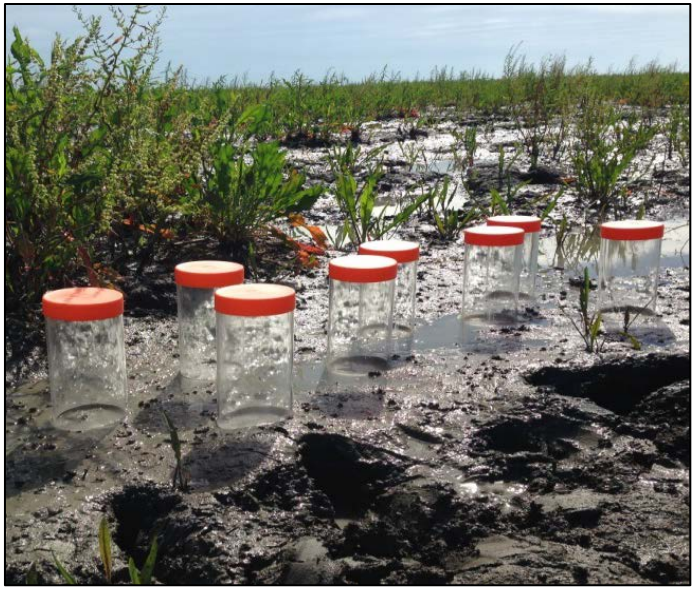


Yolo Bypass D-MCM Grid
Created from spatial data



Pore water Study

- Objectives:
  - 1) Measure flux of mercury from two land use types to assess significance of sediment-water exchange in comparison to other sources
  - 2) Determine if source water had an effect on mercury flux
- Methods:



a) Collected cores from an undisked seasonal wetland and wild rice field.

b) Incubated cores. Overlying water from Sacramento River (Lower Hg) and Cache Creek (Higher Hg).

Information & photos courtesy of W. Heim, MLML

Pore Water Mercury Flux Results

Measured sediment-water fluxes (F_M) for MeHg and THg determined using incubated cores with overlying water from either the Sacramento River (Sac) or Cache Creek (Cache). Negative values indicate flux into the sediment.

Treatment	MeHg F_M (ng m^{-2} d^{-1})	THg F_M (ng m^{-2} d^{-1})
	Mean ± SD	Mean ± SD
Wild Rice - Sac	3 ± 4	58 ± 30
Undisked Seasonal Wetland - Sac	26 ± 6	159 ± 26
Wild Rice- Cache	-13 ± 13	41 ± 12
Undisked Seasonal Wetland - Cache	36 ± 31	470 ± 142

- Mercury sediment/water diffusion differs among different land uses in the Yolo Bypass
- Results have similar magnitudes to other Delta studies
- Limited data suggests source water may be influencing pore water, but need to investigate further

Data courtesy of W. Heim, MLML

Vegetation Senescence Study

- Objectives:
  - Determine the flux of dissolved MeHg from soil and plant material (non-irrigated pasture) during flooding in the Yolo Bypass
- Methods:
  - Estimate plant biomass density MeHg concentrations on plants 3X/winter flood season
  - Each sampling event, determine dissolved MeHg flux from plants and sediments
  - Collect DO and MeHg during flood events

Information & photos courtesy of M. Stephenson, MLML

Inlet/Outlet

- Due to weather-only 1 storm event sampled (Dec. 2014)
- Mini-flood event sampled
- 3 import sites
- Sampled along the Toe Drain

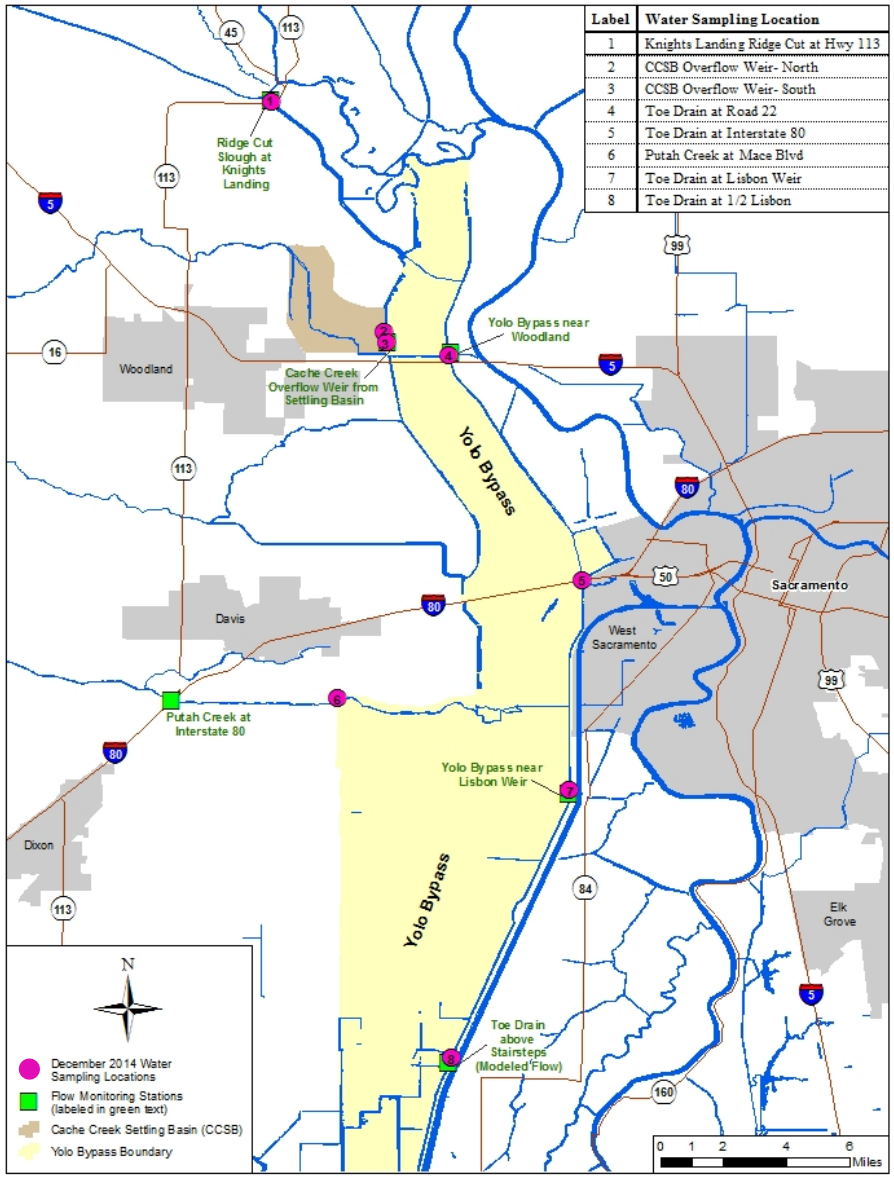
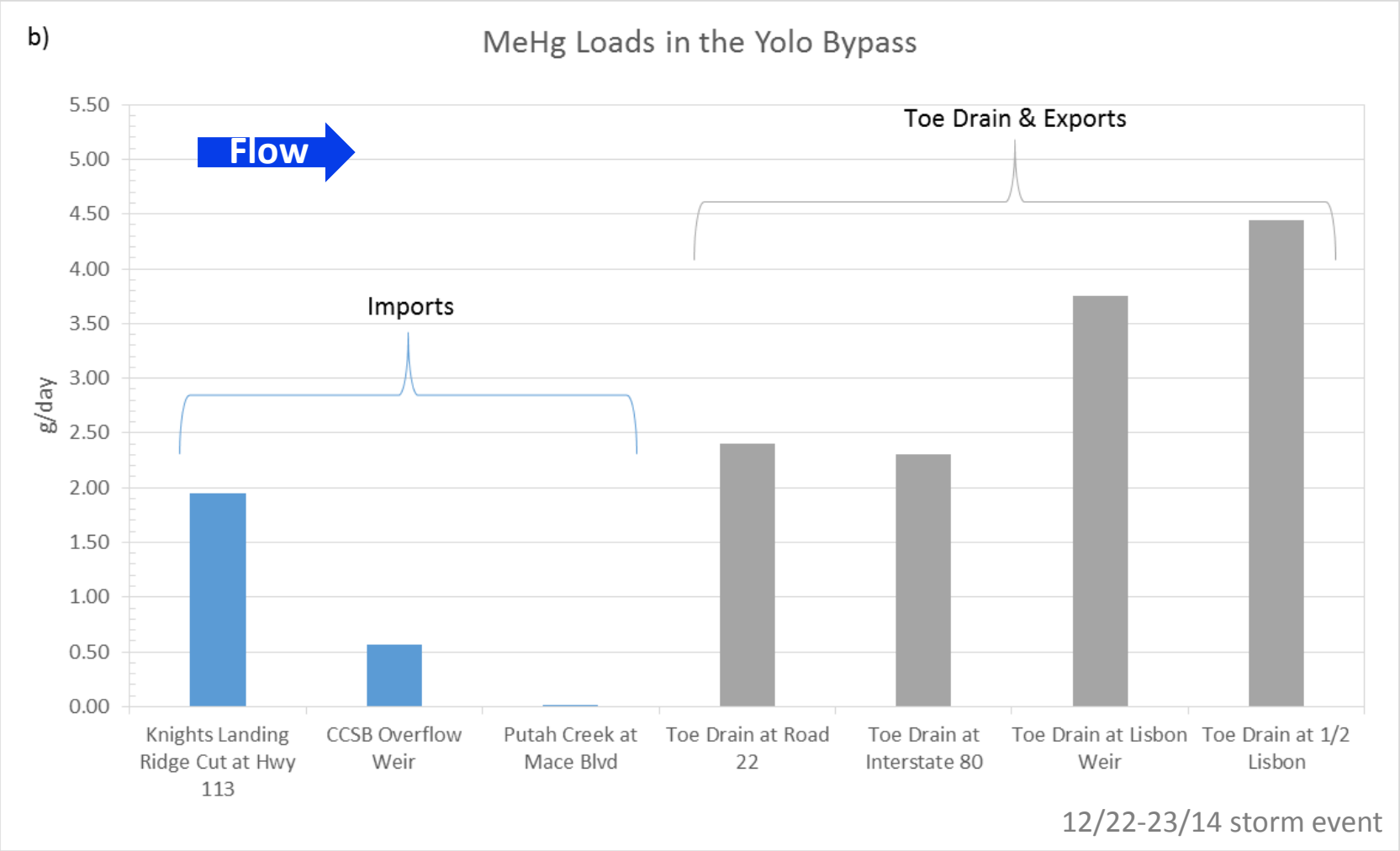


Figure courtesy of D. Bosworth, DWR

Inlet/Outlet-Loads



- Example of how inlet/outlet studies indicate whether areas are MeHg sources or sinks.

Lessons and Challenges

Hydrology and particle dynamics are critical for mercury.

… not new, but remains a challenge..

……..Lessons and Challenges- Development of an Open Water Modeling Tool

- Effects of storms on sediment transport of mercury
- How to combine datasets that don't line up in space or time….
- Yolo Bypass has some unique challenges….
  - Spatial and temporal variability
    - Multiple land uses
    - Dry and wet conditions
    - Effects of vegetation
  - More replication and spatial coverage of questions asked by this field work is needed
  - Costs and logistics

……..Lessons and Challenges-Overall Strategy

- What controls methylation rates?
  - Do different mercury sources behave the same? (atmospheric, terrestrial, marine, industrial)
  - What controls the activity of methylating microbes?
  - What controls the loss of MeHg?
  - Progress is being made… not there yet.
- Effects of climate and storms
- How do we integrate the broad range of activities and mercury issues in the Bay-Delta system? Anticipating models can help.

Project Contact Info

Project	Project Lead(s)	Contact Information
Delta Modeling	Tara Smith Jamie Anderson	Tara.Smith@water.ca.gov Jamie.Anderson@water.ca.gov
Yolo Bypass Modeling	Reed Harris	RH@reed-harris.com
Gust Chamber	David Schoellhamer Paul Work	dschoell@usgs.gov pwork@usgs.gov
Spatial and Temporal soil THg/MeHg Inlet/Outlet	David Bosworth Carol DiGiorgio	David.Bosworth@water.ca.gov Carol.DiGiorgio@water.ca.gov
Pore Water	Wes Heim Mark Stephenson	wheim@mlml.calstate.edu mstephenson@mlml.calstate.edu
Vegetation Senescence	Mark Stephenson Wes Heim	mstephenson@mlml.calstate.edu wheim@mlml.calstate.edu

Acknowledgements

Pacific Northwest National Laboratory

Gary Gill

DFW/MLML

Wes Heim

Mark Stephenson

DWR

David Bosworth

En-Ching Hsu

Hari Rajbhandari

Nicky Sandhu

Tara Smith

Reed Harris Environmental Ltd.

Cody Beals

David Hutchinson

USGS

David Schoellhamer

Kurt Weidich

Paul Work

Questions

SWIPE
YOU DON'T WANNA EAT ME! I'M LOADED WITH MERCURY!
I JUST MET A HEALTH-CONSCIOUS CARNIVORE.
©2011 John L. Hart FLP
Dist. by Creators Syndicate
www.JohnHartStudios.com