The Puget Sound Ecosystem Portfolio Model: A Regional Analysis to Support Restoration Planning

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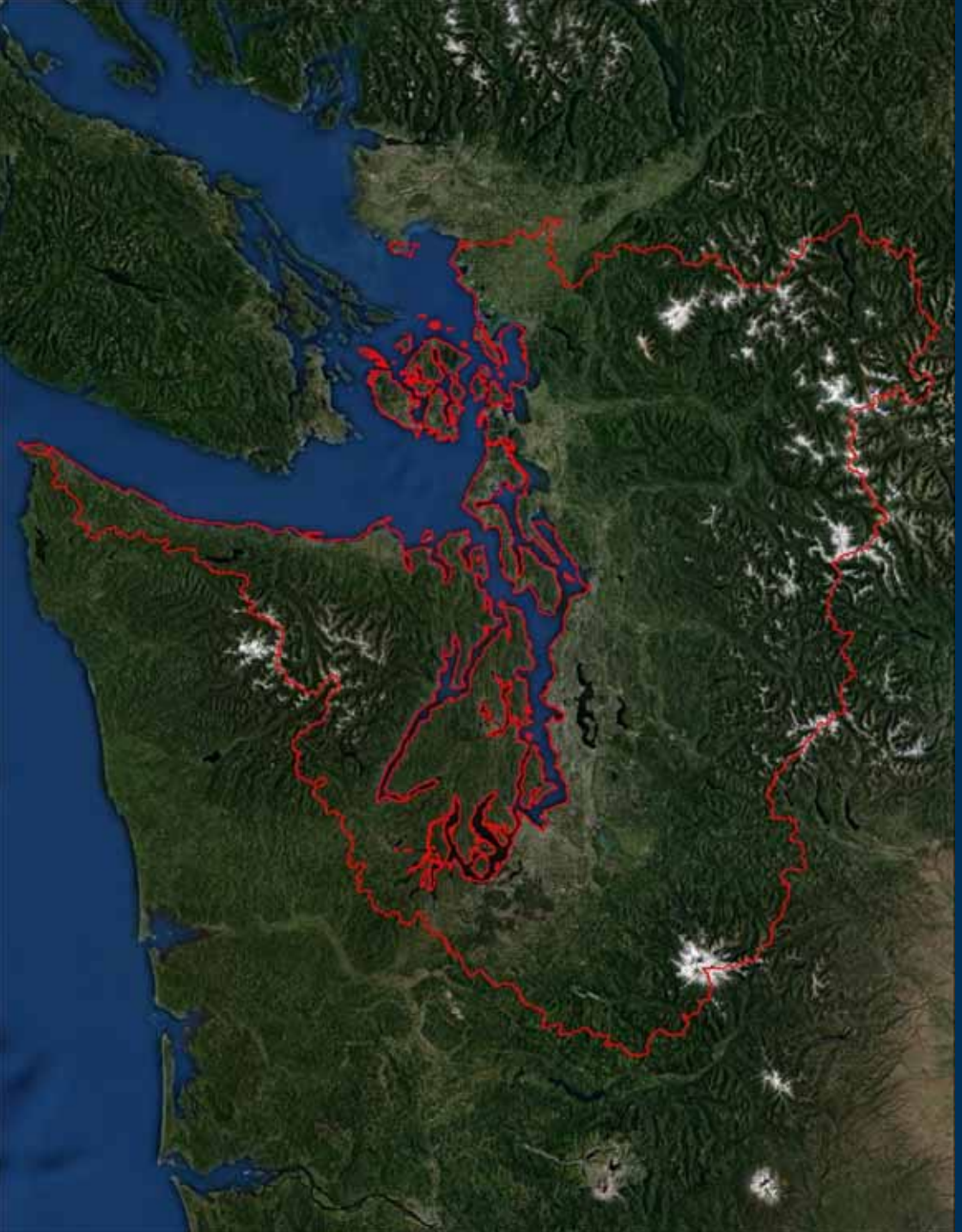
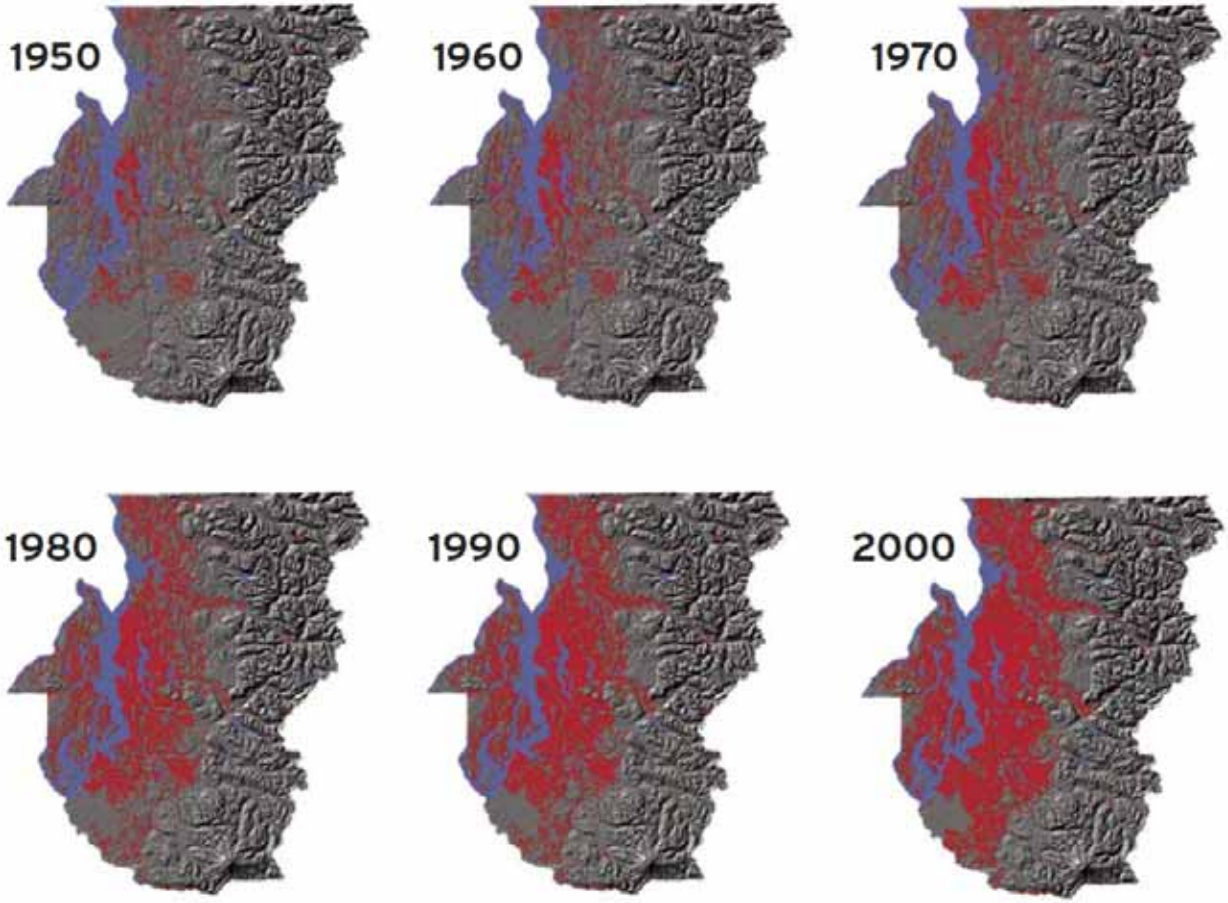


The Puget Sound Basin

Figure 4.4.1: Land cover change in central Puget Sound between 1950 and 2000.

Changes in developed land between 1950 and 2000 are derived from parcel data that track the year each parcel is developed. These data are contained in County Assessor files and were compiled by the Puget Sound Regional Council. (Source: UW Urban Ecology Research Lab 2005).



In Puget Sound the population has doubled and is expected to increase by 35% over the next 15 years – Action Agenda, 2009

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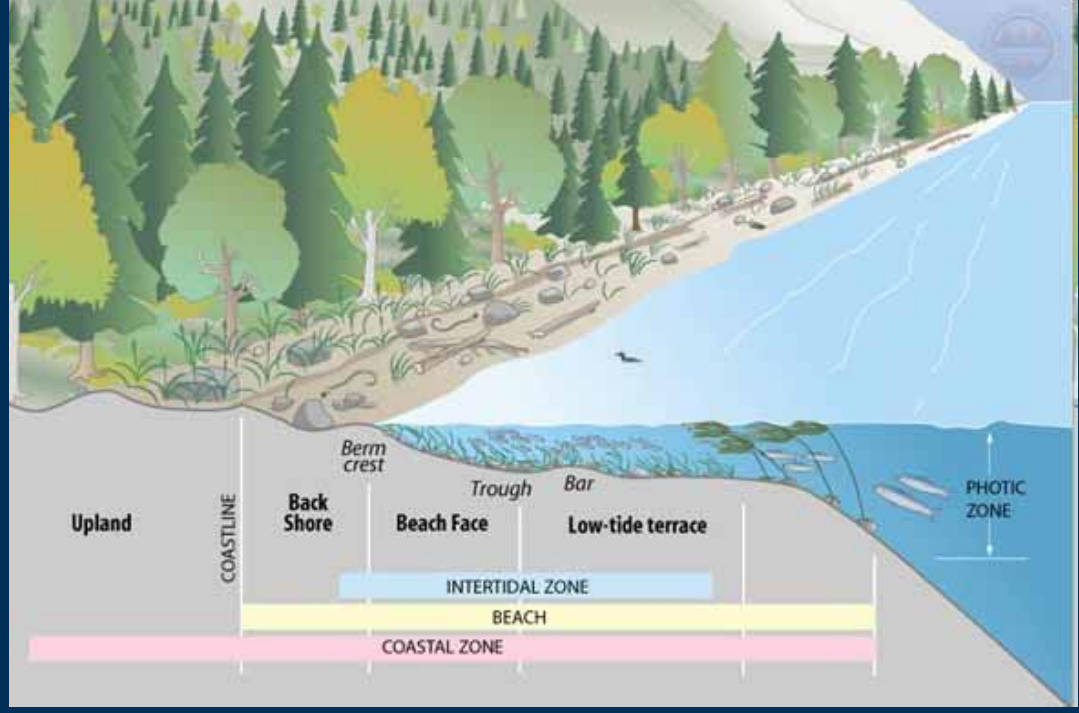
The Puget Sound Nearshore

From the top of coastal bluffs to water at depths 10 meters below MLLW, and upstream in estuaries to the head of tidal influence



http://www.kingcounty.gov/environment/watersheds/central-puget-sound/nearshore-environments.aspx

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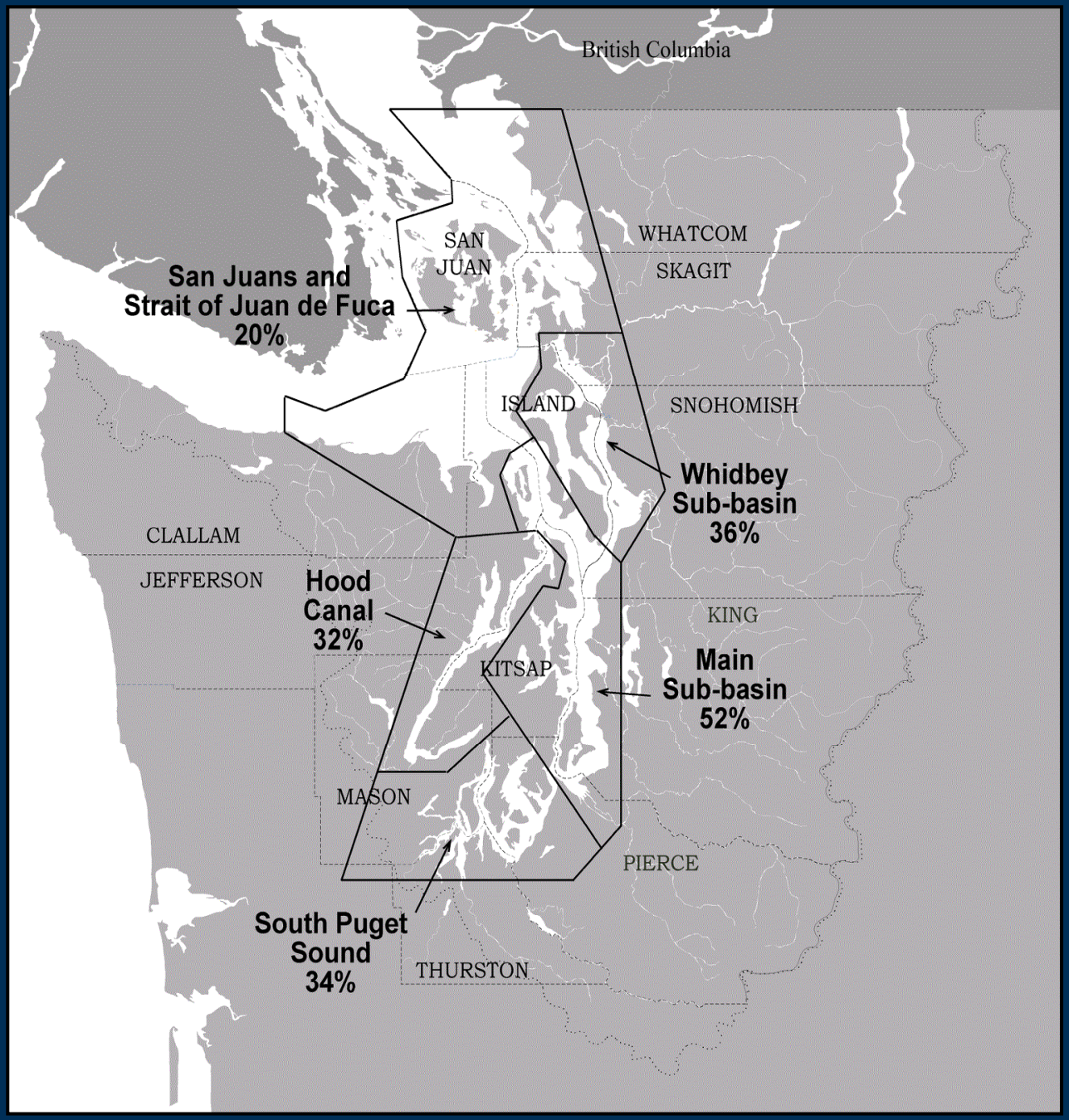

Modified Shoreline on Puget Sound

[DNR, 1998]

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Puget Sound Nearshore Ecosystem Restoration Project

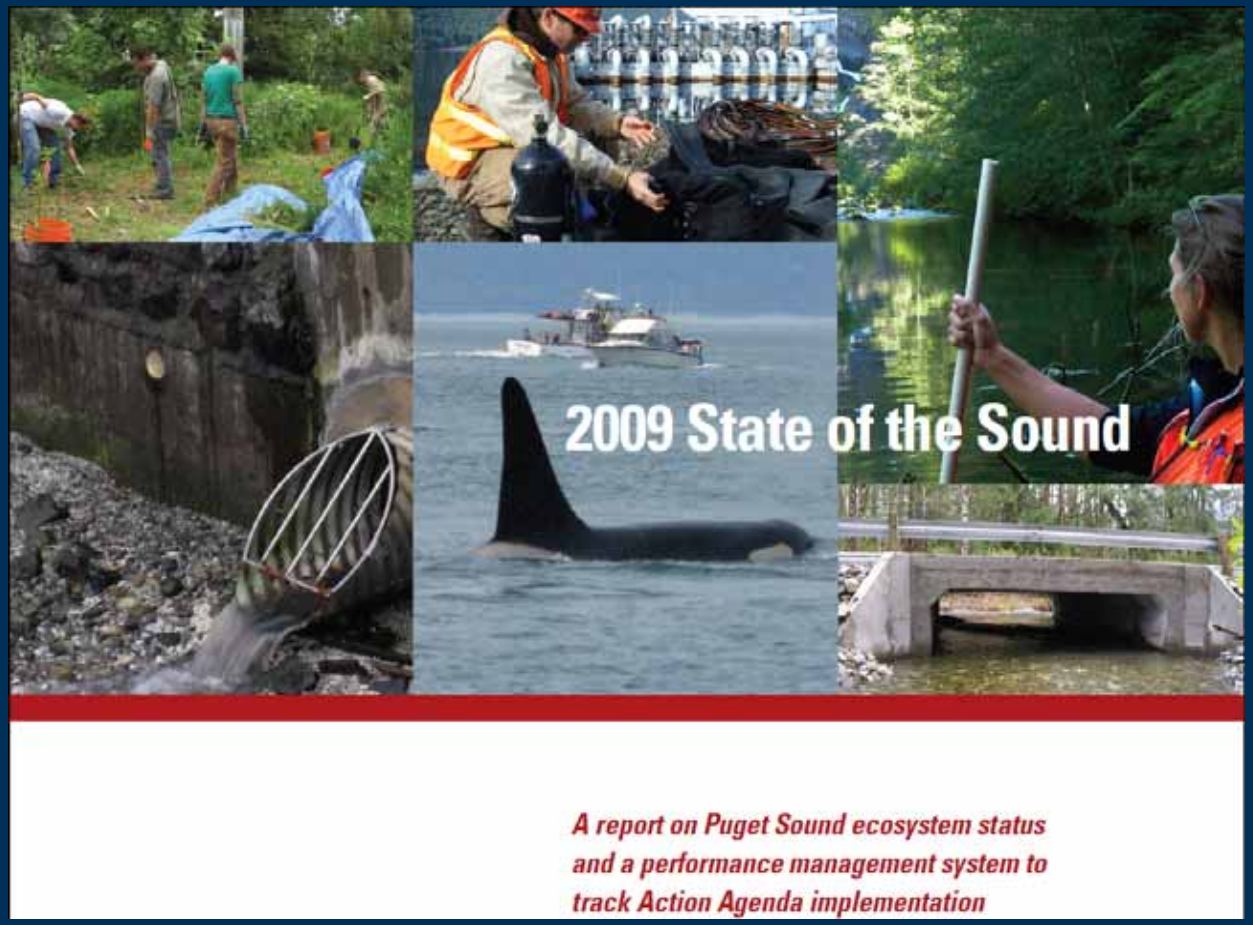
US Army Corps of Engineers

Washington Department of FISH and WILDLIFE

Mission

Restore nearshore habitat of Puget Sound for the benefit of the biological resources and the integrity of the ecosystem, including the functions and natural processes of the basin.

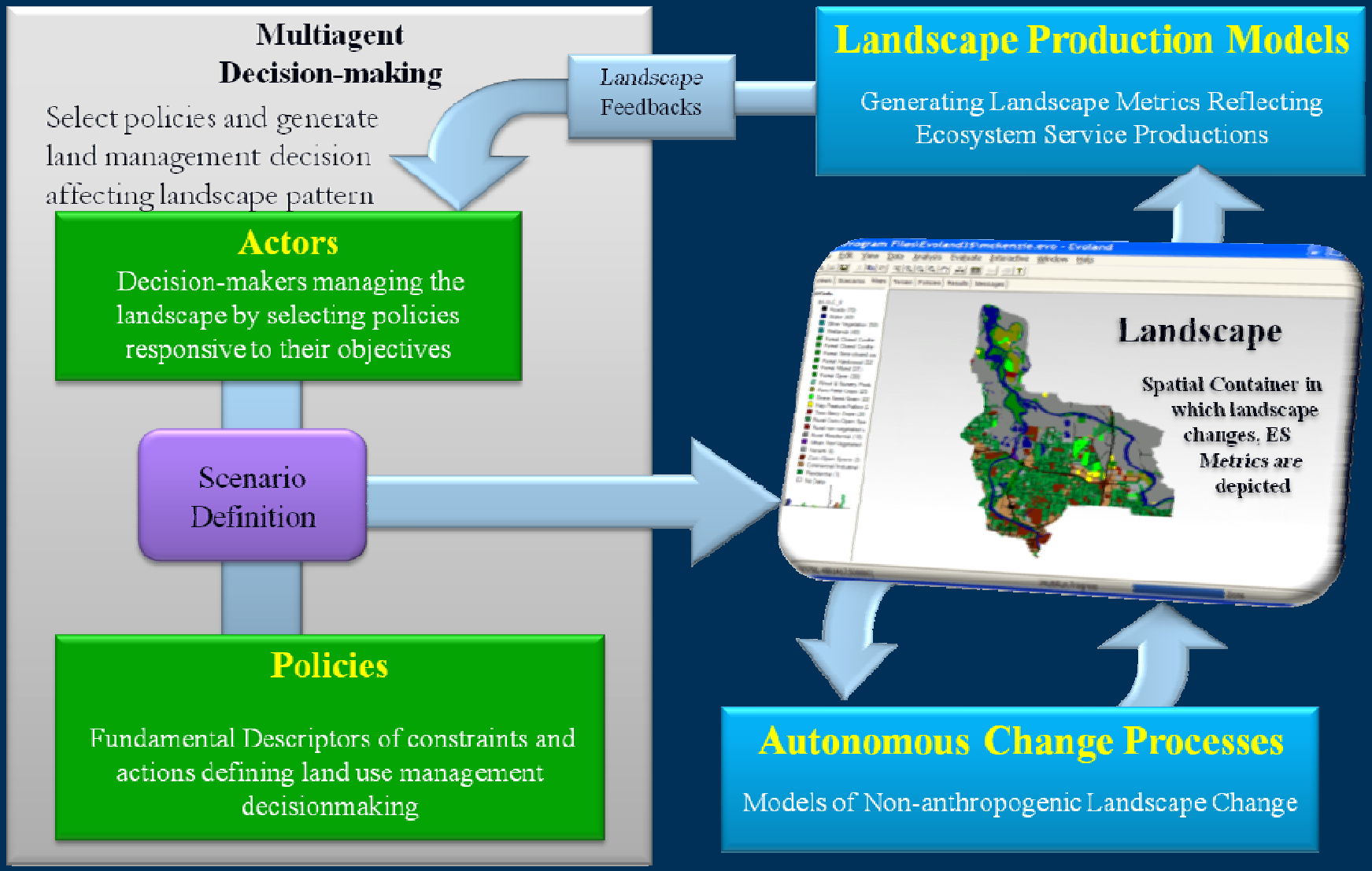
The Puget Sound Partnership: a community effort to restore and protect Puget Sound.



PSP Performance Management System: Results Chains link Strategies to Threat Reduction Targets:
Reduction in Stormwater Contaminants; Restored Sediment Delivery and Transport

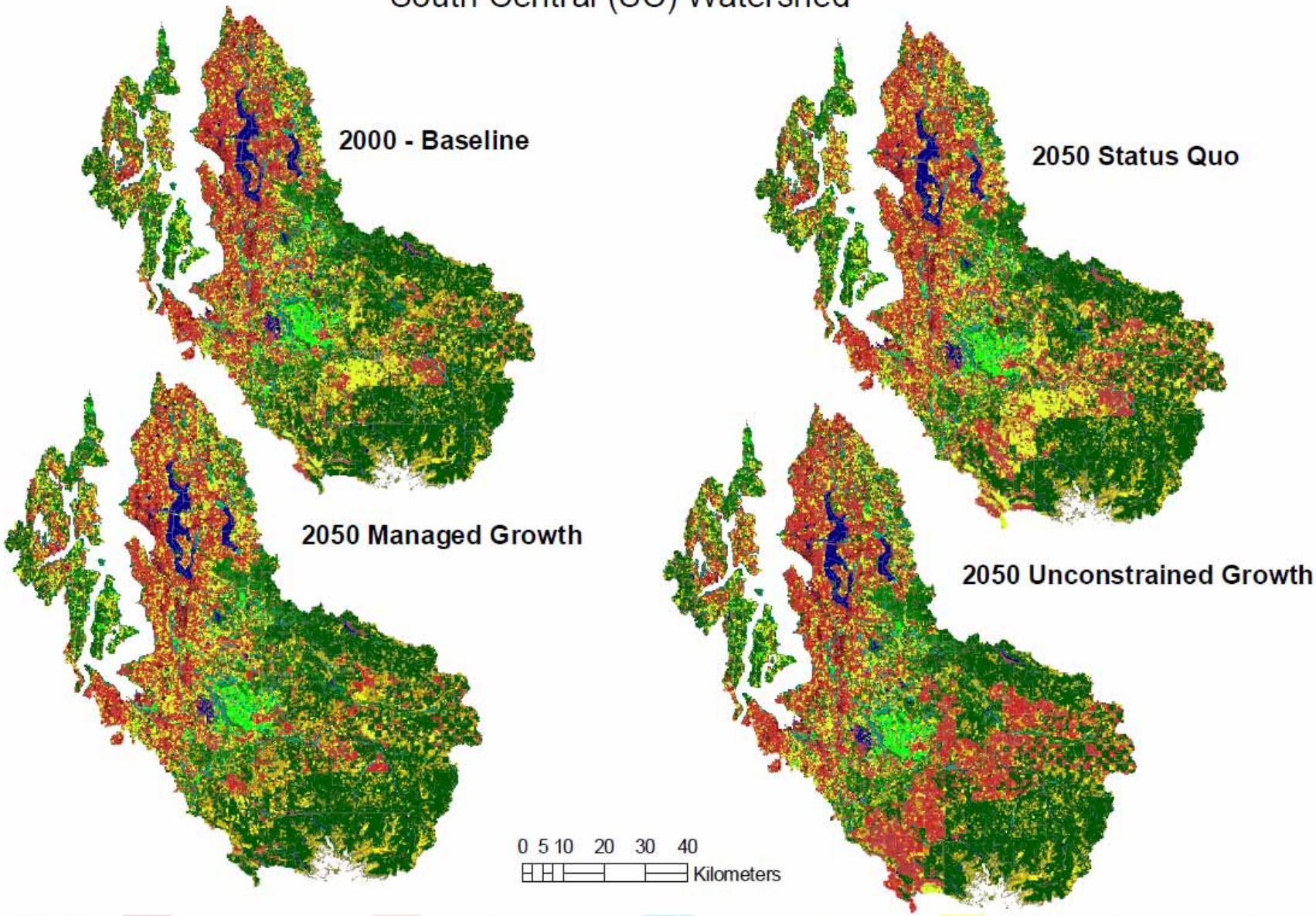
PSEPM: Compares environmental outcomes within a scenario-based alternative futures framework that considers major uncertainties of land use conversion and climate change

ENVISION scenario generation



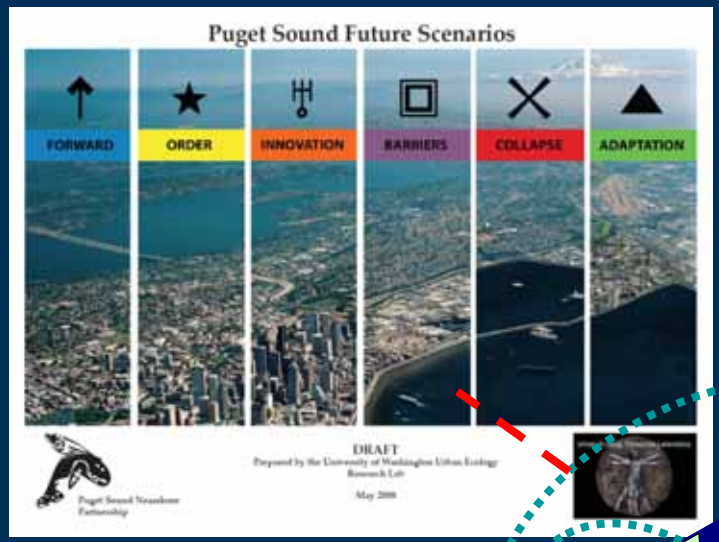
John Bolte - Oregon State University

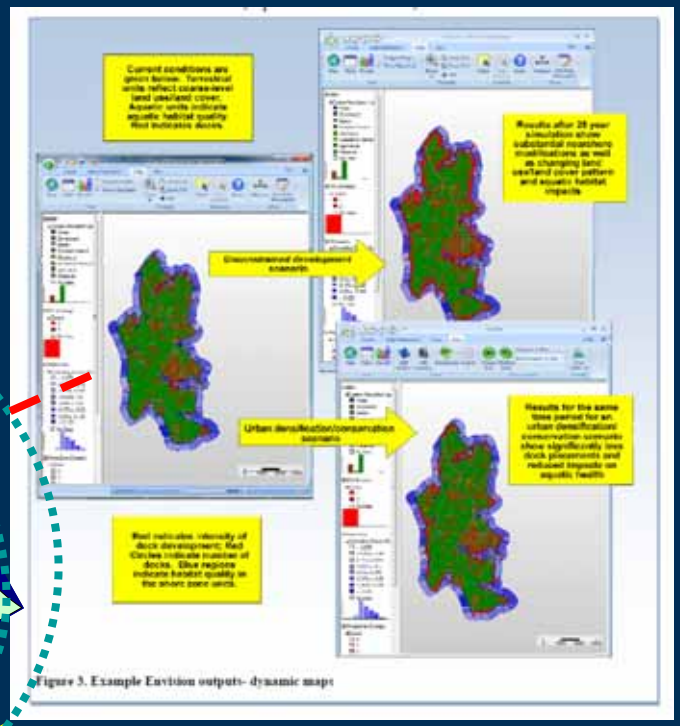
Scenario Comparison - Landcover
South Central (SC) Watershed

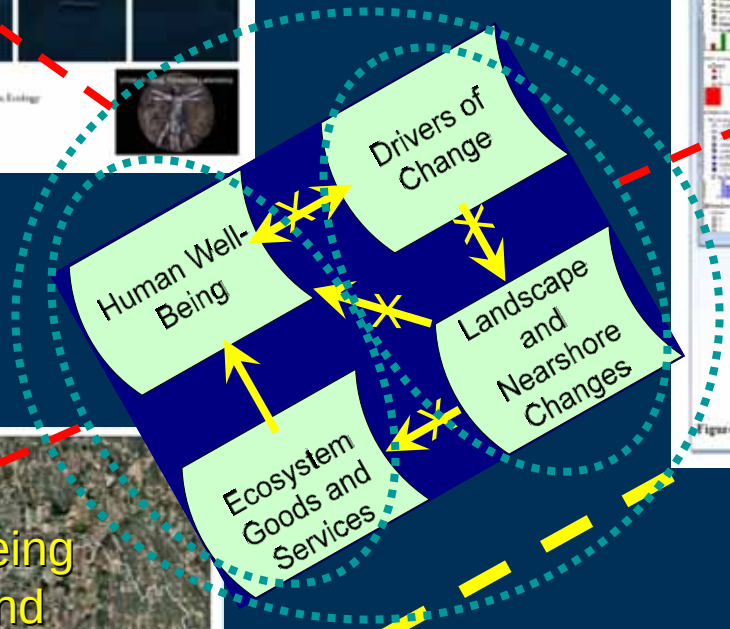


Alberti et al, Future Scenarios Report

Bolte et al, FRAP decadal maps of projected change in nearshore tiers under scenarios







Future Scenarios, FRAP, and EPM

PSEPM components

EPM Criteria	Related to Ecosystem Service	Model
Eelgrass habitat suitability	Biodiversity, habitat, food provision	Based on Controlling Factors Model (Thom et al.)
Forage fish spawning potential	Food provision, food web support, iconic species	WDFW data and WDFW and USGS modeling collaboration
Shellfish pathogens	Food provision, recreation	Statistical model based on WDOH water quality data
Beach erosion index	Erosion control, beach condition, recreation	Index based on PSNERP, Coastal Geologic Services data
Coastal recreation	Recreation, tourism	Statistical model based on State Park visitation data
Nearshore nutrient loading	Beach condition (eutrophication, DO), recreation	USGS SPARROW model

Works in progress…

- Forage fish spawning potential
  - DFW Salmonscape data (simple overlays for now)
- Nutrient loading to nearshore
  - USGS SPARROW model
    - Statistical model relating land-use, other sources and sinks, to nutrient concentrations and loadings within stream network; routes loads
- Eelgrass habitat suitability
  - Collaboration to modify Controlling Factors Model (PNNL, Ron Thom, others) to work with EPM
    - Relates local conditions to scored model of habitat suitability

The Land-Water-Human Connection
An example: Bluff-backed Beaches

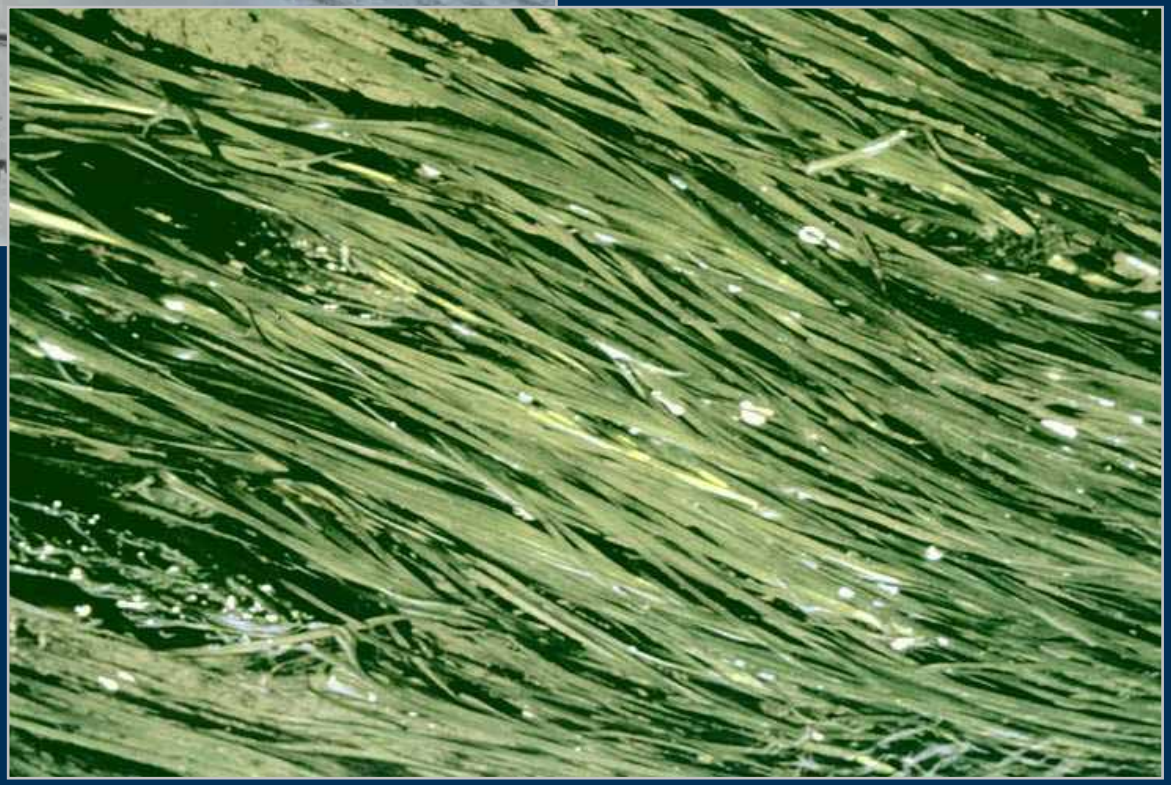
Scenarios of shoreline modifications/ Land use change/ Population distribution

- **Beach geomorphology changes/ Changes in erosion potential**
  - **Recreational beach use**
  - **Forage fish habitat**
  - **Eelgrass habitat suitability**
- **Beach water quality changes/ Increased pathogen concentrations**
  - **Recreational beach use**
  - **Commercial/Tribal shellfish harvest**

Impacts of Shoreline Armoring

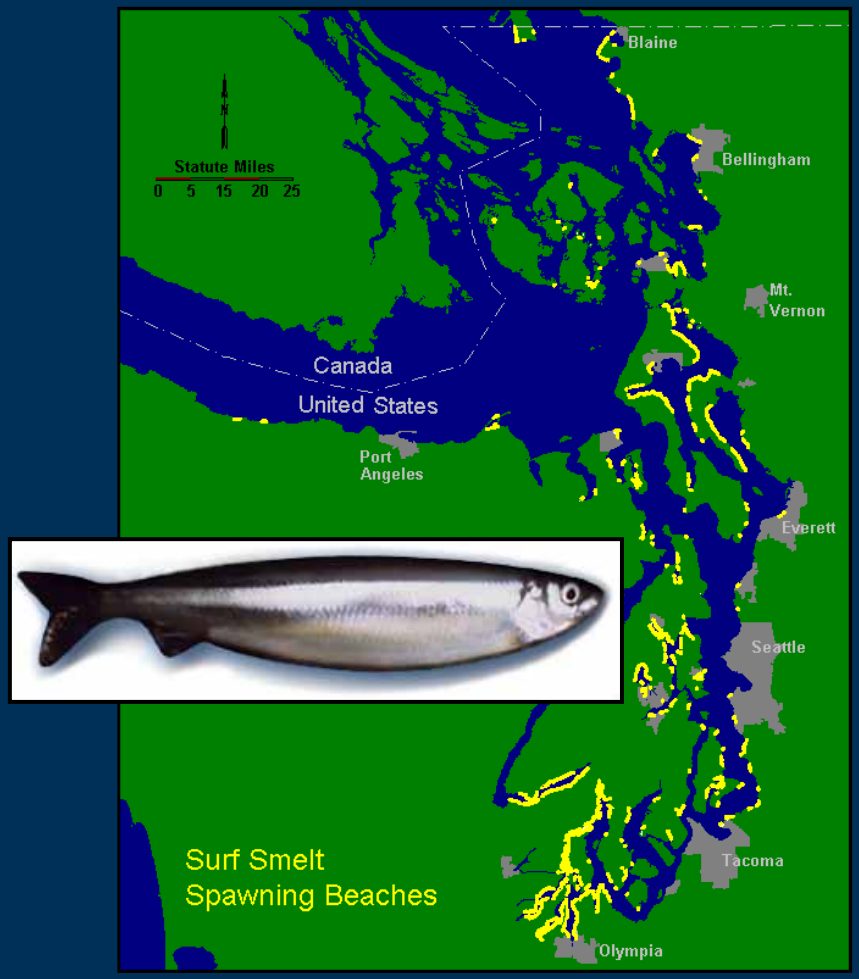
- Loss of littoral sediment
- Wave reflection/scour
- Hydrological impacts
- Loss of riparian vegetation
- Passive erosion
- Cumulative impact

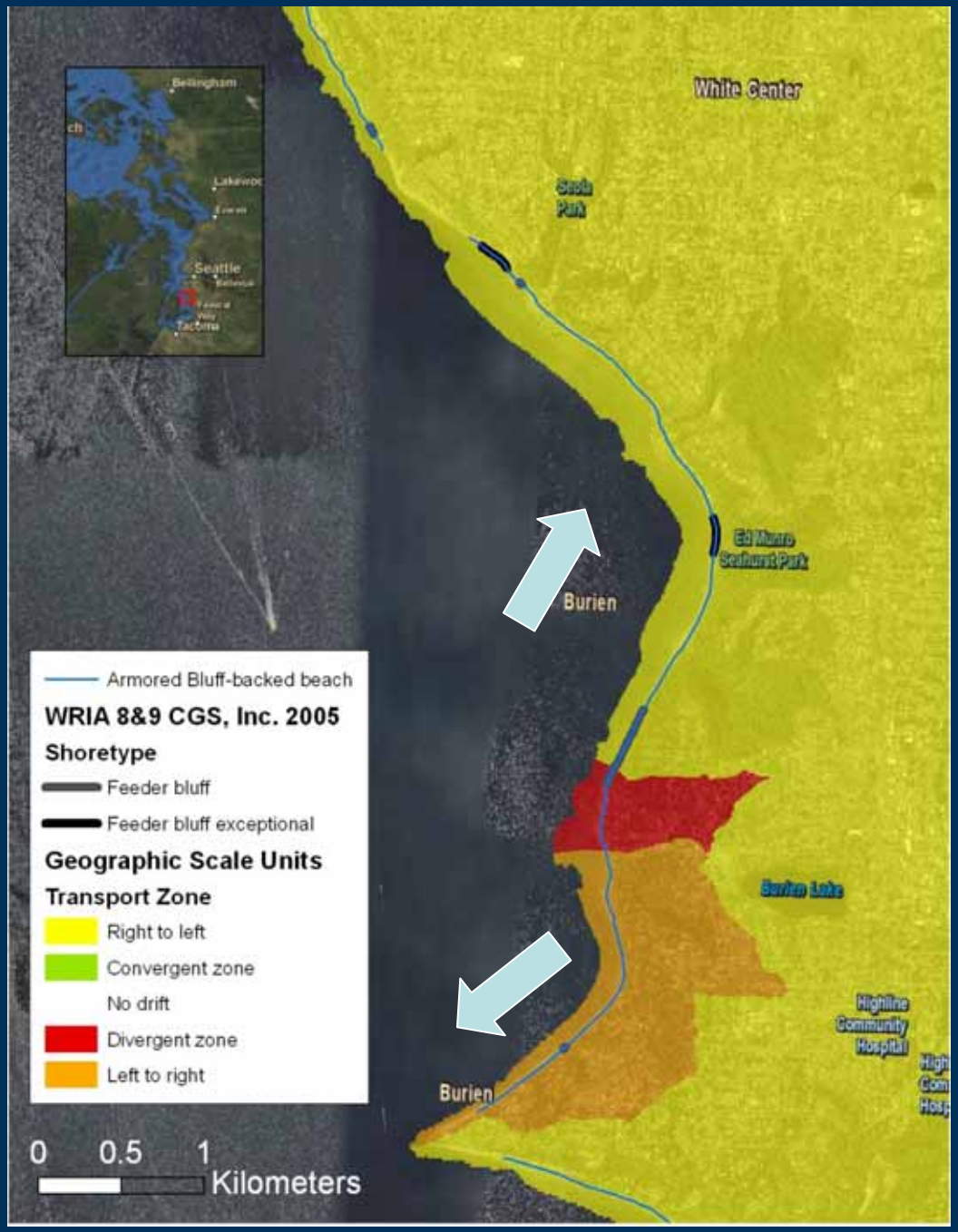
Eelgrass



Forage Fish

Surf Smelt
Sand Lance





General Concept

How will armoring affect beaches at the armoring site and beaches downdrift of armoring location?

Currently a factor of:

1. Fetch distance at beach
2. Length of armoring on beach's bluff
3. Length of armoring on updrift bluffs within drift cell

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The PSEPM Beach Erosion Index:

For a given bluff-backed or barrier beach:

- The relative potential of a beach to erode due to loss of sediment supply from shoreline armoring

Data Source:

PSNERP Change Analysis Geodatabase
ENVISION armoring scenario data

Outcome Goal: Index (1-5) represents potential for reduced beach width and substrate changes that have consequences for ecosystem goods and services such as recreation and forage fish spawning habitat

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Index Calculation:

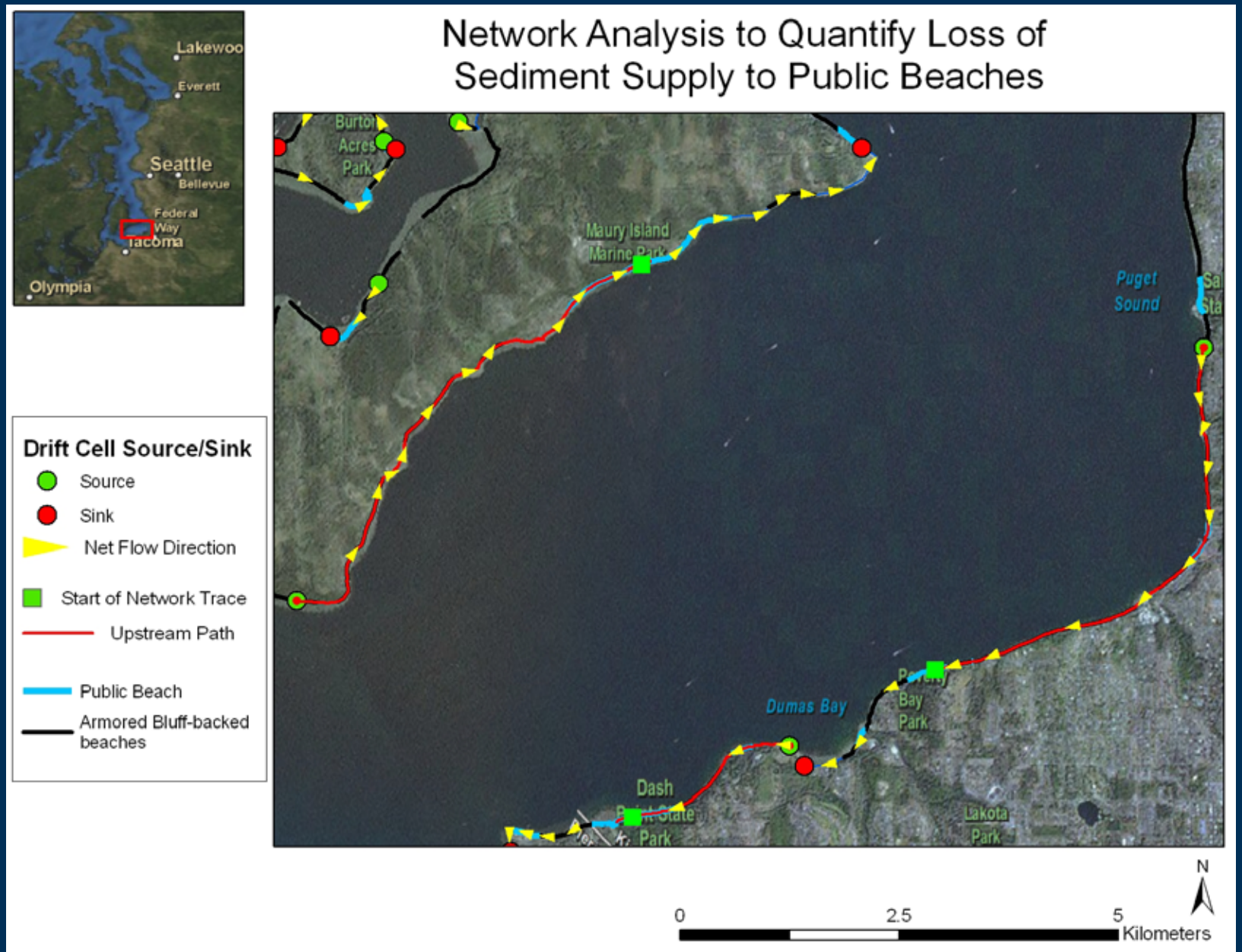
P_Armor: Percent length of beach X that is armored
P_Up_Armor: Percent of bluff-backed beach length updrift of beach X that is armored
FD: Mean fetch distance at beach X

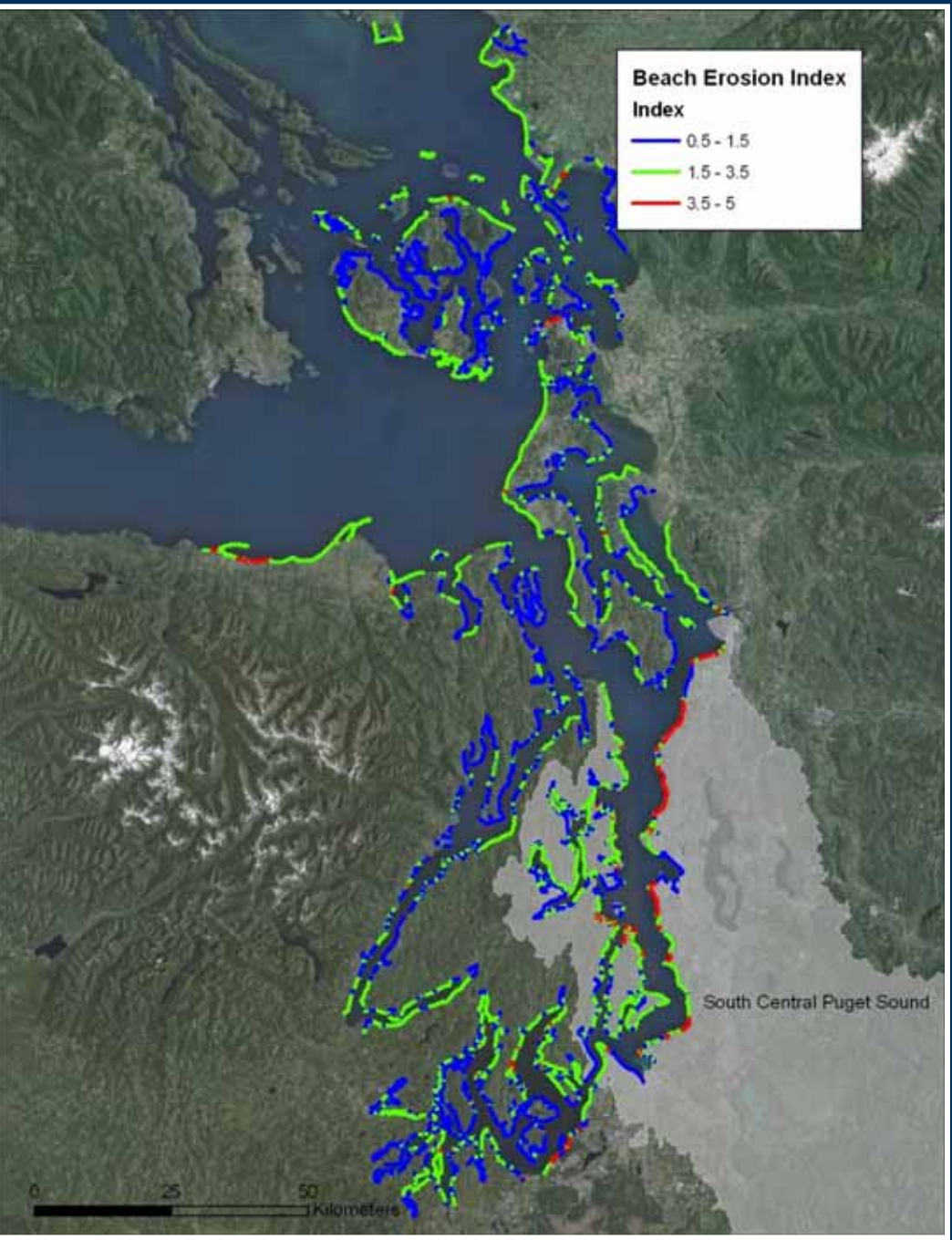
Variable scores based on which quartile the beach's data fall into

Index values range 1 to 5

Index: Score(P_Armor) + Score(P_Up_Armor) + *2 Score(FD)*2

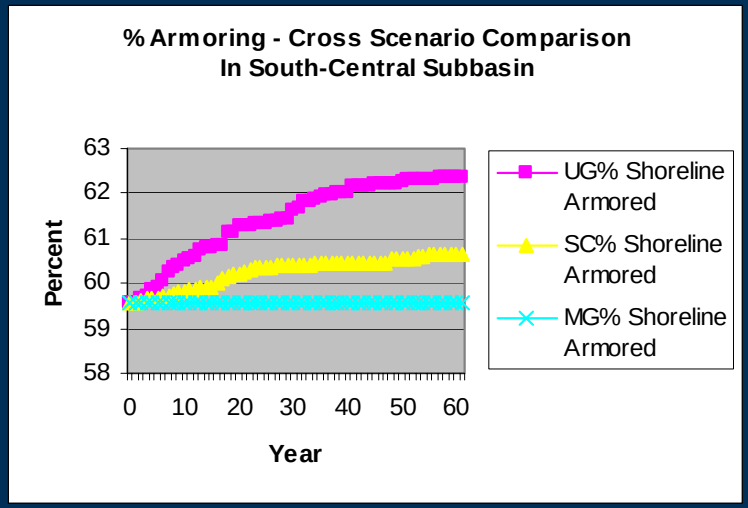
Length of updrift armored bluffs calculated with "upstream accumulation" tool

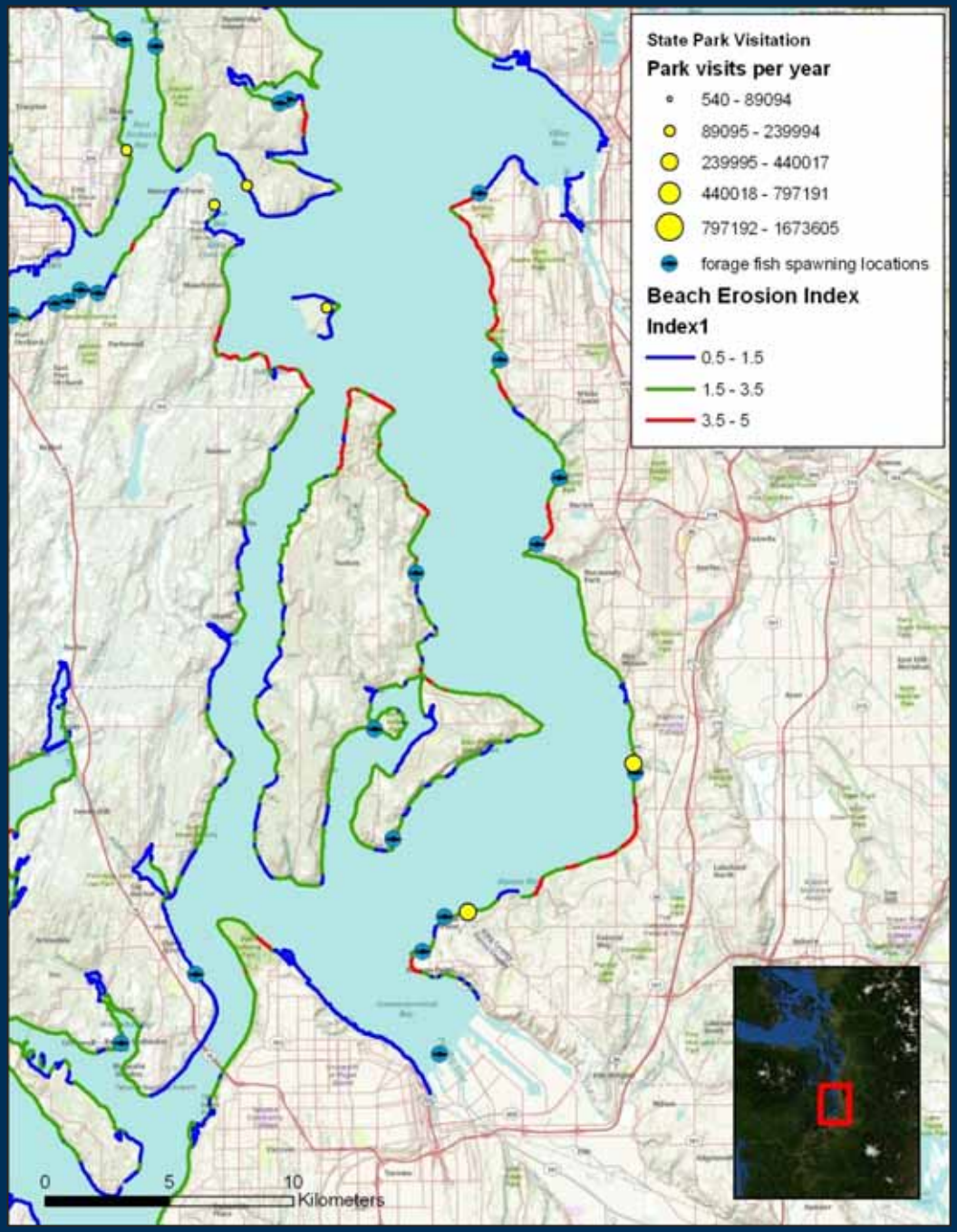




Beach Erosion Index Results

3% increase in armoring length across scenarios





Overlay of Beach Erosion Index values with

Park Visitation Projections and Forage Fish Spawning Locations

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Challenges and Next Steps

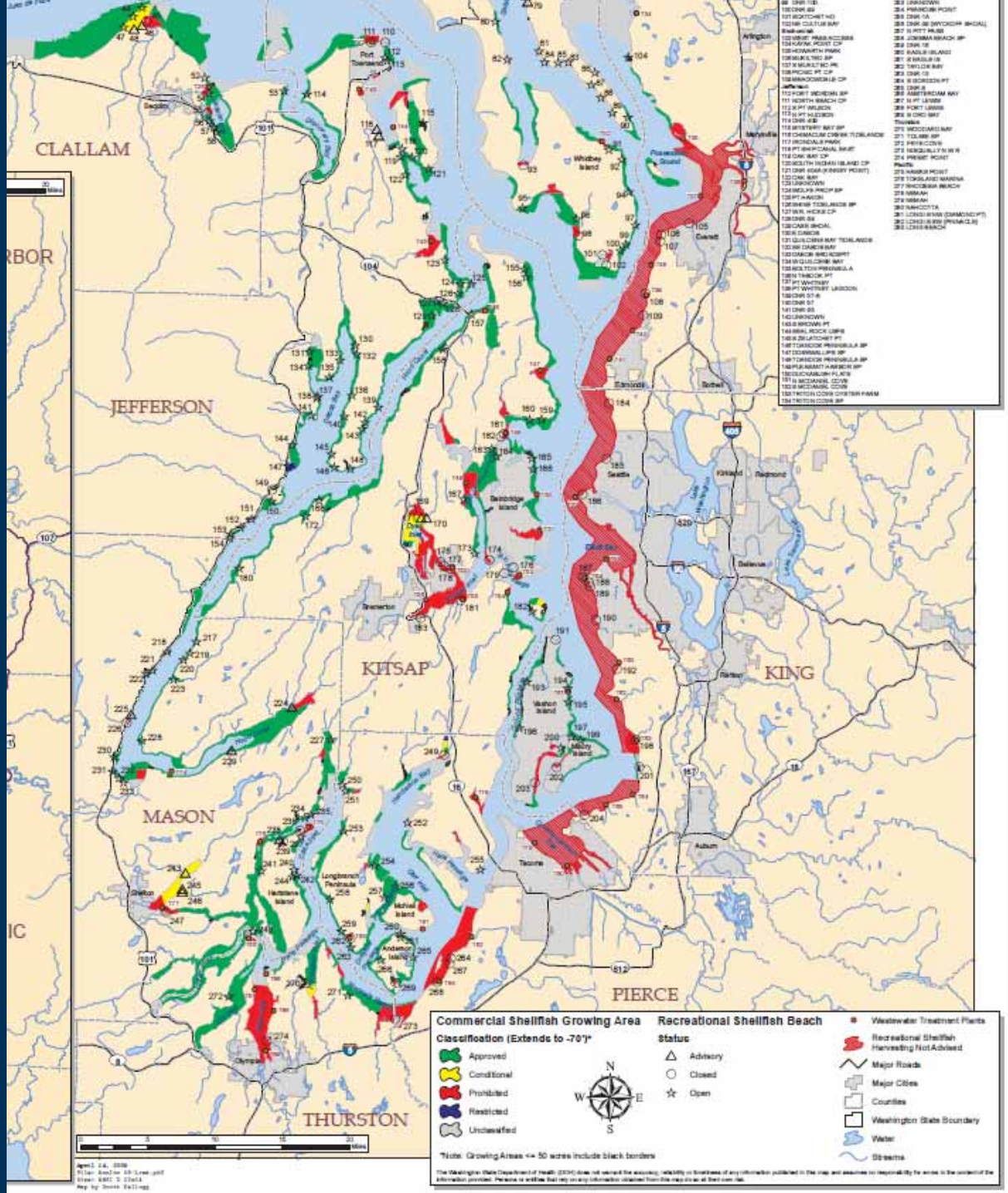
- Scenario improvement – Sea level rise and adaptation strategies
- Expert workshops – guide index development and review model results

<u>Data Acquisition</u>

- *To characterize wave energy at a beach:* Develop and test multiple fetch variables
- *To characterize bluff sediment supply:* Use current feeder bluff maps produced by Coastal Geologic Services, Inc. (CGS) (Johannessen et al. 2005).
- *To characterize longshore sediment transport:* calculate longshore sediment transport rates updrift of each beach using the CERC formula (USACE 1984).

<u>Validation</u>

- Conduct historical shoreline mapping to compare beach morphology and ecology before and after armoring
- Sensitivity analysis of the index variables



Washington Department of Heath Office of Shellfish and Water Protection

Commercial and Recreational Shellfish Growing Areas

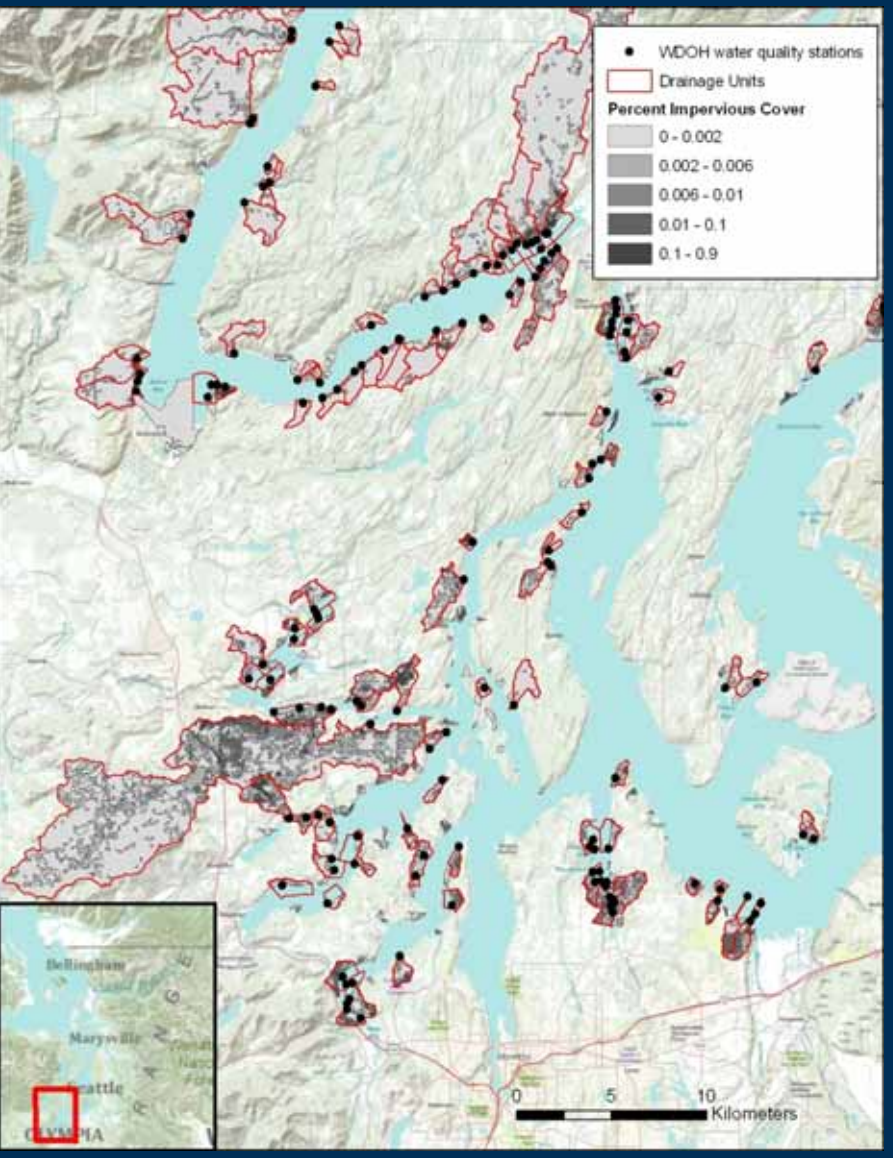
Classified based on pathogen data

Shellfish Pathogen Model

Watershed study to statistically relate land cover to fecal coliform bacteria counts in commercial shellfish growing areas

Water Quality Data

- WDOH commercial shellfish water quality stations, years 2000, 2001, 2002
- Dependent variable: for each drainage, geometric mean of 3 randomly selected wet season (Nov. – March) samples and 3 randomly selected dry season (April – Oct.) samples (Alberti and Bidwell 2005)
- No datapoints in urbanized Seattle-Tacoma corridor



Drainages: PSNERP change analysis geodatabase drainage units >0.25 km^2

Explanatory Variables:

Watershed Scale

Percent land cover for NLCD 2001 land cover classes
Population density
Average slope
Edge density for each forest, ag, and developed classes
Mean perimeter-area ratio for each forest, ag, and developed classes
Water salinity
Water temperature

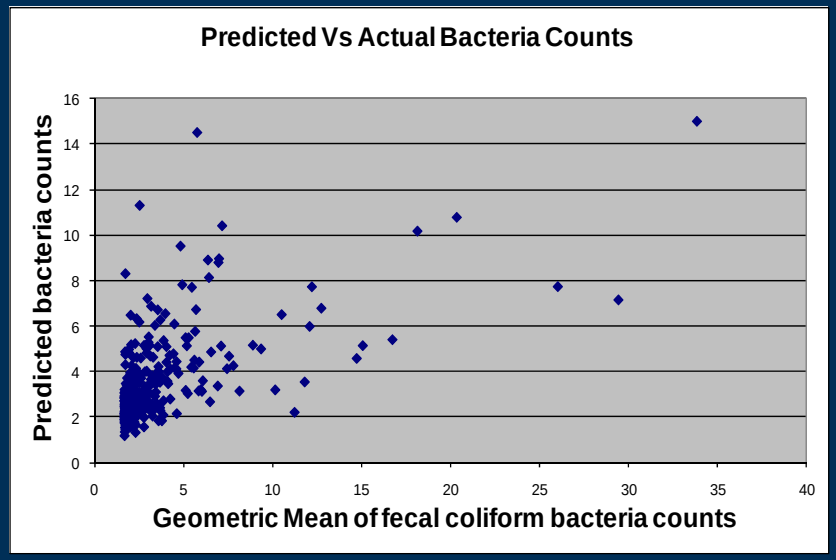
Stream Scale: 90-meter buffer around streams or canal/ditches in NHD+

Percent landcover for NLCD 2001 land cover classes
Average slope
Water temperature
Water salinity

Negative binomial regression of fecal coliform count data

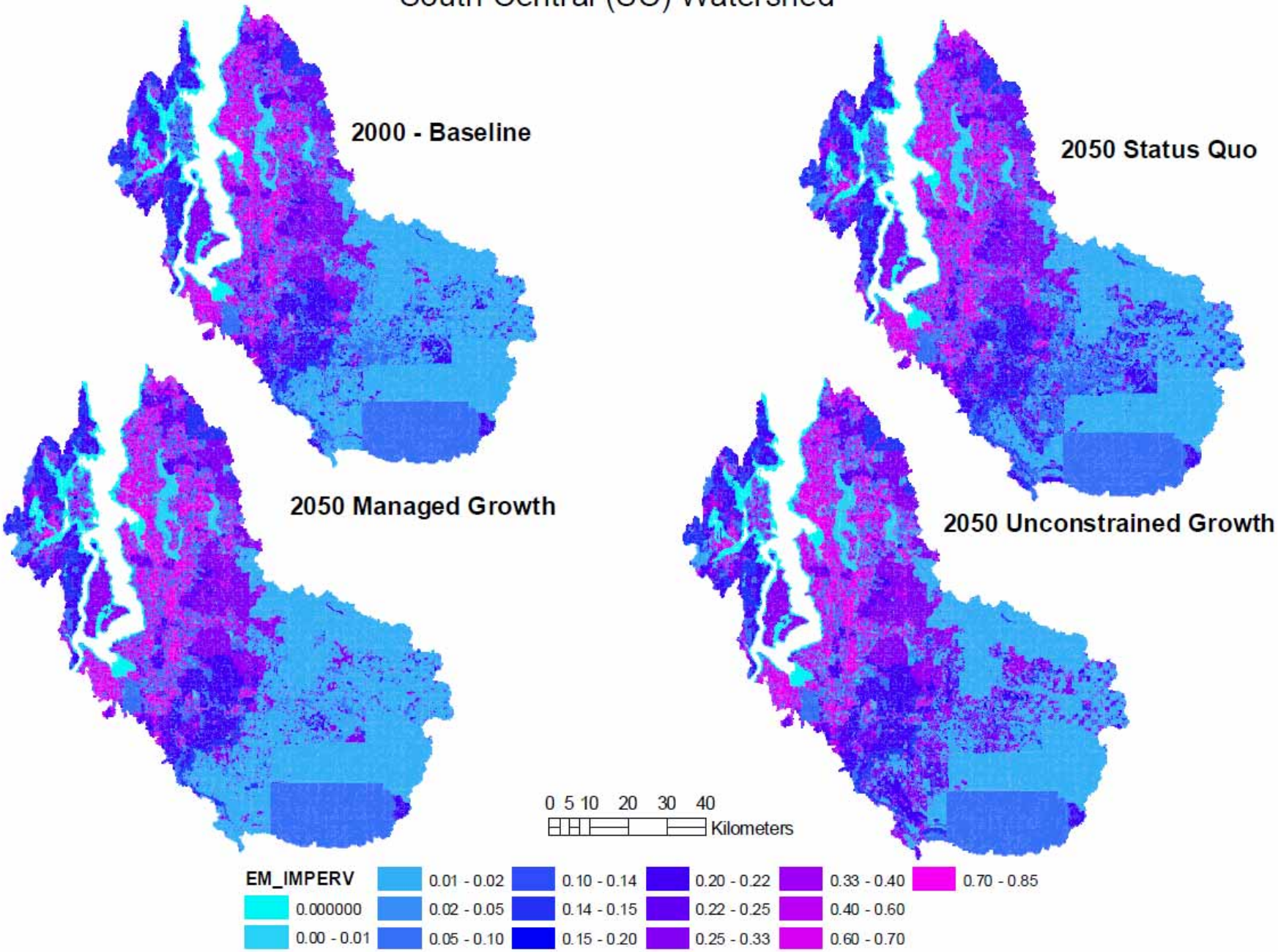
Negative binomial regression — Number of obs = 335
Dispersion = mean — Wald chi2(4) = 95.97
Log likelihood = -650.62276 — Prob > chi2 = 0.0000

Fecal coliform count	Coef.	Bootstrap Std. Err.	Z	P>|z|	Normal-based [95% Conf. Interval]	
salinity	-.089	.0107	-8.34	0.000	-.1101416	-.0682253
watertemp	.128	.0416	3.08	0.002	.0467553	.2097516
evergreen forest	-.004	.0016	-2.44	0.015	-.0070958	-.0007754
impervious cover	.025	.0130	1.96	0.051	-.0000623	.0507593
_cons	2.21	.459	4.82	0.000	1.311329	3.111131

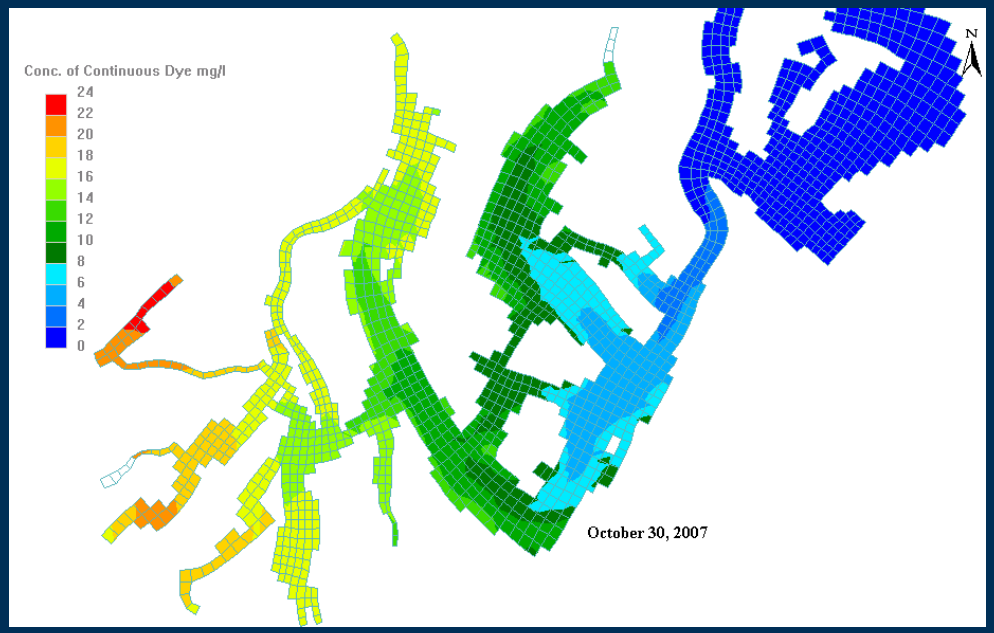


Significant, but still lots of variation.

Scenario Comparison - % Impervious
South Central (SC) Watershed



Next steps: Additional data for land use/pathogen model:



DRAFT Model of flushing times for South Puget Sound: Contour plot of dye concentrations remaining in the region after approximately 15 months of the dye release. (Washington Department of Ecology)

At Water Quality Stations:

- Flushing times by season, common harvest times

In Drainages:

- Test scales of analysis
- SPARROW-type model for pathogen stream loading
- Waste water infrastructure (Daniele Spirandelli, UW Ph.D. candidate)

Further questions: Will estuarine changes (e.g. salinity) associated with climate change influence pathogens?

What is potential pathogen exposure to commercial/recreational/tribal shellfish consumers? On a monthly time scale, does increased pathogen risk coincide with higher consumption periods?

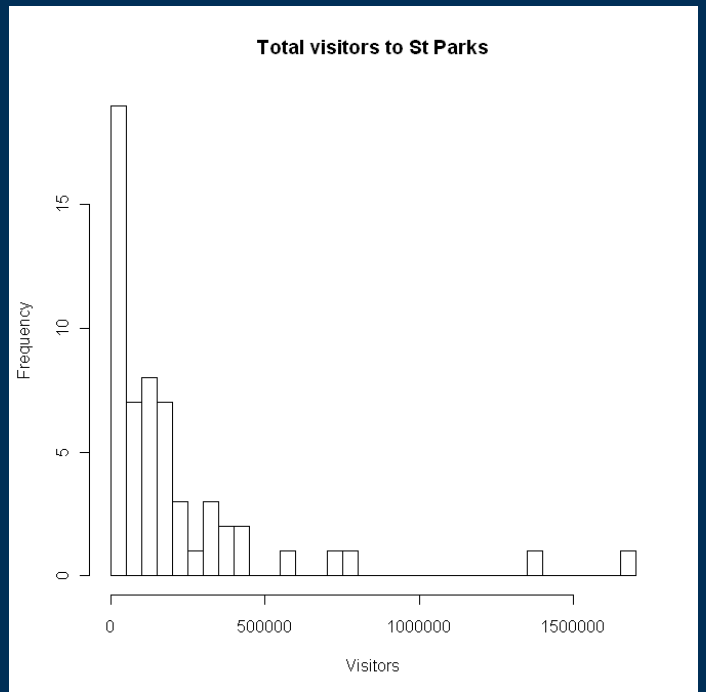
Recreation as an Ecosystem Service

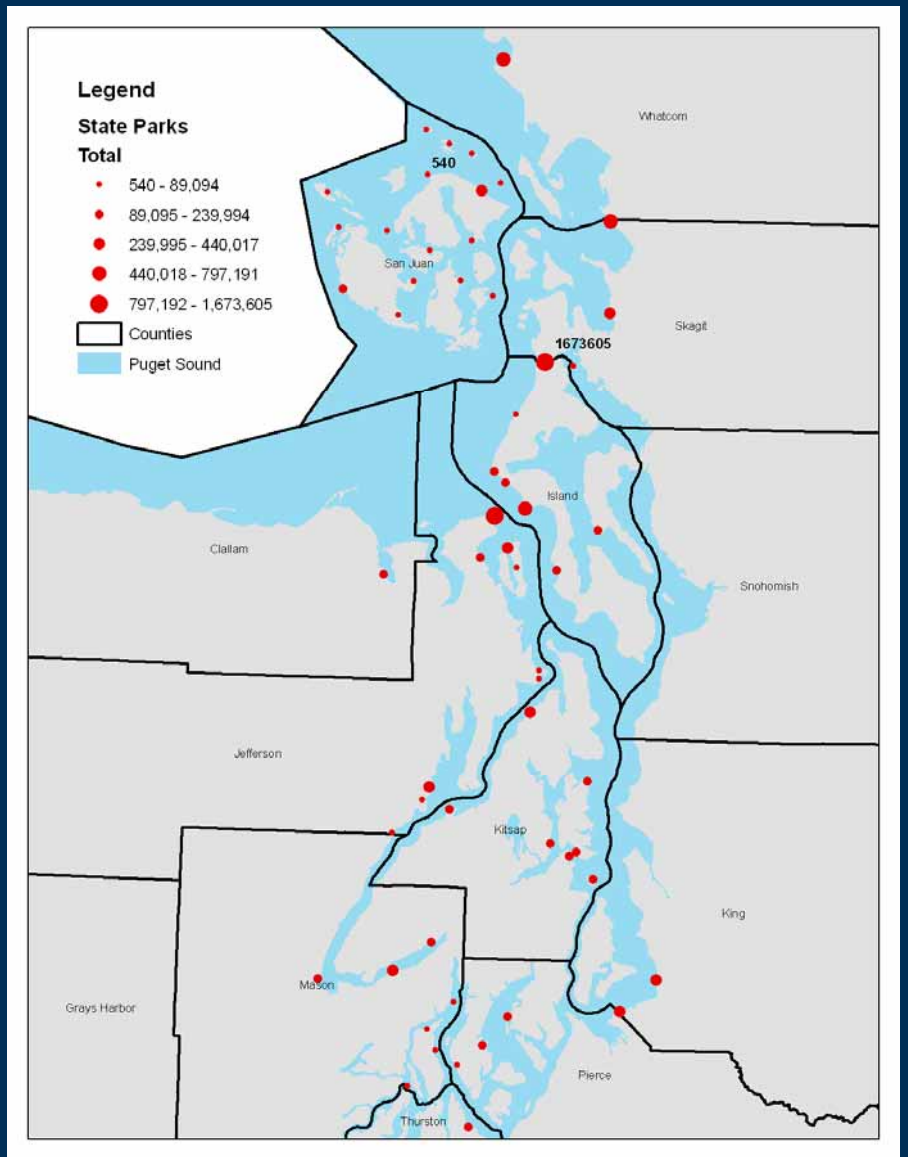
- Recreation one measure of human well-being, particularly in PS, and a direct link between people and the environment

- What affects visitation rate?
- How will it change over time and between scenarios?
- How important is the future land use pattern or future env condition?

Visitation to PS State Parks

- 540 / 200,000 / 1.6 million (Min / mean / max)
- 11.7 million in 2008 for coastal parks or ~ 3 per capita
- 2nd dataset containing zip codes of origins





Model and initial results

- What factors affect annual visitation?
- Annual visitation ~ condition, demand, and access
  - Condition: env quality, park characteristics and amenities
  - Demand: # of people nearby
  - Access: travel cost and legal access

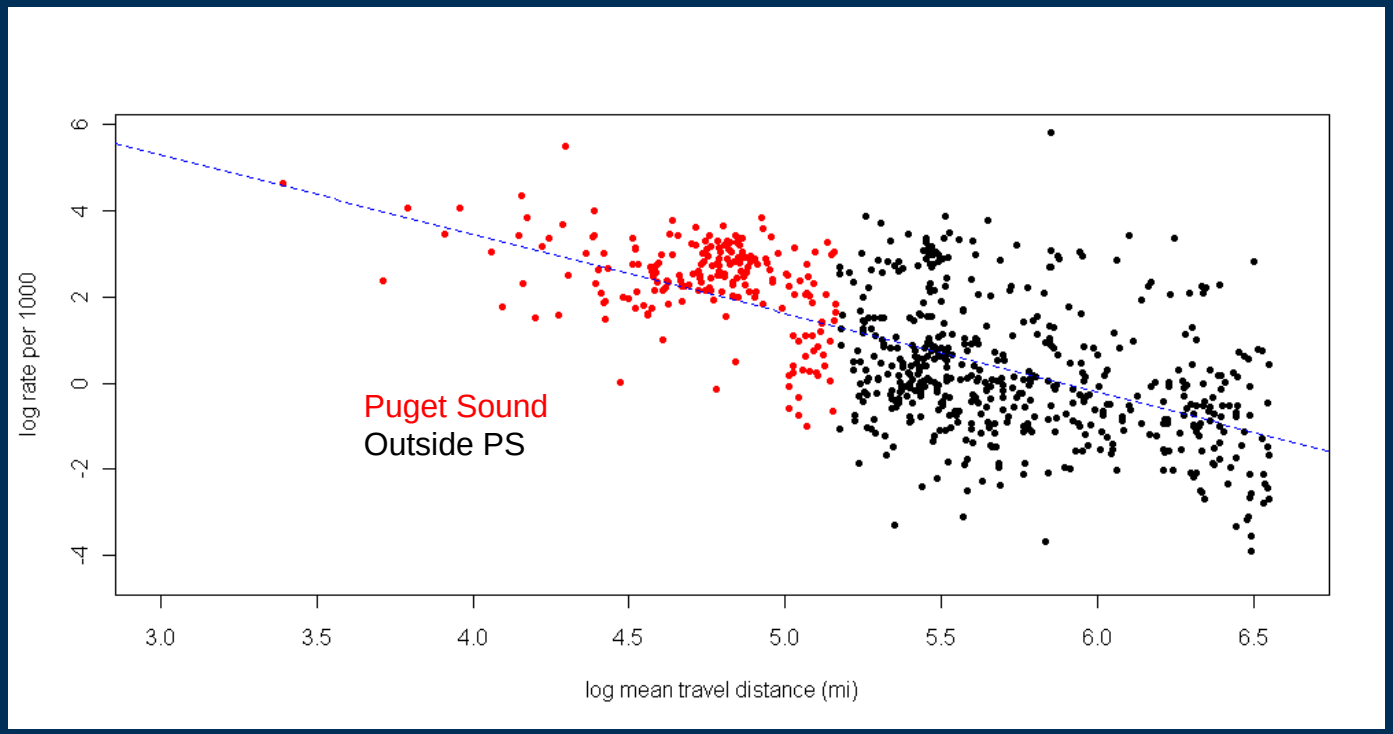
Table 1: Initial negative binomial model results for the mean annual visitation rate to State Parks with coastal access to Puget Sound, in relation to condition, demand and access characteristics.

Independent variables	coefficients	standard error	*p*-value
Intercept	9.43	0.90	<0.001
Water quality	-0.27	0.16	0.077
Camping (y/n)	1.05	0.26	<0.001
Heritage site (y/n)	1.10	0.39	0.006
ln shore length	0.29	0.105	0.005
Ferry	-1.53	0.34	<0.001
Island w/ no pub transport (y/n)	-1.87	0.495	<0.001
Population within 2 hrs	-0.02808	0.07031	0.689

n = 57, null deviance = 186.83, residual deviance = 66.03

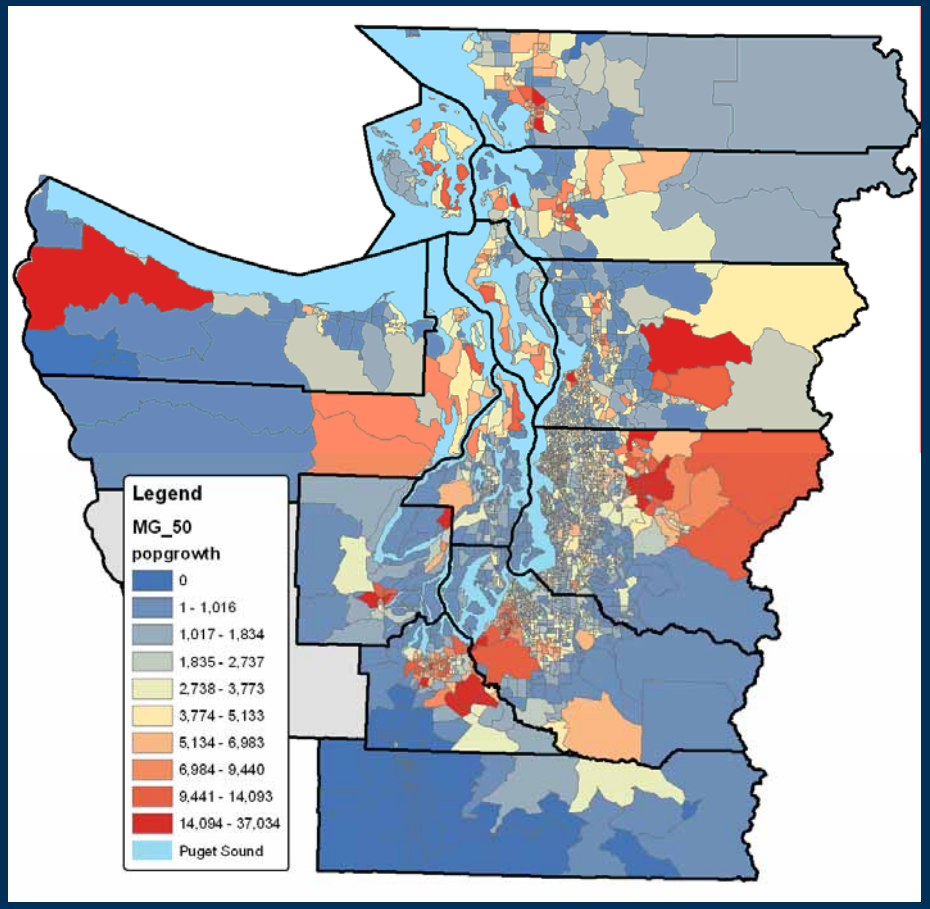
Initial demand function

- Visitation rate ~ travel distance
  - Where are people coming from?
  - 60% of visits from within PS basin
  - Could be used for travel cost ($) to determine consumer surplus



In the future?

- How will visitation likely change with 1 million more people, and how will it vary by scenario?
- How might water quality affect # of visits? (link to water quality model)



Visitation_{60} ~ f(access, condition[**yr60**], demand [**yr60 population]**)

Value of a change in condition

- What is the economic value of lost recreation? And what would be the value of improving water quality?
  - Benefits transfer approach:

  # sites * change in visits* value of a visit ($$$)
- Where to place new parks to maximize visits or to make accessibility equal?

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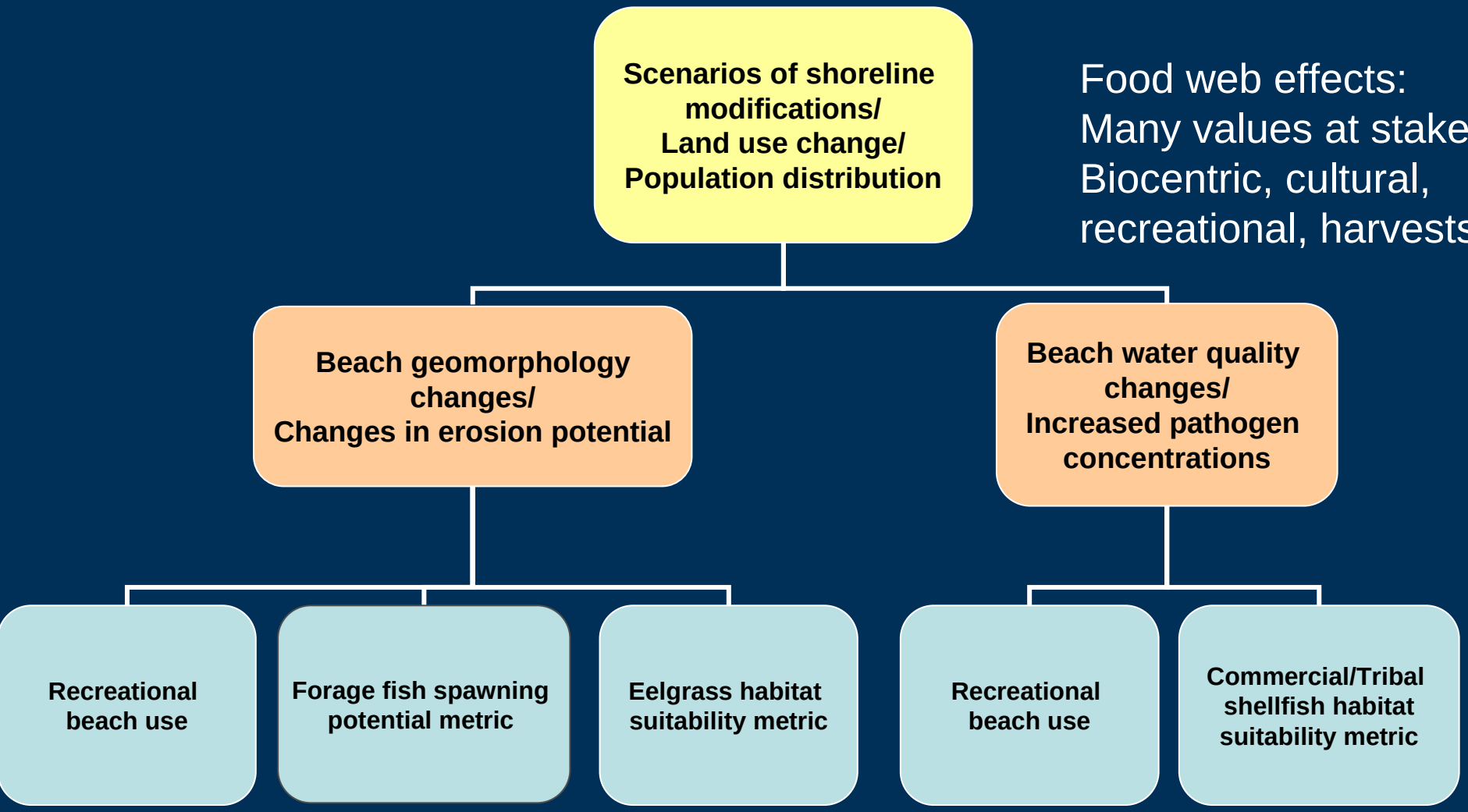
Taking it further: Scenarios to Services



Food web effects:
Many values at stake:
Biocentric, cultural, recreational, harvests

Harvests, $$$
Recreational benefits, $$$

Where we would like to go in the next two years …

- Improve scenarios
  - Sea level rise scenarios and impact scenarios
  - Land price changes and feedbacks
- Improve current EPM models
  - Model testing (case studies, workshops)
  - Better use of existing data (e.g., ECY oblique shoreline photos)
  - Longer-term – new data (e.g., lidar, stakeholder surveys)
- Additional EPM criteria/metrics
  - River delta metrics related to agriculture, salmon restoration
  - Relating nearshore habitats to intermediate variables and ultimately human activities

PSEPM Contributors

USGS Core Team:

- **Bill Labiosa (PI, project manager)**
- **Kristin Byrd (Beach erosion, pathogens)**
- **Jason Kreitler (Shoreline recreation)**
- **Mike Gould (Web design)**

Pathogens:

- Mindy Roberts, WDOE
- Skip Albertson, WDOE
- Tim Determan, WDOH
- Greg Coombs, WDOH
- Ashley Scott, WDOH
- Stuart Glasoe, WDOH
- Scott Kellogg, WDOH

Recreational visitation:

- Mike Papenfus, NatCap, Stanford
- Bill Krause, WA St Parks
- Camille Speck, DFG

Beach erosion:

- Guy Gelfenbaum, USGS
- Jim Johannessen, CGS, Inc.
- David Finlayson, USGS
- Hugh Shipman, WDOE
- Scott Campbell, USACE
- Tom Leschine, UW

ENVISION model:

- John Bolte, OSU
- Kellie Vache, OSU

Nutrient loading:

- Dan Wise, USGS
- Hank Johnson, Hydrologist
- Steve Sobieszcyk

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