



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

Daniele Spirandelli, Urban Design & Planning  
danieles@uw.edu



# 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?

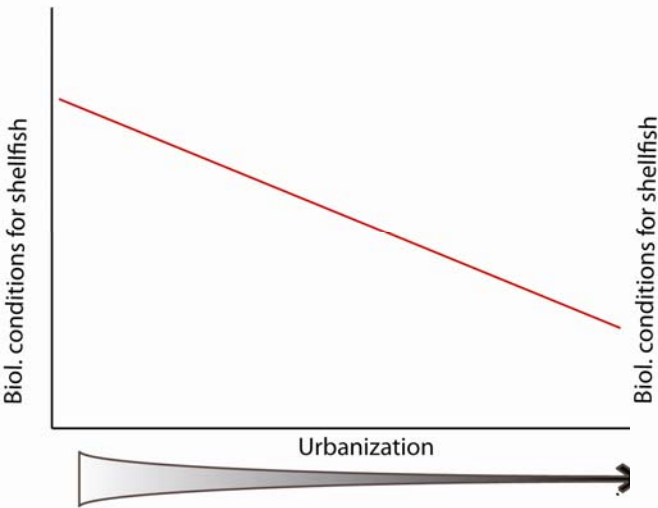


Kitsap WWTP

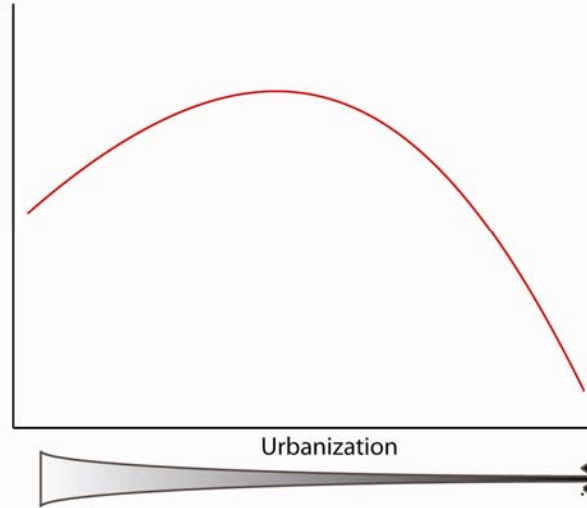
Septic tank

# Relationship between shellfish and urbanization

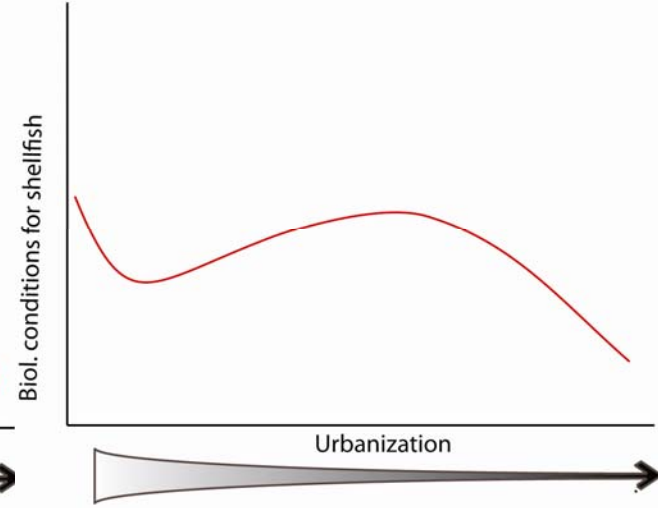
Biological conditions for shellfish



Biological conditions for shellfish



Biological conditions for shellfish



# Why shellfish?

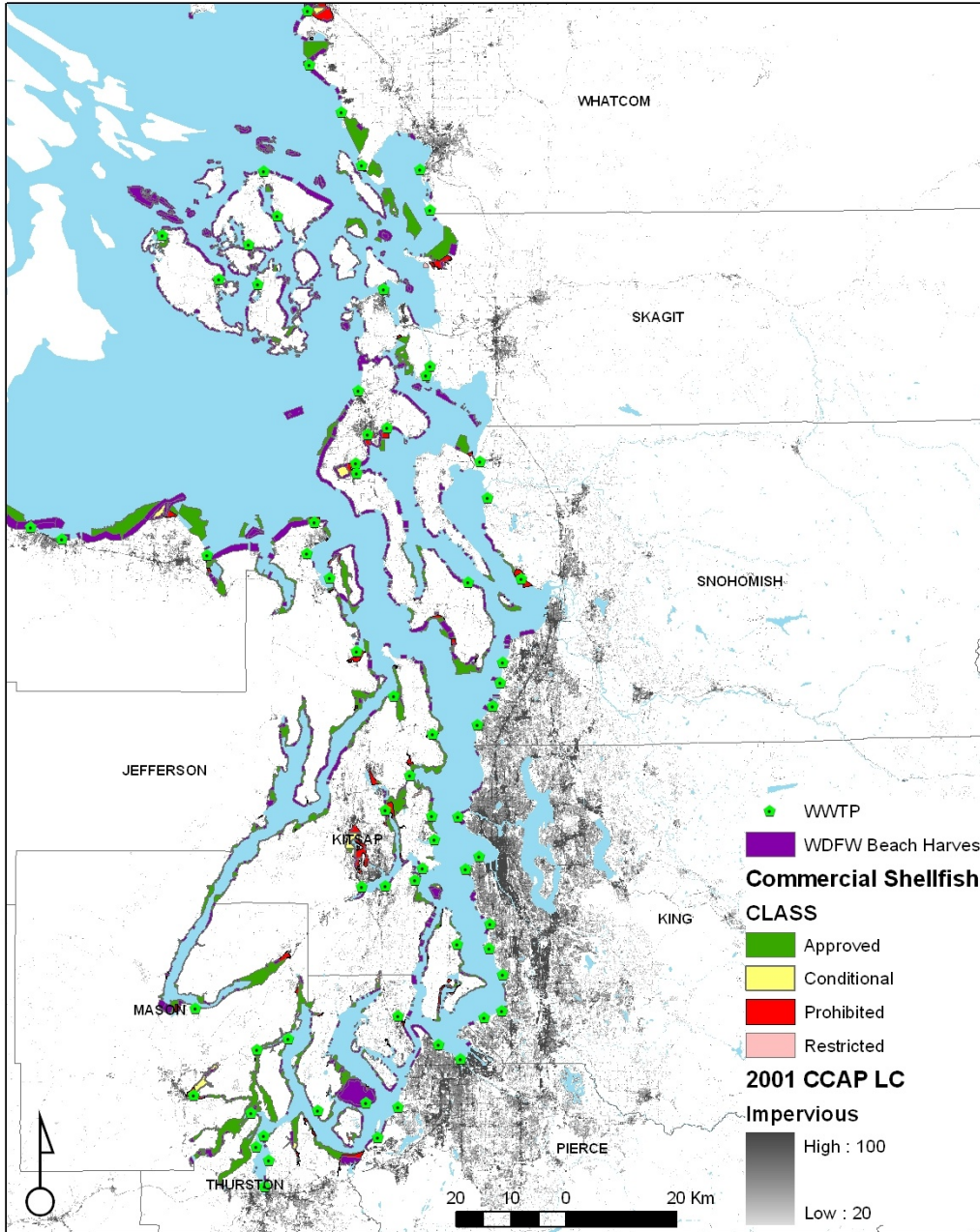


- Filter feeders
  - ▣ Pump water for food & oxygen
  - ▣ Take in bacteria, viruses, and chemical contaminants
- Provide physical structure
- Prized food source
- Support local economy & recreation
- Indicators of water quality and human health in urbanizing estuaries

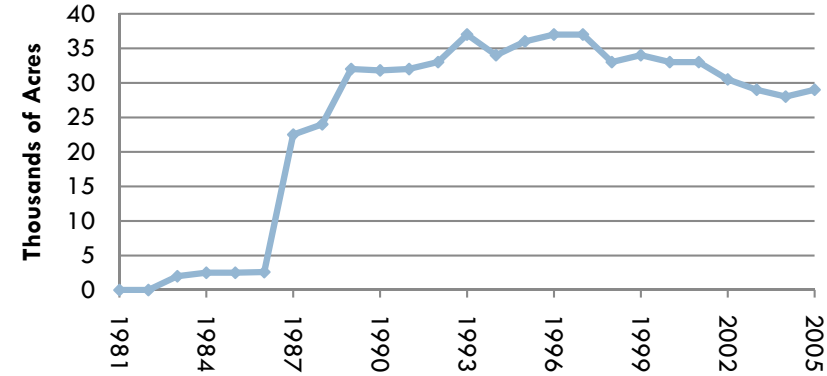


Pacific Coast Shellfish Growers Assoc, 2001

## Commercial Shellfish sites and WDFW Beach Harvest Sites



## Commercial shellfish closed from 1981-2005



- In 2005, nearly 30,000 acres of commercial growing areas closed.

# WA. State Water Quality Standards

<b>MARINE WATER STANDARDS<sup>1</sup></b>		
<i>Parameters</i>	<i>Extraordinary Aquatic, Primary Contact</i>	<i>Excellent Aquatic, Primary Contact</i>
<b>Fecal Coliform Bacteria (FC)</b>	<p><u>Level 1</u>: &lt;14 FC/100 ml. (geomean)</p> <p><u>Level 2</u>: Not more than 10% of all samples obtained for calculating a geomean &gt;43 FC/100 ml.</p>	Same as Extraordinary Aquatic, Primary Contact waters
Dissolved Oxygen	>7.0 mg/L	> 6.0 mg/L
pH	7.0 – 8.5 units	7.0 – 8.5 units
Temperature	≤13.0 <sup>0</sup> C	≤16.0 <sup>0</sup> C

<sup>1</sup> Chapter 173-201A of Washington Administrative Code, WA. DOE

# How are shellfish in PS managed?



**PUBLIC HEALTH AND SOCIAL SERVICES**  
*Always working for a safer and healthier community*



**FDA U.S. Food and Drug Administration**



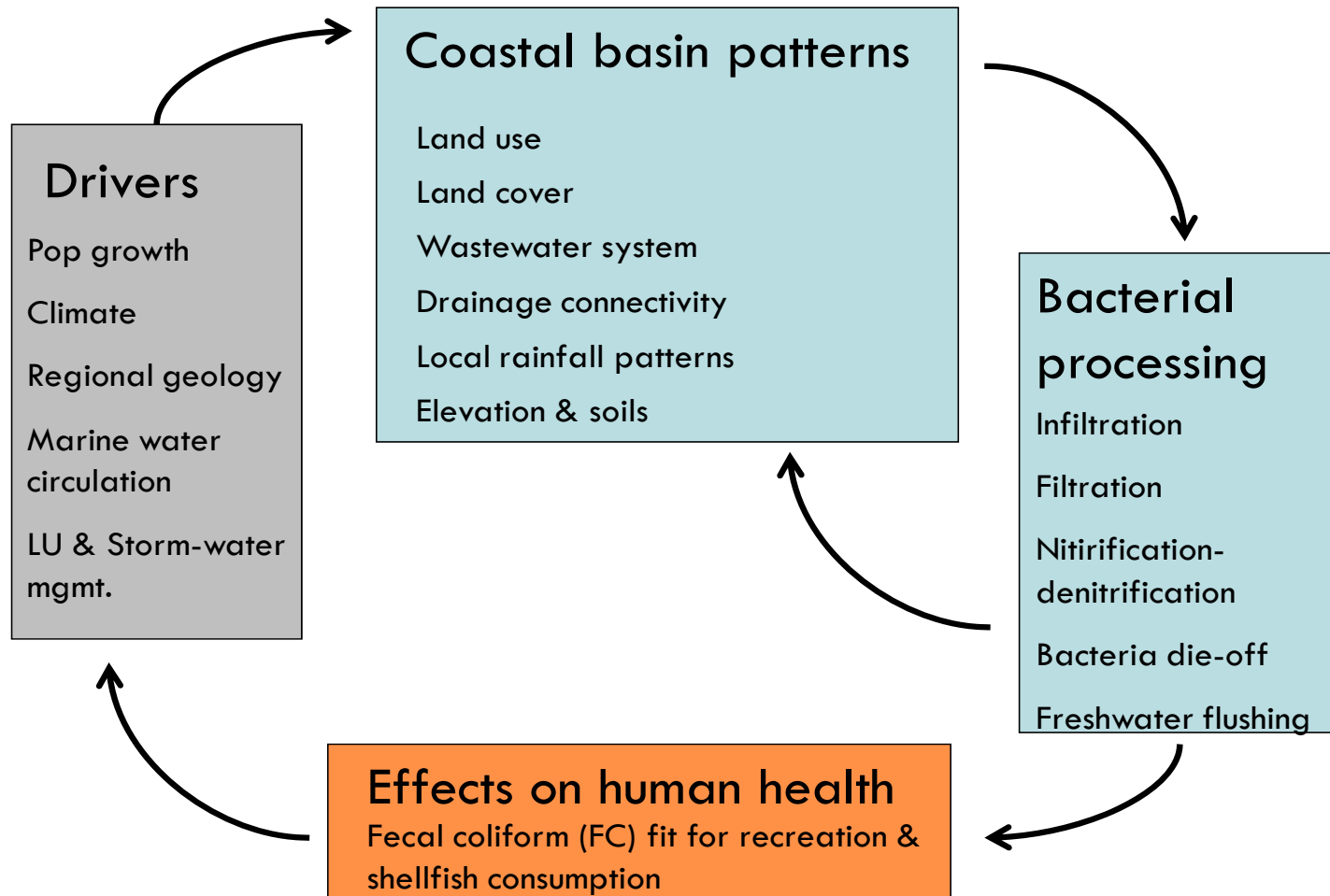
 **Puget Sound RESTORATION FUND**



# Impacts of urbanization on shellfish

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

# Waste processing in a coupled human-natural system





# 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

## Overall Research Strategy

- 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
- 90<sup>th</sup> percentile
- Variance of FC content
- % FC samples > 43 cfu/100ml (WQS level II)
- # of violations of the DOH standards

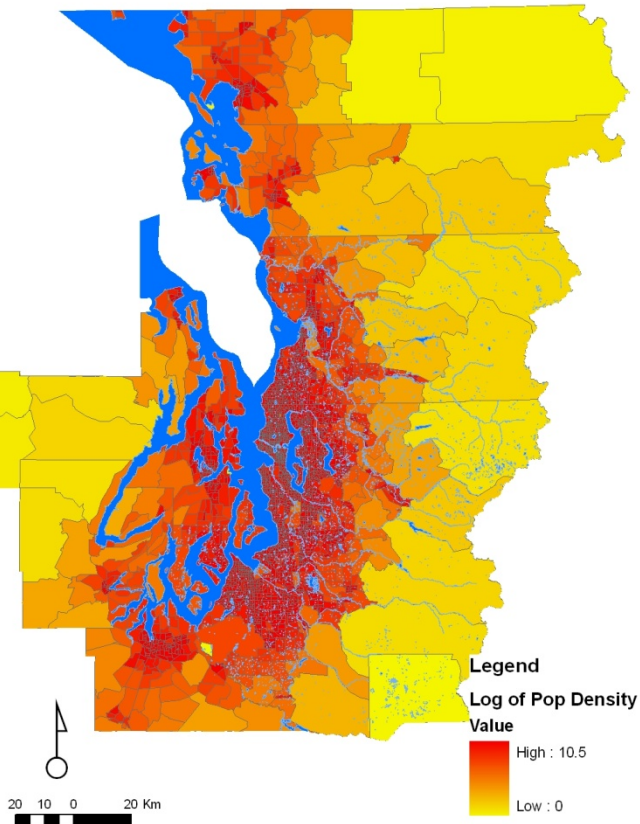
## Predictor Variables

- **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

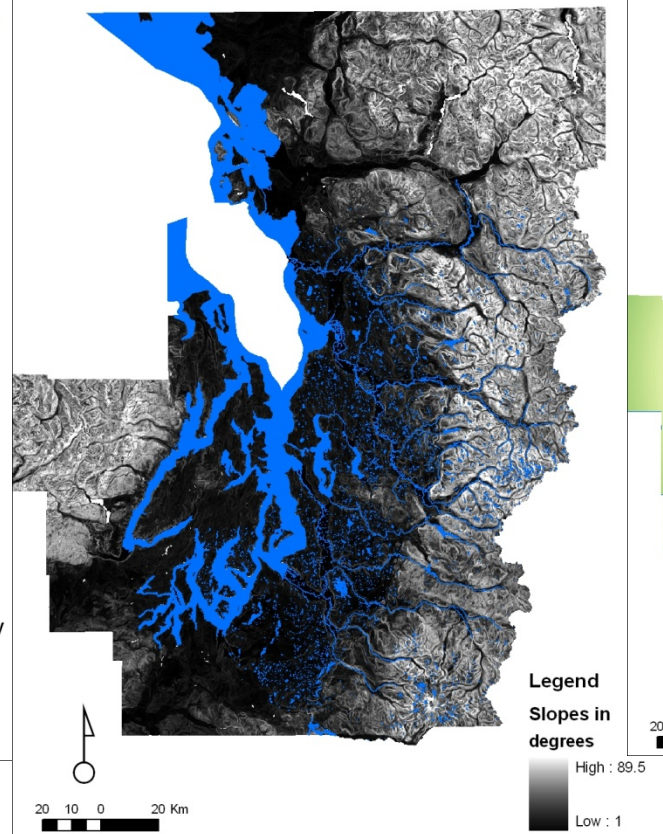
*"An urban area is not simply a human-dominated area" (McIntyre, 2000).*

Log of Population Density



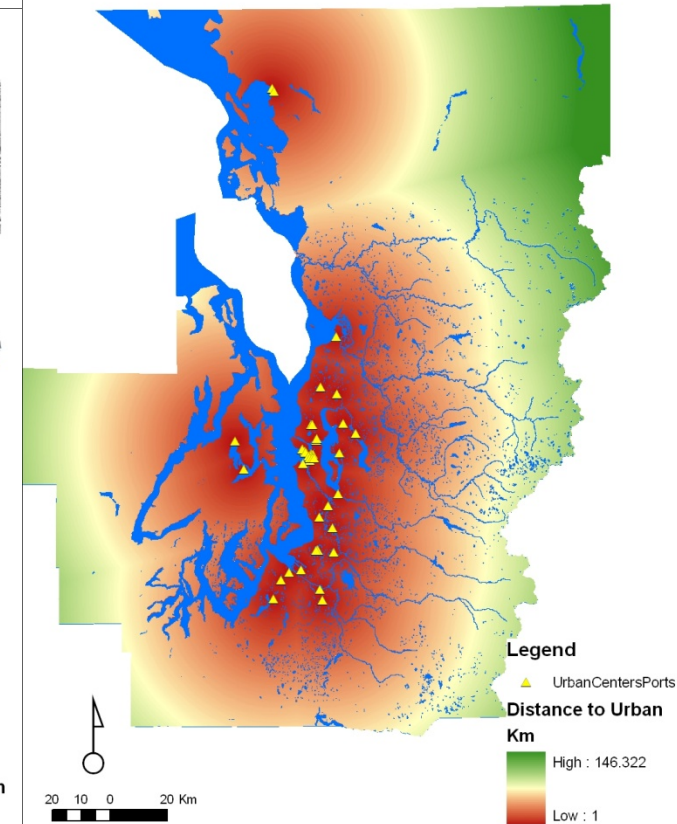
Population Density from 2000 Census data

Puget Sound Slopes



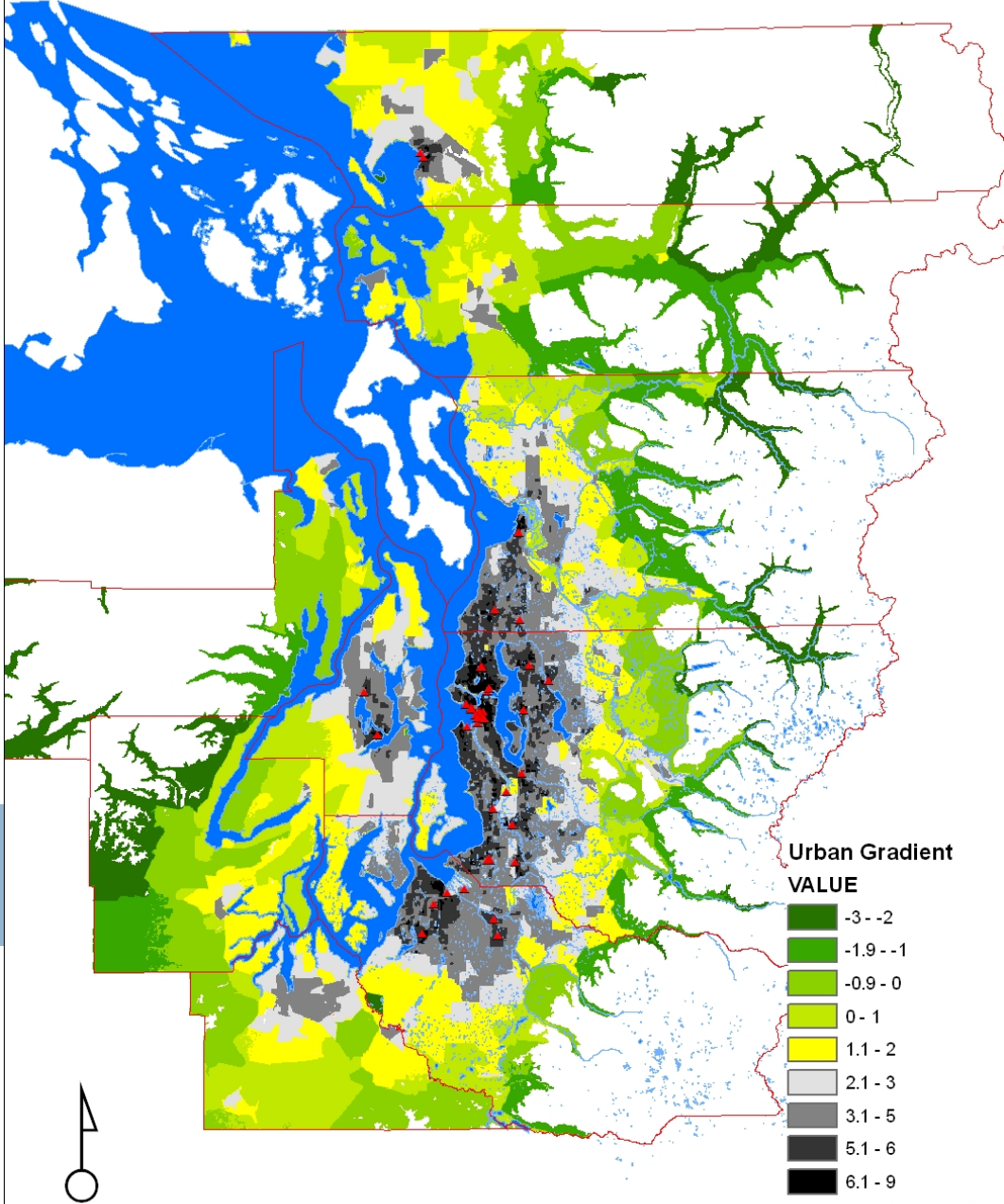
Slope in degrees from 30m DEM

Distance to Urban Centers & Ports



Distance from Urban Centers from PSRC data and Port locations

# Urban Gradient



## Gradient Map

# DOH Water Quality Points

**Study Area:** 6 County  
Central Puget Sound

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

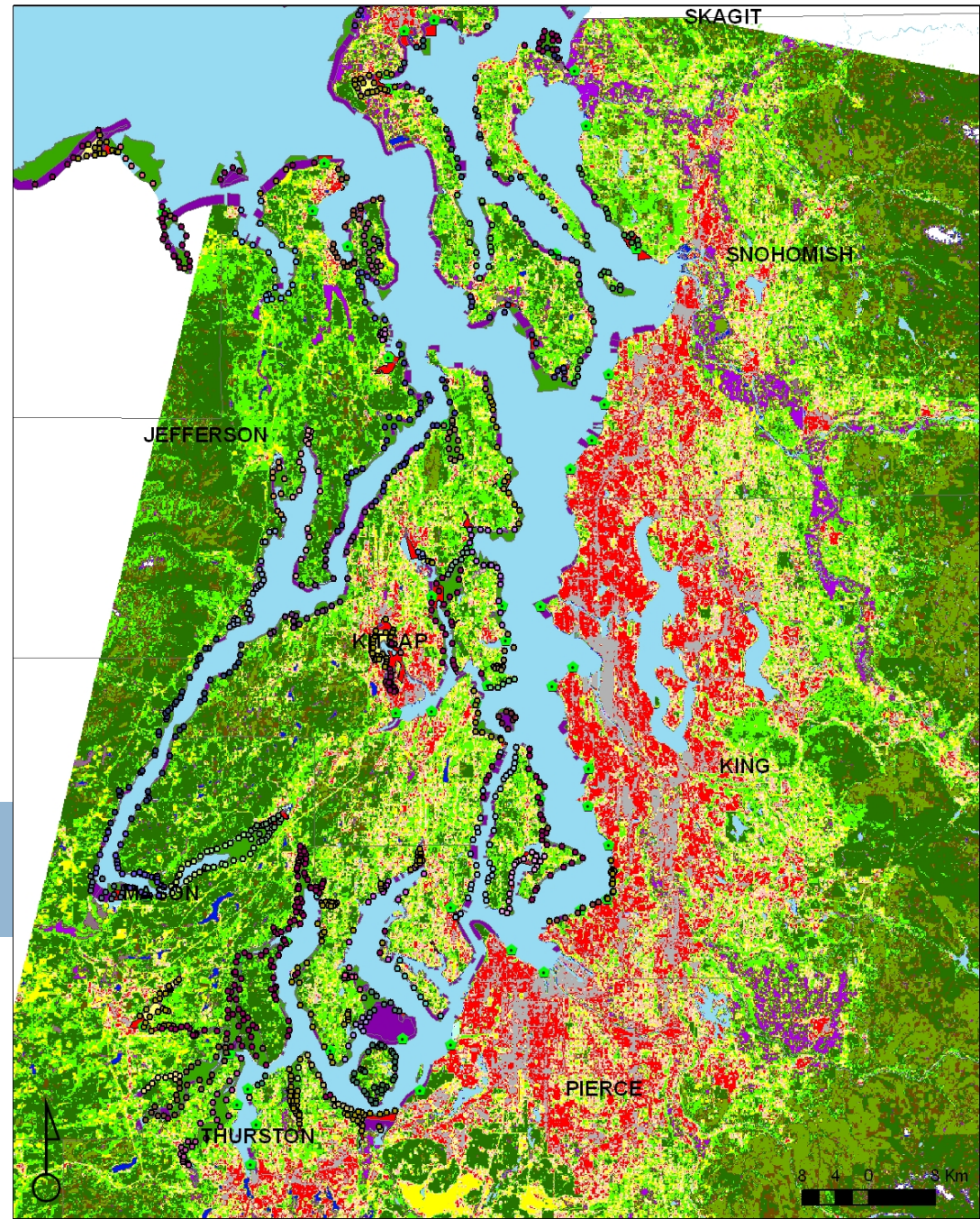
**Landscape data:** 2007  
Land cover

County parcel & LU

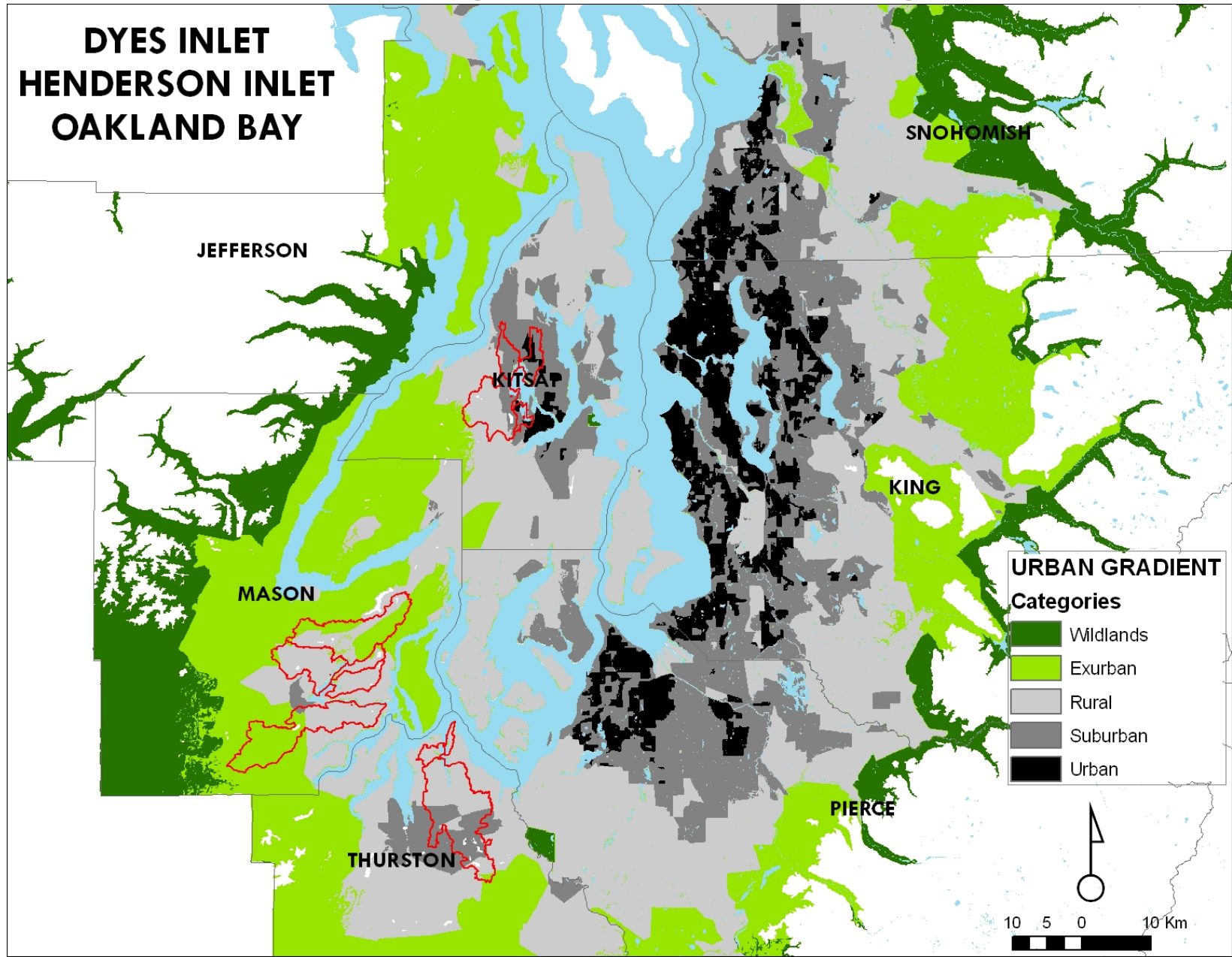
County roads

County OWTS &  
WWTS

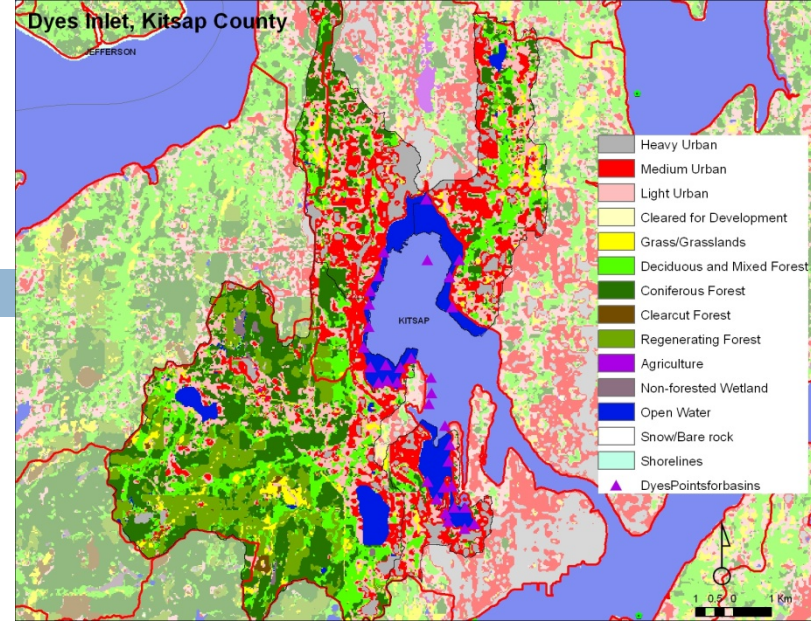
Drainage infrastructure



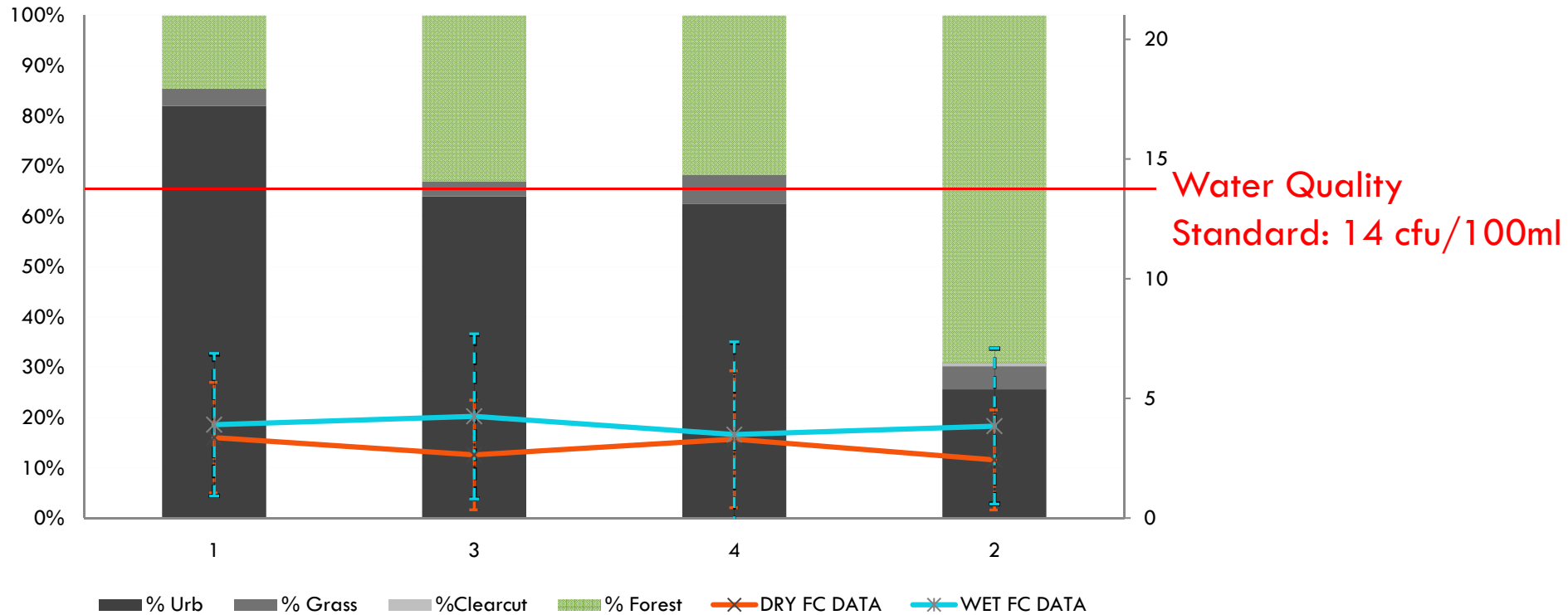
# Basins along the urban gradient



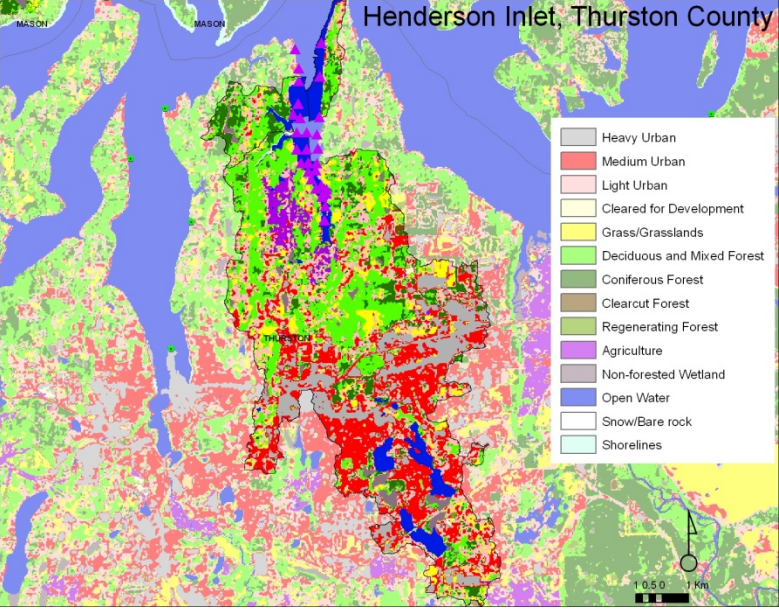
# Dyes Inlet



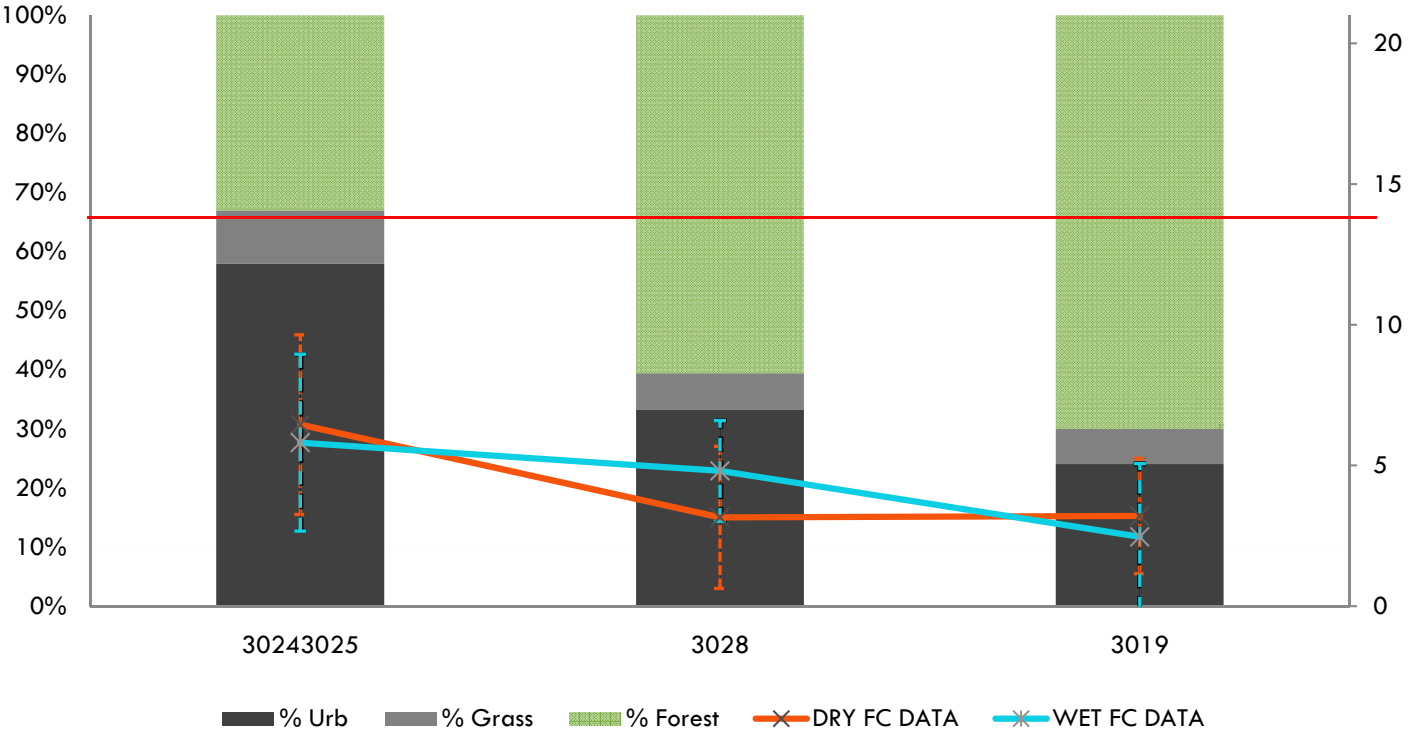
Dyes Inlet 2007 Land cover & FC data



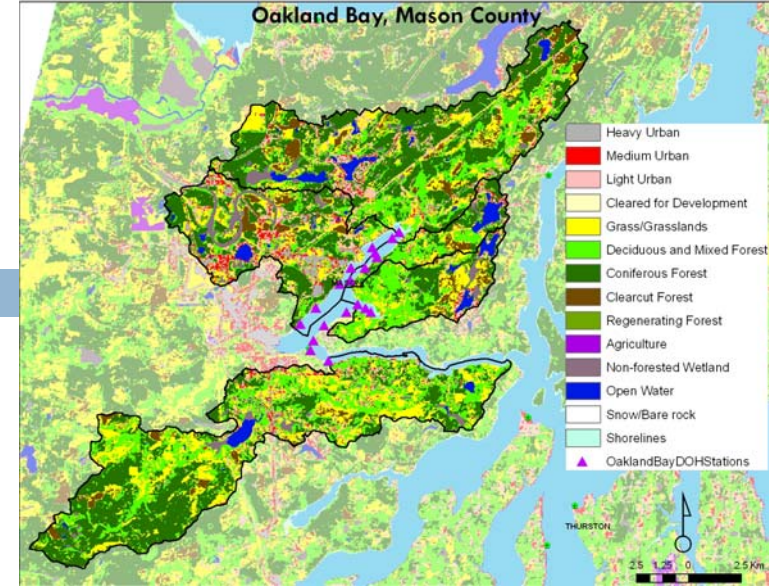
# Henderson Inlet



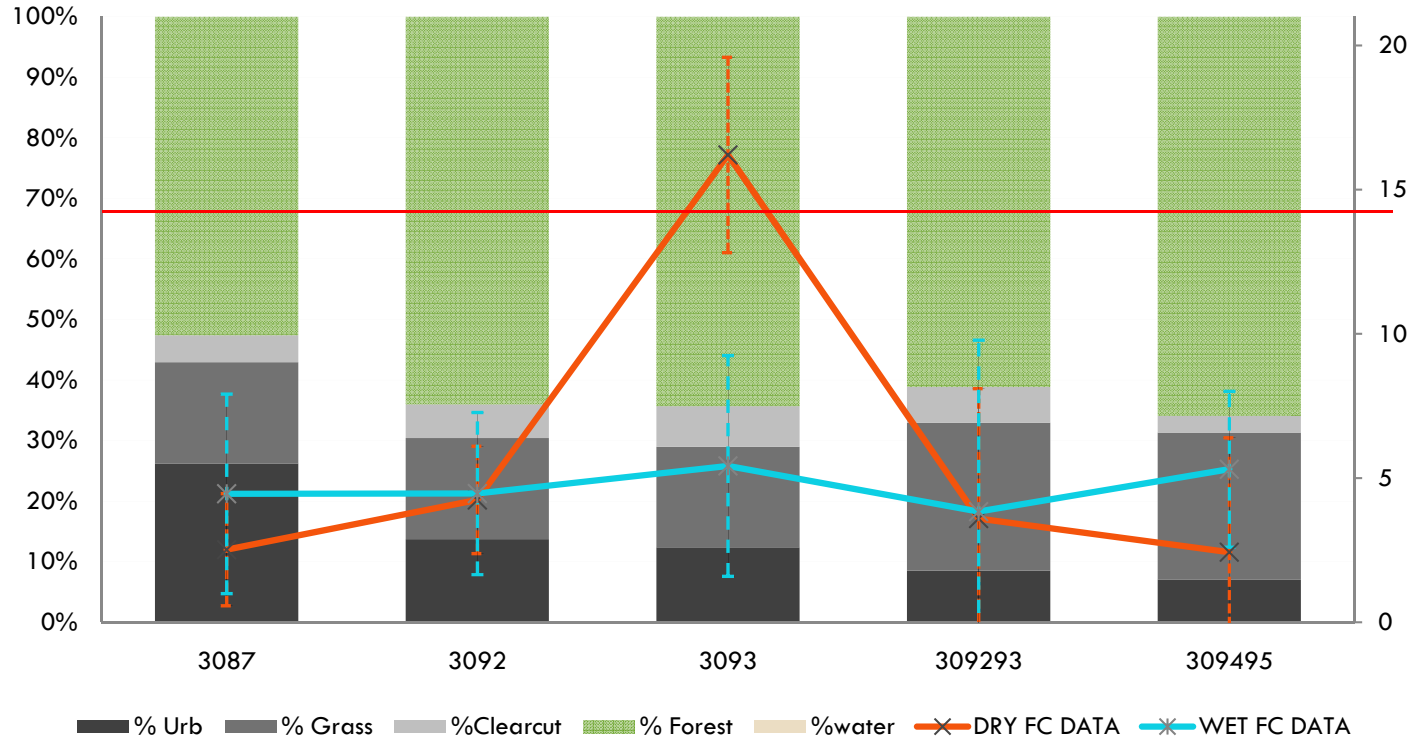
**Henderson Inlet 2007 Land cover & FC data**



# Oakland Bay



**Oakland Bay 2007 Land cover & FC data**



# 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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