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

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See next page for additional authors

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McKane, Robert; Halama, Jonathan; Pettus, Paul Bryce; Barnhart, Bradley; Brookes, Allen; Djang, Kevin; Khangaonkar, Tarang; Kaplan, Isaac; Harvey, Christopher James; Howe, Emily; Levin, Phillip S.; Schmidt, Michael; and Girardin, Raphael, "An integrated environmental and human systems modeling framework for Puget Sound restoration planning" (2018). *Salish Sea Ecosystem Conference*. 369.  

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Speaker
Robert McKane, Jonathan Halama, Paul Bryce Pettus, Bradley Barnhart, Allen Brookes, Kevin Djang, Tarang Khangaonkar, Isaac Kaplan, Christopher James Harvey, Emily Howe, Phillip S. Levin, Michael Schmidt, and Raphael Girardin

This event is available at Western CEDAR: https://cedar.wwu.edu/ssec/2018ssec/allsessions/369
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: \( \approx 42,000 \text{ mi}^2 \)

Water area: \( \approx 7,000 \text{ mi}^2 \)

http://staff.wwu.edu/stefan/SalishSea.htm
Puget Sound Land-Water Interactions

Harmful algal blooms

Modified from Darryl Marois
25 Vital Signs to help identify whether Puget Sound recovery targets are being met

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

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

<table>
<thead>
<tr>
<th>Water Quantity</th>
<th>Species and Foodweb</th>
</tr>
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<tbody>
<tr>
<td>• Summer Stream Flows</td>
<td>• Chinook Salmon</td>
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</table>

### 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
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- Good Governance
- Sense of Place
- Cultural Practices

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

---

**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
Salmon
Juvenile
Adult
Puget Sound Systems Modeling Framework

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

**Marine**
- Ocean circulation
- Biogeochemistry

**Salish Sea Model**
http://salish-sea.pnnl.gov/

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

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

Processes Simulated
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- **Linkage to Fish & Marine Models**

Brad Barnhart
Friday 10:45am, Rm 616
Urban Stormwater and Green Infrastructure
VELMA Watershed Model
Transport & fate of water, nutrients, toxics

Processes Simulated
- **Hydrology**: stream water quality & quantity, soil moisture
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Urban Stormwater and Green Infrastructure

→ **Linkage to Fish & Marine Models**
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<td>✓ Cultural Practices</td>
</tr>
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<td>Species and Foodweb</td>
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<tr>
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<td>• Pacific Herring</td>
</tr>
<tr>
<td></td>
<td>✓ Birds *</td>
</tr>
<tr>
<td>Protect and Restore Habitat</td>
<td>✓ Estuaries (Salt Marshes)</td>
</tr>
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<td></td>
<td>✓ Floodplains *</td>
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* With links to additional models or indicators
Salish Sea Model
Hydrodynamic Component
Salish Sea Model
Hydrodynamic Component
PUGET SOUND VITAL SIGNS

Water Quantity
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* With links to additional models or indicators
Salish Sea Model ← VELMA
Land-Water Interactions
Atlantis Ocean Food Web Model

Human impacts submodel

Foodweb submodel

Hydrographic submodel

Climate, oceanography

Biogeochemistry

from SSM
Atlantis Ocean Food Web Model

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

Hydrographic submodel

Climate, oceanography

Biogeochemistry

from SSM
**PUGET SOUND VITAL SIGNS**

**Water Quantity**
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✓ **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
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- ✓ Pacific Herring
- ✓ Birds

**Protect and Restore Habitat**
- ✓ Estuaries
- • Floodplains
- • Land Cover and Development

✓ **Eelgrass**
- • Shoreline Armoring

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**Atlantis Ocean Foodweb Model**

- **Human impacts submodel**
- **Foodweb submodel**
- **Hydrographic submodel**

- **Human sectors**
- **Climate, oceanography**
- **Biogeochemistry**

- (Salish Sea Model)
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**Quality of Life**

• Sound Stewardship
• Economic Viability
• Good Governance
• Sense of Place
• Cultural Practices

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**Puget Sound Systems Modeling Framework**

- **Terrestrial**
  - Hydrology
  - Biogeochemistry
  - Fish & Wildlife

- **Marine**
  - Ocean circulation
  - Biogeochemistry

- **Salish Sea Model**
  - Nutrients
  - Toxics

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

- **Atlantis Model**
  - Salmon
  - Nutrients
  - Toxics

---

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

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*