ASSESSING LAND USE / LAND COVER PATTERNS, WASTEWATER INFRASTRUCTURE AND BIOLOGICAL CONDITIONS FOR PUGET SOUND SHELLFISH

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Research Questions:

(1) What is the relationship between land use, land cover, wastewater infrastructure, and biological conditions for shellfish growing areas?

(2) How does this relationship vary across a gradient of urbanization?
Relationship between shellfish and urbanization

Biological conditions for shellfish

Biological conditions for shellfish

Biological conditions for shellfish

Urbanization

Biol. conditions for shellfish

Biol. conditions for shellfish

Biol. conditions for shellfish
Why shellfish?

- Filter feeders
  - Pump water for food & oxygen
  - Take in bacteria, viruses, and chemical contaminants
- Provide physical structure
- Prized food source
- Support local economy & recreation
- Indicators of water quality and human health in urbanizing estuaries

Pacific Coast Shellfish Growers Assoc, 2001
In 2005, nearly 30,000 acres of commercial growing areas closed.

Source: PS Action Team; WA DOH
# WA. State Water Quality Standards

## MARINE WATER STANDARDS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Extraordinary Aquatic, Primary Contact</th>
<th>Excellent Aquatic, Primary Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fecal Coliform Bacteria (FC)</strong></td>
<td>Level 1: (&lt;14 \text{ FC}/100 \text{ ml. (geomean)})</td>
<td>Same as Extraordinary Aquatic, Primary Contact waters</td>
</tr>
<tr>
<td></td>
<td>Level 2: Not more than 10% of all samples obtained for calculating a geomean &gt;43 FC/100 ml.</td>
<td></td>
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<tr>
<td><strong>Dissolved Oxygen</strong></td>
<td>&gt;7.0 mg/L</td>
<td>&gt; 6.0 mg/L</td>
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<tr>
<td><strong>pH</strong></td>
<td>7.0 – 8.5 units</td>
<td>7.0 – 8.5 units</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>(\leq 13.0^\circ \text{ C})</td>
<td>(\leq 16.0^\circ \text{ C})</td>
</tr>
</tbody>
</table>

1 Chapter 173-201A of Washington Administrative Code, WA. DOE
How are shellfish in PS managed?
## Impacts of urbanization on shellfish

<table>
<thead>
<tr>
<th>AUTHOR</th>
<th>STUDY AREA</th>
<th>URBAN VARIABLES</th>
<th>Water Pollution</th>
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<tbody>
<tr>
<td>Duda and Cromartie, 1982</td>
<td>N.C. watersheds</td>
<td>Density of septics; % impervious</td>
<td>↑</td>
</tr>
<tr>
<td>Lipp et al. 2001</td>
<td>Charlott Harbor, FL.</td>
<td>Density of septics</td>
<td>↑</td>
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<tr>
<td>Kelsey et al. 2003</td>
<td>Murrells Inlet, S.C.</td>
<td>Proximity to septics; proximity to urban</td>
<td>↑</td>
</tr>
<tr>
<td>Young &amp; Thackston, 1999</td>
<td>4 urban watersheds, TN.</td>
<td>Sewered basins</td>
<td>↑</td>
</tr>
<tr>
<td>White et al. 2000</td>
<td>Jump Run Creek, NC.</td>
<td>Ditching; Bulkhead; Channeling</td>
<td>↑</td>
</tr>
<tr>
<td>Hatt et al. 2004</td>
<td>15 streams in Melbourne</td>
<td>Density of septics; Drainage connection</td>
<td>↑</td>
</tr>
<tr>
<td>Mallin et al. 2001</td>
<td>5 watersheds in N.C.</td>
<td>Total population; % Dev Land; % Impervious</td>
<td>↑</td>
</tr>
<tr>
<td>Alberti &amp; Bidwell, 2005</td>
<td>32 Puget Sound basins</td>
<td>% Forest; forest Fragmentation; Imperv aggreg.; Road density</td>
<td>↑</td>
</tr>
<tr>
<td>Ensign &amp; Mallin, 2001</td>
<td>Goshen Swamp, NC.</td>
<td>Forest re-growth</td>
<td>↓</td>
</tr>
</tbody>
</table>
Waste processing in a coupled human-natural system

Drivers
- Pop growth
- Climate
- Regional geology
- Marine water circulation
- LU & Storm-water mgmt.

Coastal basin patterns
- Land use
- Land cover
- Wastewater system
- Drainage connectivity
- Local rainfall patterns
- Elevation & soils

Bacterial processing
- Infiltration
- Filtration
- Nitirification-denitrification
- Bacteria die-off
- Freshwater flushing

Effects on human health
- Fecal coliform (FC) fit for recreation & shellfish consumption

Adapted from Alberti et al. (2003)
Research Questions

(1) What is the relationship between land use, land cover, wastewater infrastructure, and biological conditions for shellfish growing areas?

- What landscape pattern metrics best predict water quality in nearshore environments for shellfish growing areas?
- How do these landscape metrics interact with wastewater infrastructure, and at what scale to impact shellfish?

(2) How do landscape pattern variables vary across a gradient of urbanization?
Research Design

- Cross-sectional and longitudinal analysis of landscape patterns
- Explore relationships between landscape patterns, wastewater infrastructure & FC
- Analyze patterns at two scales
- Use multi-regression to assess relationships
Research Design

**Response Variables**
- Geometric mean of Fecal Coliform (FC)
- Geometric Standard deviation of FC
- 90th percentile
- Variance of FC content
- % FC samples > 43 cfu/100ml (WQS level II)
- # of violations of the DOH standards

**Predictor Variables**
- **LANDSCAPE COMPOSITION:**
  - % impervious area; % forest cover; % grass
- **LANDSCAPE CONFIGURATION:**
  - Aggregation of impervious surfaces; fragmentation of forest; aggregation of grass
- Wastewater infrastructure (septic, separated sewer, combined sewer)
- Road density
- Drainage connection
Gradient Analysis

“An urban area is not simply a human-dominated area” (McIntyre, 2000).

Population Density from 2000 Census data

Slope in degrees from 30m DEM

Distance from Urban Centers from PSRC data and Port locations
**Study Area:** 6 County Central Puget Sound

**FC Data:** WA DOH; WA DOE; local health depts.

**Landscape data:** 2007 Land cover
County parcel & LU
County roads
County OWTS & WWTS
Drainage infrastructure
Basins along the urban gradient
Dyes Inlet

Dyes Inlet 2007 Land cover & FC data

Water Quality
Standard: 14 cfu/100ml
Henderson Inlet

Henderson Inlet 2007 Land cover & FC data

- Henderson Inlet, Thurston County
- Urbanization
- Grassland
- Forest
- DRY FC DATA
- WET FC DATA

Map showing land use and forest cover data for Henderson Inlet in 2007.
Oakland Bay

Oakland Bay 2007 Land cover & FC data

Legend:
- % Urb
- % Grass
- % Clearcut
- % Forest
- % Water
- DRY FC DATA
- WET FC DATA

Oakland Bay, Mason County

Legend:
- Heavy Urban
- Medium Urban
- Light Urban
- Cleared for Development
- Grass/Grasslands
- Deciduous and Mixed Forest
- Coniferous Forest
- Clearcut Forest
- Regenerating Forest
- Agriculture
- Non-Knowled Wetland
- Open Water
- Shrub/Savanna
- Retention Area
- Oakland Bay DOH Stations
Management implications for shellfish

- Consider landscape patterns are interacting with wastewater infrastructure to control fecal pollution
- Consider whole basin landscape attributes and factors at local scale
- Explanatory model can help improve predictive models of pollution loads
- Improve design guideline and BMPs to improve water quality & prioritize pollution cleanup efforts
Thank you!

Questions?

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