An integrated environmental and human systems modeling framework for Puget Sound restoration planning

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Speaker
Bob McKane, Jonathan Halama, Paul Pettus, Bradley Barnhart, Allen Brookes, Kevin Djang, Tarang Khangaonkar, Isaac Kaplan, Chris Harvey, Emily Howe, Phillip Levin, Michael Schmidt, and Raphael Girardin

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An integrated environmental and human systems modeling framework for Puget Sound restoration planning

Bob McKane¹, Brad Barnhart¹, Paul Pettus¹, Jonathan Halama¹, Allen Brookes¹, Kevin Djang², Tarang Khangoankar³, Chris Harvey⁴, Isaac Kaplan⁴, Hem Nalini Morzaria Luna⁴, Michael Schmidt⁵, Emily Howe⁶, Phillip Levin⁶

¹U.S. Environmental Protection Agency, and ²CSRA, Corvallis, OR
³Pacific Northwest National Laboratory, Seattle
⁴National Oceanic and Atmospheric Administration, Seattle
⁵Long Live the Kings, Seattle
⁶The Nature Conservancy, Seattle
Puget Sound Basin

Land area: ~13,000 mi²
Water area: ~1,000 mi²
The Salish Sea

Land area: ~42,000 mi²
Water area: ~7,000 mi²

http://staff.wwu.edu/stefan/SalishSea.htm

Inset, previous slide
Puget Sound Land-Water Interactions
25 Vital Signs to help identify whether Puget Sound recovery targets are being met

Puget Sound Partnership
http://www.psp.wa.gov/vitalsigns/
## Puget Sound Vital Signs

### Water Quantity
- Summer Stream Flows

### Water Quality
- Marine Water Quality
- Freshwater Quality
- Marine Sediment Quality
- Toxics in Fish

### Healthy Human Population
- Onsite Sewage
- Shellfish Beds
- Outdoor Activities
- Local Foods
- Air Quality
- Drinking Water

### Quality of Life
- Sound Stewardship
- Economic Viability
- Good Governance
- Sense of Place
- Cultural Practices

### Species and Foodweb
- Chinook Salmon
- Orcas
- Pacific Herring
- Birds

### Protect and Restore Habitat
- Estuaries
- Floodplains
- Land Cover and Development
- Eelgrass
- Shoreline Armoring

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25 Vital Signs to help identify whether Puget Sound recovery targets are being met

Puget Sound Partnership
http://www.psp.wa.gov/vitalsigns/
# PUGET SOUND VITAL SIGNS

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Integrated terrestrial-marine models are needed to:

- Synthesize decades of terrestrial & marine data
- Identify comprehensive recovery solutions across habitats & scales...
Puget Sound Systems Modeling Framework

**Terrestrial**
- Hydrology
- Biogeochemistry
- Fish habitat, pop.

**Marine**
- Ocean circulation
- Biogeochemistry

**Marine Food Web**
- Diet
- Movement
- Mortality factors

**Nutrients** → **Toxics** → **Saltwater** → **Salmon**
- Adult
- Juvenile

**Toxics** → **Nutrients** → **Terrestrial** → **Fish habitat, pop.**
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**Salish Sea Model**
http://salish-sea.pnnl.gov/

**Atlantis Model**
https://www.nwfsc.noaa.gov/research/divisions/cb/ecosystem/marineecology/aem.cfm

**VELMA**
https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20

**EDT**
VELMA Watershed Model
Transport & fate of water, nutrients, toxics

Processes Simulated
- **Hydrology**: stream water quality & quantity, soil moisture
- **Plants & soils**: plant growth, SOM formation & turnover, fate/transport of nutrients & toxics
- **Disturbances**: climate, additions of nutrients & toxics, harvest, fire, grazing...
- **Linkage to Fish & Marine Models**
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Linkage to Fish & Marine Models
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| Species and Foodweb | ✓ Chinook Salmon* |
|                     | ✓ Orcas |
|                     | ✓ Pacific Herring |
|                     | ✓ Birds* |
| Protect and Restore Habitat | ✓ Estuaries (Salt Marshes) |
|                     | ✓ Floodplains * |
|                     | ✓ Land Cover and Development |
|                     | ✓ Eelgrass |
|                     | ✓ Shoreline Armoring |

* With links to additional models or indicators
Salish Sea Model
Hydrodynamic Component
Salish Sea Model
Hydrodynamic Component
Salish Sea Model
Biogeochemical Component

Δ Temperature
Δ Dissolved O₂
Δ pH

Δ Salinity
Δ Dissolved O₂
Δ pH

Annual Average
Salish Sea

Annual Average
Snohomish Estuary

March

September

[Graph showing changes in temperature, dissolved oxygen, and pH in the Salish Sea and Snohomish Estuary]
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Salish Sea Model ← VELMA
Land-Water Interactions
Atlantic Ocean Food Web Model

Human impacts submodel

Foodweb submodel

Hydrographic submodel

Climate, oceanography

Biogeochemistry

from SSM
Juvenile salmon from VELMA-EDT
Foodweb submodel
Adult salmon to VELMA-EDT

Hydrographic submodel

Climate, oceanography

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* With links to additional models or indicators
Major goal: Effects of alternative development scenarios on stormwater runoff to Puget Sound

Year 2000 % Impervious

Year 2060 % Impervious
Managed Growth Scenario

Major goal: effects of alternative development scenarios on stormwater runoff to Puget Sound

Integrating environmental and human systems models

ENVISION Decision Support Framework

**Left side:** Environmental system models such as VELMA

**Right side:** Human system models (agent based)
Questions?

VELMA model: Bob McKane, Brad Barnhart, EPA
Salish Sea Model: Tarang Khangaonkar, PNNL
Atlantis model: Chris Harvey, Isaac Kaplan, Hem Nalini Morzaria Luna, NOAA-NWFSC; Michael Schmidt, Long Live the Kings
Urban stormwater data & models: Emily Howe, Phil Levin, The Nature Conservancy