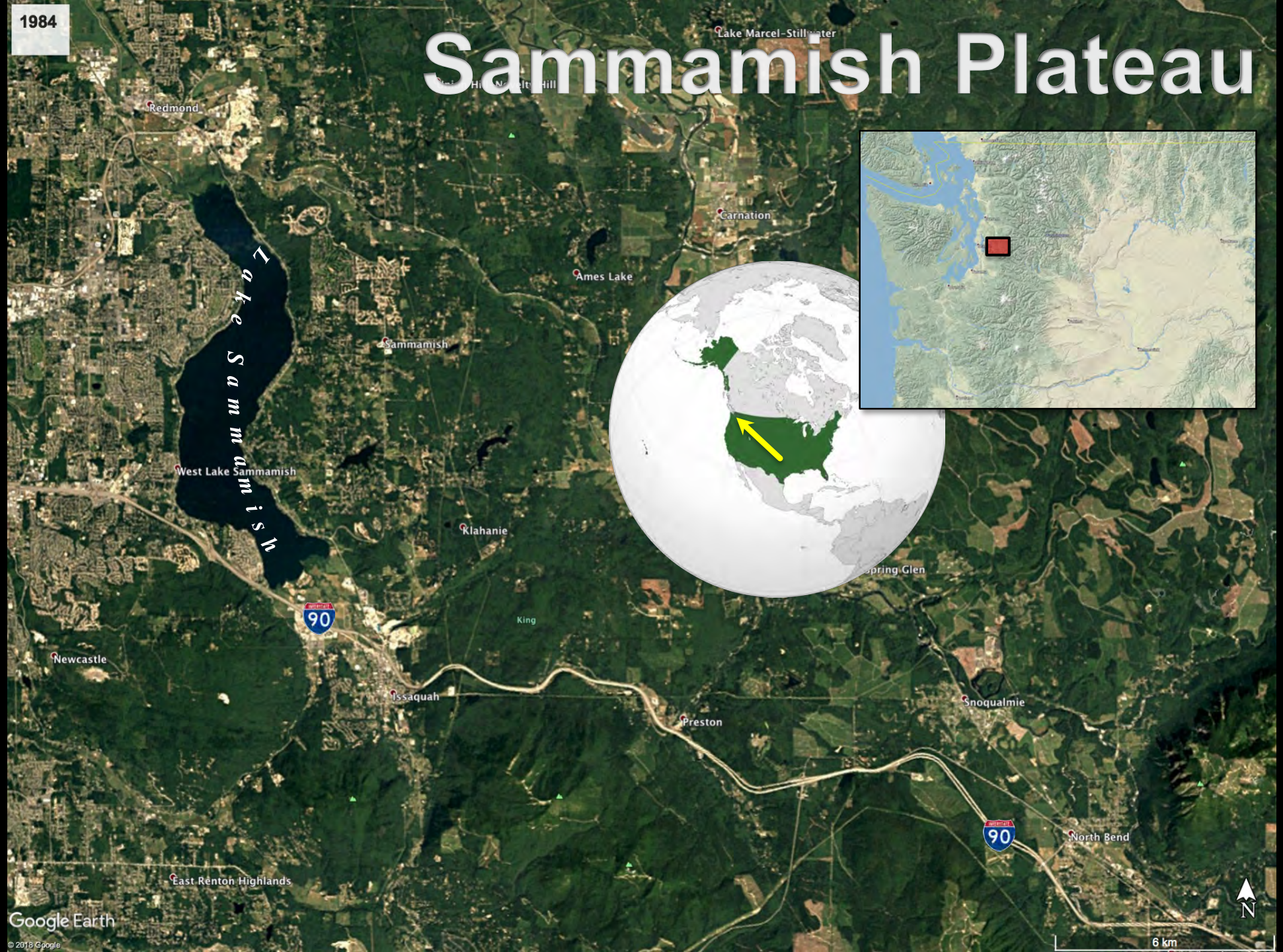
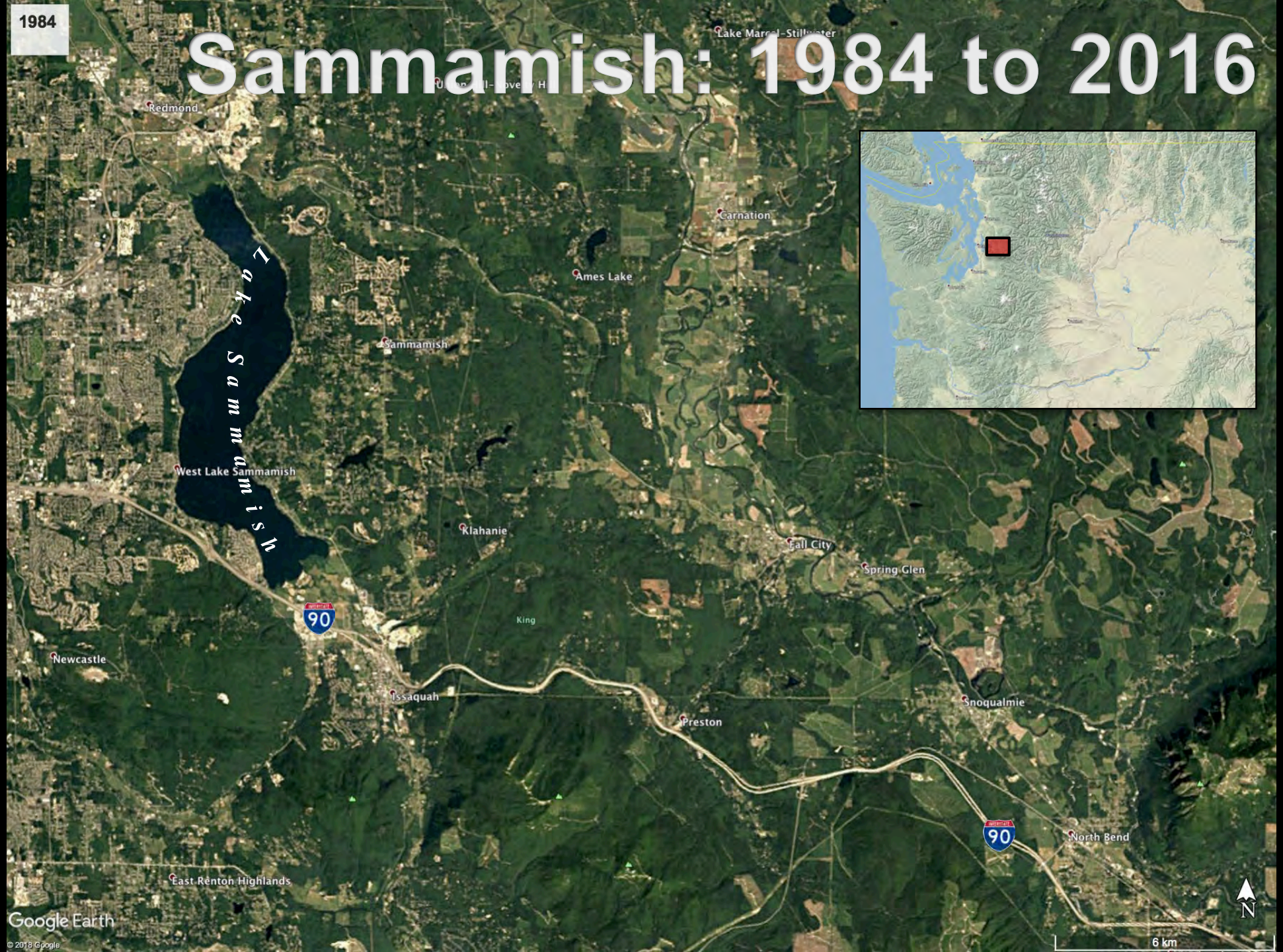
Dubai: United Arab Emirates

Dubai: 1984 to 2016

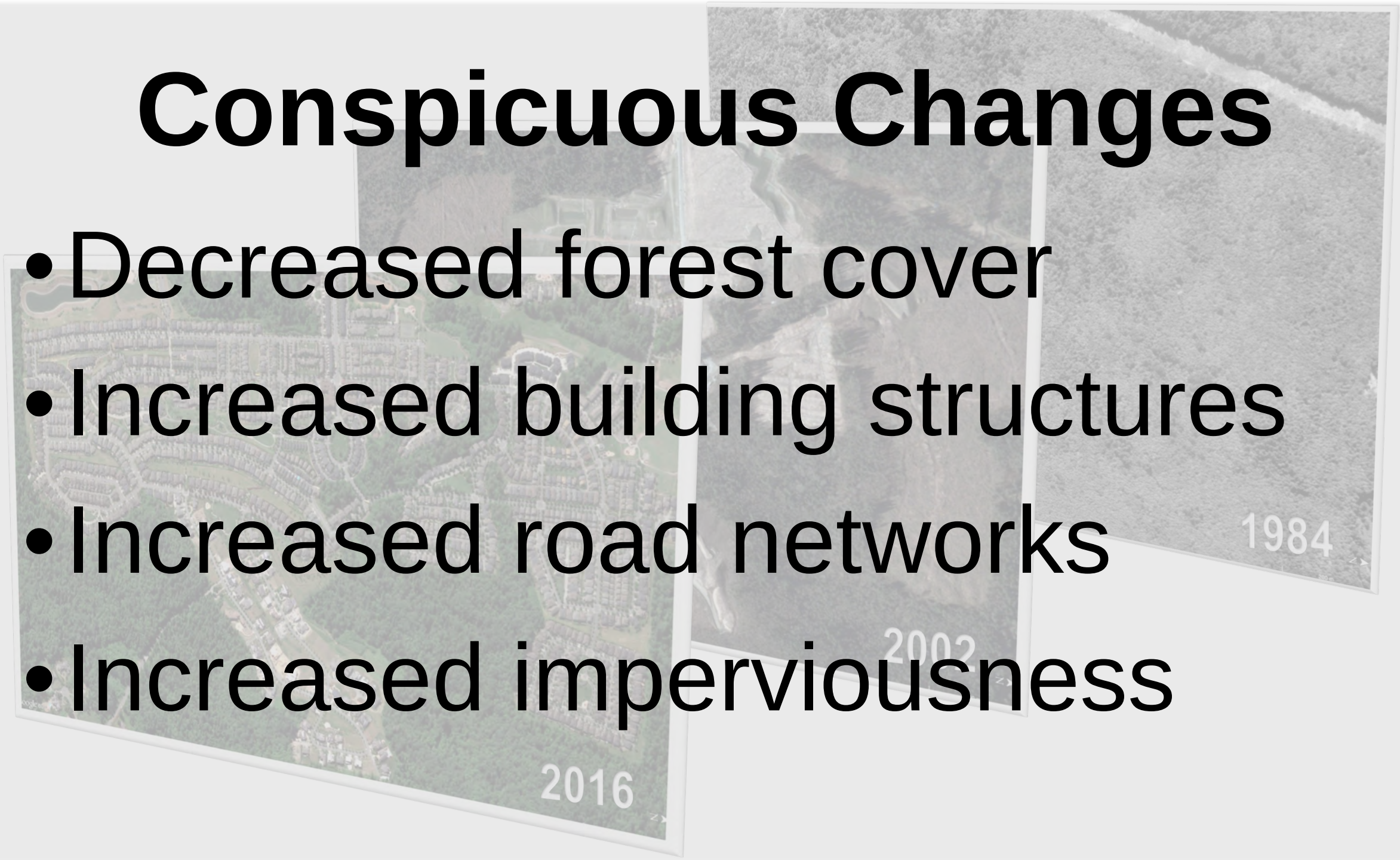

1984
Sammamish Plateau
Lake Marcel-Stillwater
Redmond
Carnation
Ames Lake
Sammamish
Lake Sammamish
West Lake Sammamish
Klahanie
Spring Glen
King
Newcastle
Issaquah
Preston
Snoqualmie
North Bend
East Renton Highlands
90
90
N
6 km
Google Earth
© 2018 Google

Sammamish: 1984 to 2016



Conspicuous Changes

- Decreased forest cover
- Increased building structures
- Increased road networks
- Increased imperviousness



“Inconspicuous” Changes

- Water chemistry
  - Temperature ↑
  - Oxygen ↓
  - pH ↓
- Water quality
  - Pathogens ↑
  - Contaminants ↑
  - Nutrients ↑
- Ecological Consequences
  - Homogenization
  - Dramatic shifts in community structure, composition and health

Dying Before You Spawn

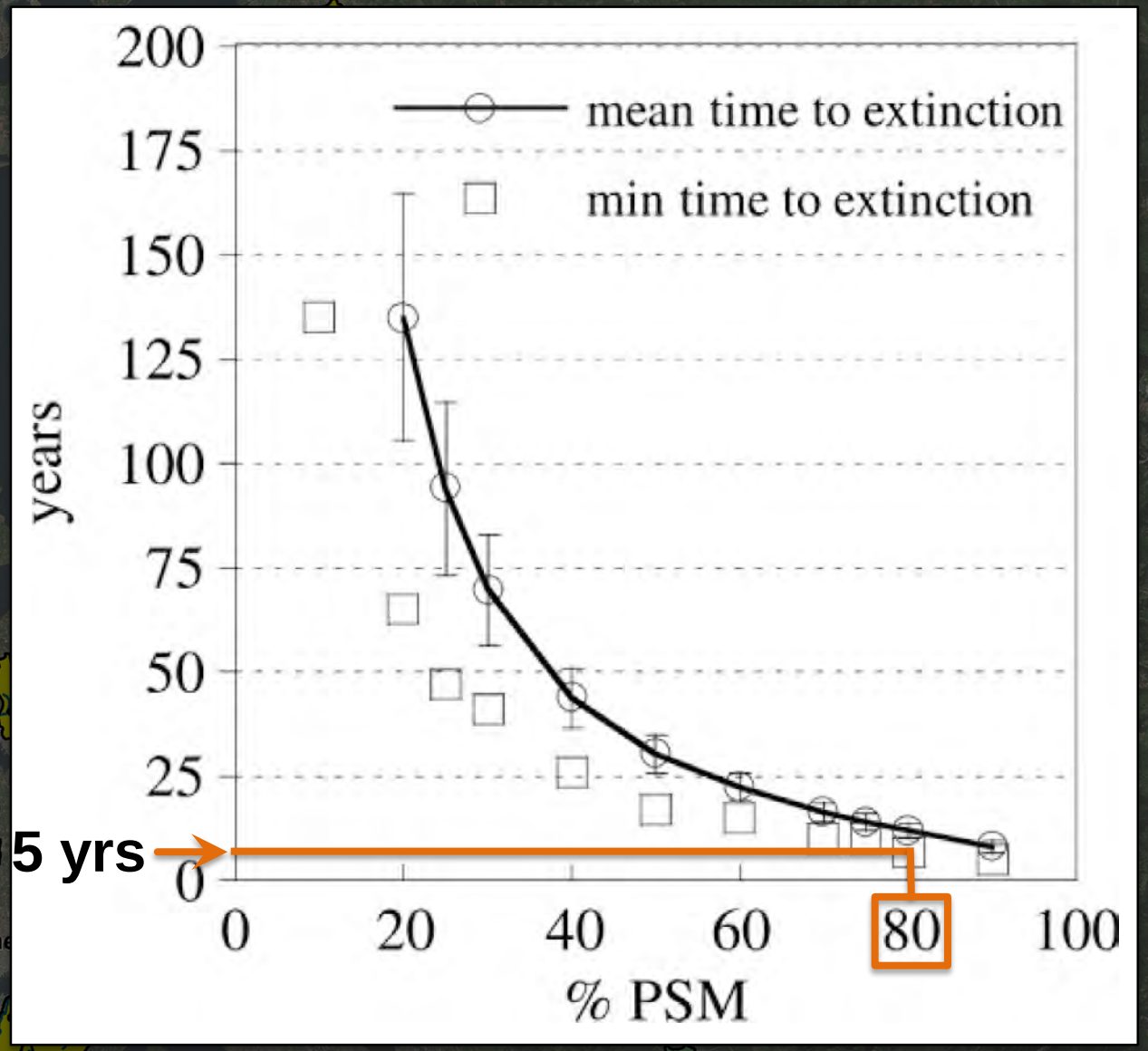
- In the late 1990s, stream restoration monitoring personnel documented apparently healthy coho dying within hours of arriving in spawning reaches
- Symptomatic fish showed signs of acute neurological distress

Dying Before You Spawn

When females were examined, they were full of healthy, ripe eggs that had not been released

Mean mortality

- < 10%
- 10 - 40%
- > 40%



Spromberg & Scholz 2011 Integr. Environ. Assess. Manag.

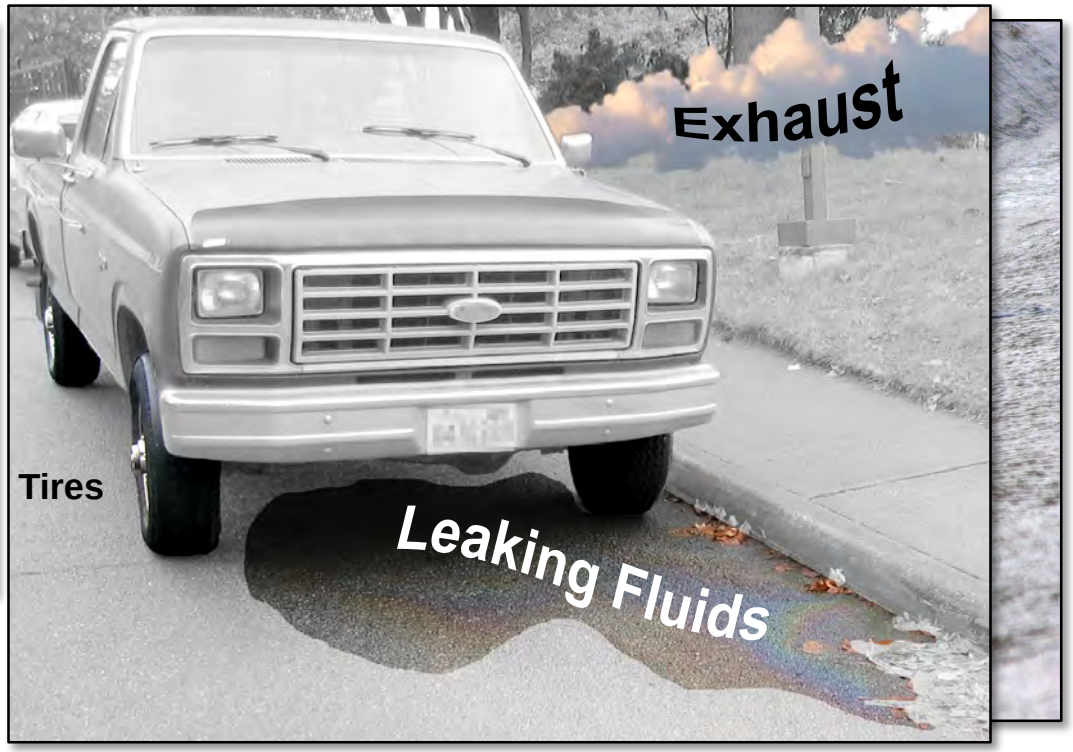
Widespread phenomenon and coho are likely impacted across even larger geographic area

Coho population level consequences including local extinctions

10 km

What is the cause?

- ~20 years of forensic evidence strongly suggests urban stormwater runoff as the culprit
- More likely than not that substances deposited by motor vehicles on roadways are lethal to coho



Scholz et al. 2011 PLoS ONE
Spromberg et al. 2016 J. Appl. Ecol.

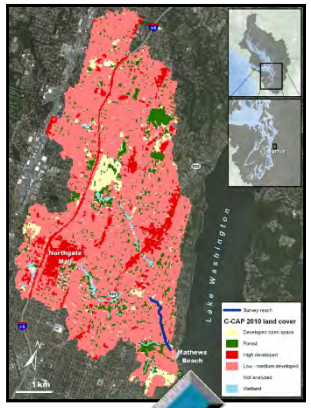
Current and Future Vulnerability Mapping for the Coho Urban Mortality Syndrome in Puget Sound

Blake Feist
Eric Buhle
David Baldwin
Julann Spromberg
Nat Scholz

Jay Davis

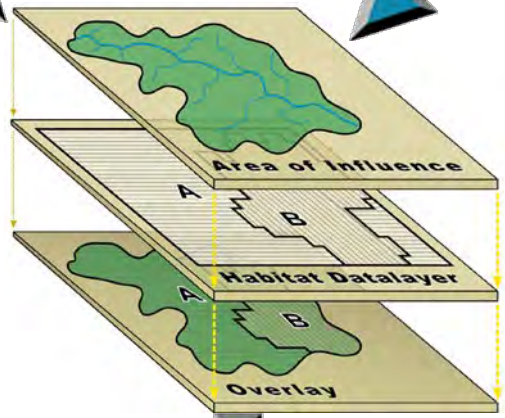
Nazca Lines, Southern Perú

Analysis Overview

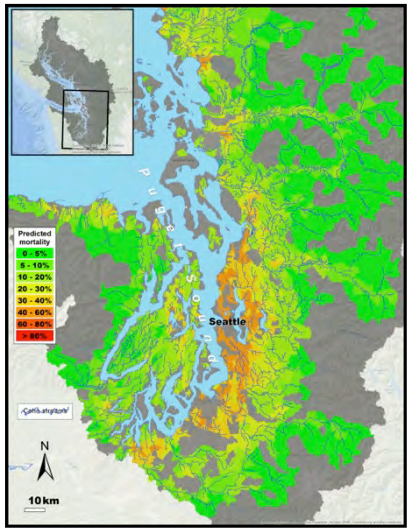


Landscape Data

Spatial Analyses



Statistical Analyses



- Correlated Variables
- Predictive Model of Spawner Mortality

Statistical Approach

$$P\left(\mathbf{A}_0,\mathbf{A},\mathbf{Z},\boldsymbol{\sigma},\boldsymbol{\Phi},\boldsymbol{\Gamma},\boldsymbol{\sigma}_\beta,\boldsymbol{\beta},\sigma_\delta,\mathbf{p}\,|\,\mathbf{X},\mathbf{y},\mathbf{n},\mathrm{ppt}_{su},\mathrm{ppt}_{fa}\right)\propto$$
$$P\left(\mathbf{A}_0,\mathbf{A},\boldsymbol{\sigma},\boldsymbol{\Phi},\boldsymbol{\Gamma},\boldsymbol{\sigma}_\beta,\sigma_\delta\right)$$
$$\times\mathrm{N}\left(\mathbf{Z}\,|\,\mathbf{0},\mathbf{I}\right)$$
$$\times\mathrm{N}\left(\mathbf{X}_N\,|\,\mathbf{Z},\mathbf{A}_0,\mathbf{A},\boldsymbol{\sigma}\right)$$
$$\times\mathrm{G}\left(\mathbf{X}_G\,|\,\mathbf{Z},\mathbf{A}_0,\mathbf{A},\boldsymbol{\Phi}\right)$$
$$\times\mathrm{N}\left(\boldsymbol{\beta}\,|\,\mathbf{Z},\boldsymbol{\Gamma},\boldsymbol{\sigma}_\beta\right)$$
$$\times\mathrm{N}\left(\mathrm{logit}\left(\mathbf{p}\right)\,|\,\boldsymbol{\beta},\mathrm{ppt}_{su},\mathrm{ppt}_{fa},\sigma_\delta\right)$$
$$\times\mathrm{Bin}\left(\mathbf{y}\,|\,\mathbf{n},\mathbf{p}\right)$$

In the interest of time…

…I'll spare you the gory details of the excruciatingly complex statistical methods

$$g\left(\boldsymbol{\mu}\right)=\mathbf{A}_0+\mathbf{Z}\mathbf{A}^{\mathsf{T}}$$
$$\mathbf{Z}_{s,1:L}\sim\mathrm{MVN}\left(\mathbf{0},\mathbf{I}\right)$$
$$\mathbf{X}\sim f\left(\boldsymbol{\mu},\boldsymbol{\Phi}\right)$$

$$\beta_0^{(s)}=\gamma_{00}+\sum_{l=1}^{L}\gamma_{0l}z_{sl}+v_{0s}$$
$$\beta_1^{(s)}=\gamma_{10}+\sum_{l=1}^{L}\gamma_{1l}z_{sl}+v_{1s}$$
$$\beta_2^{(s)}=\gamma_{20}+\sum_{l=1}^{L}\gamma_{2l}z_{sl}+v_{2s},$$

$$x_{sj}=a_{0j}+\sum_{l=1}^{L}a_{jl}z_{sl}+\varepsilon_{sj}$$
$$z_{sl}\sim\mathrm{N}\left(0,1\right)$$
$$\varepsilon_{sj}\sim\mathrm{N}\left(0,\sigma_j\right),$$

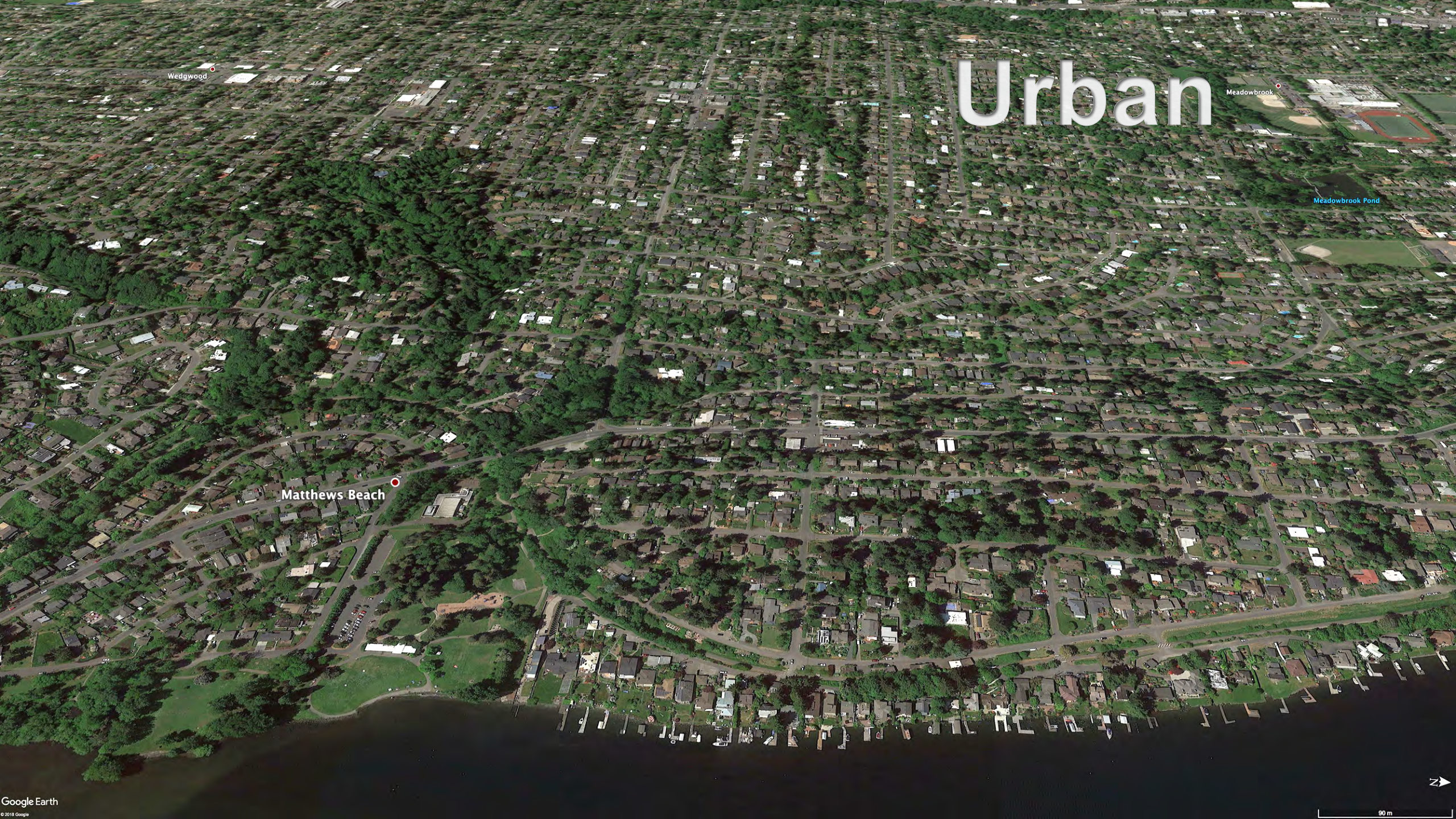
$$\mathbf{X}=\mathbf{A}_0+\mathbf{Z}\mathbf{A}^{\mathsf{T}}+\boldsymbol{\varepsilon}$$
$$\mathbf{Z}_{s,1:L}\sim\mathrm{MVN}\left(\mathbf{0},\mathbf{I}\right)$$
$$\boldsymbol{\varepsilon}_{s,1:D}\sim\mathrm{MVN}\left(\mathbf{0},\boldsymbol{\Sigma}\right)$$

$$g\left(\mu_{sj}\right)=a_{0j}+\sum_{l=1}^{L}a_{jl}z_{sl}$$
$$z_{sl}\sim\mathrm{N}\left(0,1\right)$$
$$x_{sj}\sim f_j\left(g^{-1}\left(\mu_{sj}\right),\phi_j\right),$$

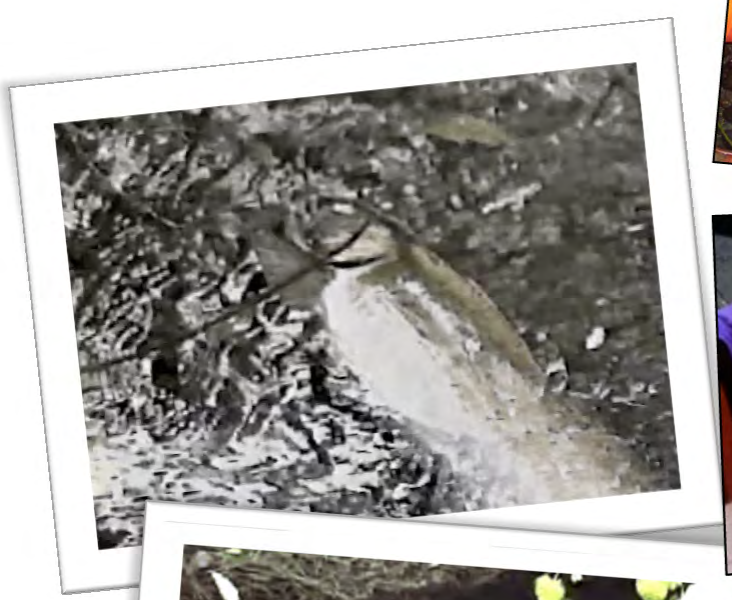
$$y_{i[s]}\sim\mathrm{Bin}\left(n_{i[s]},p_{i[s]}\right)$$
$$\mathrm{logit}\left(p_{i[s]}\right)=\beta_0^{(s)}+\beta_1^{(s)}\mathrm{ppt}_{su,i[s]}+\beta_2^{(s)}\mathrm{ppt}_{fa,i[s]}+\delta_{i[s]},$$

Forested
Google Earth
© 2018 Google
50 m

Urban


Wedgwood
Meadowbrook
Meadowbrook Pond
Matthews Beach
Google Earth
© 2018 Google
90 m

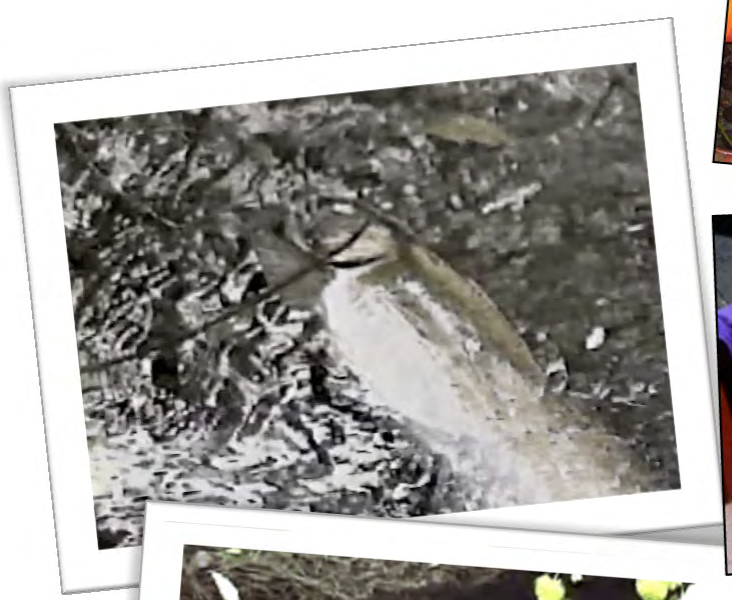
Coho Mortality



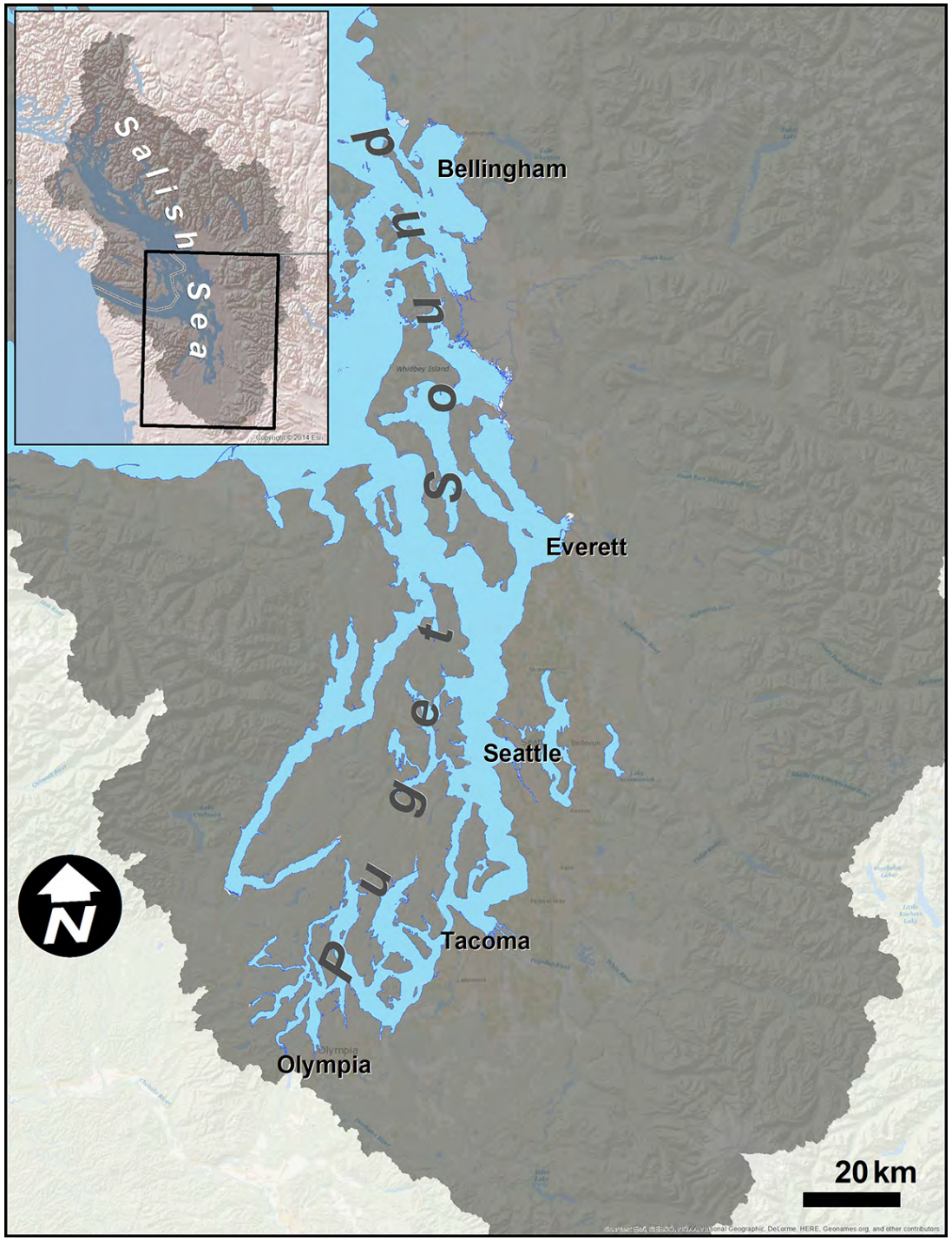
Local Roads

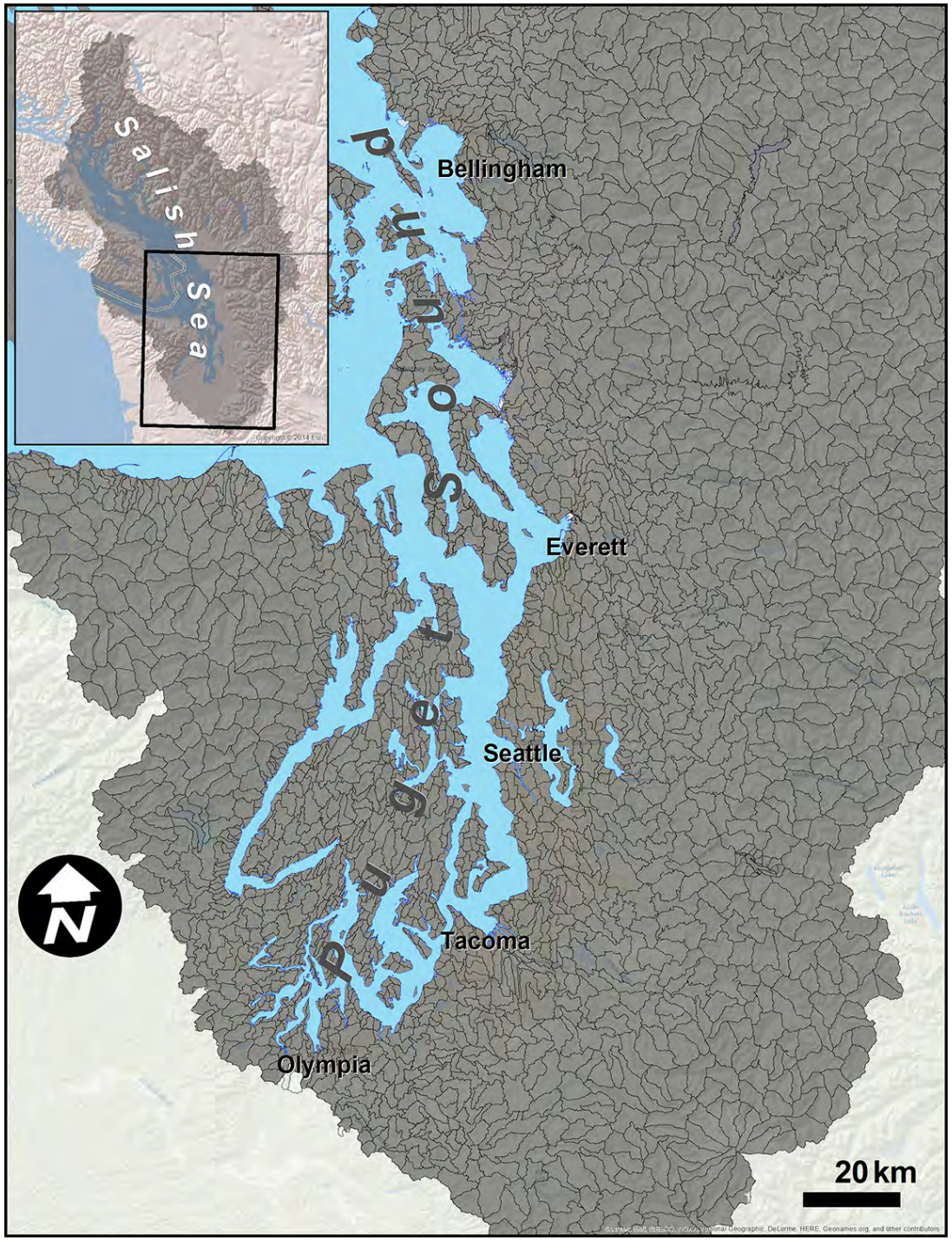
Heavily Used Roads

Coho Mortality



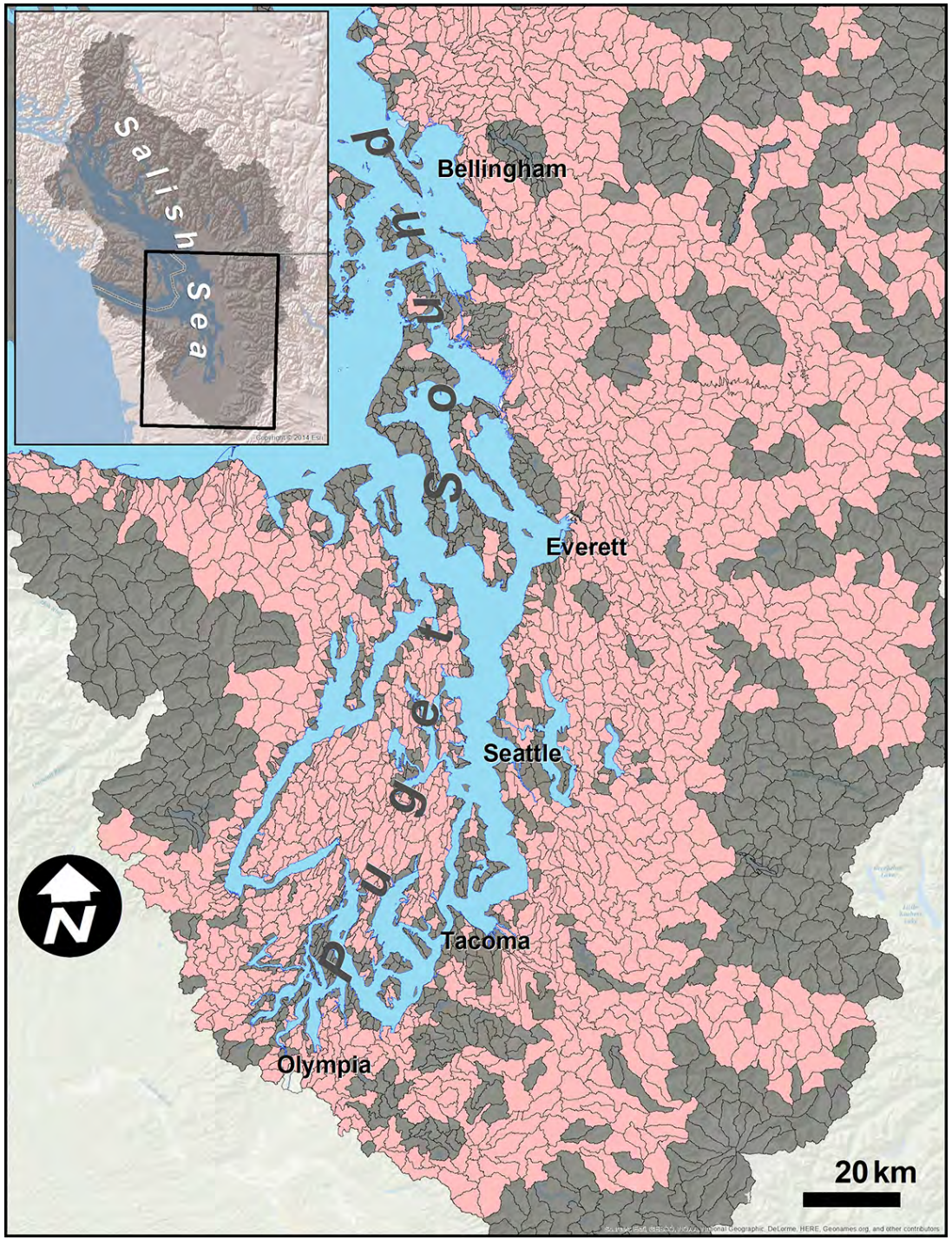
Coho Mortality Predictions





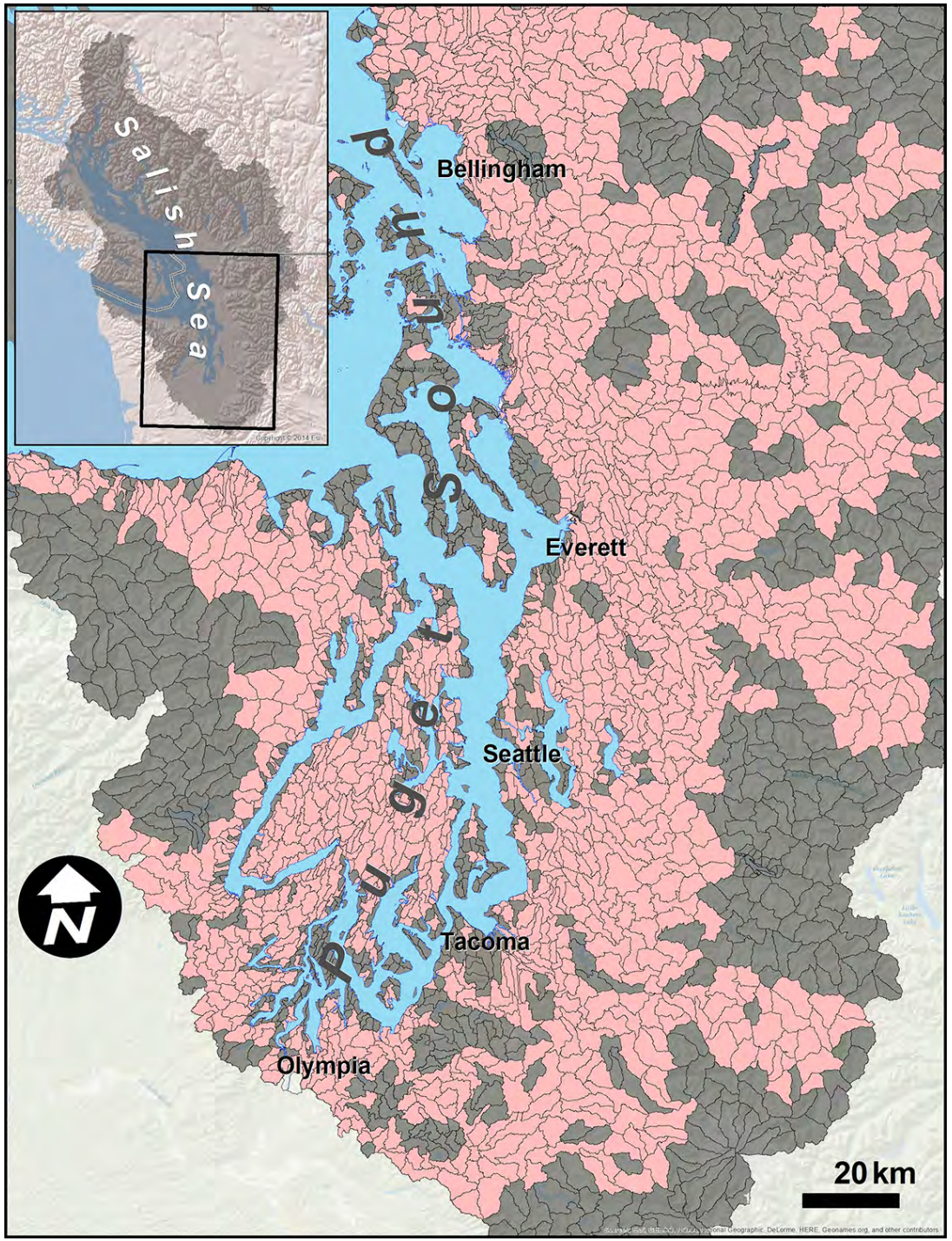
Coho Mortality Predictions

- WADOE Puget Sound Watershed Characterization Project basins



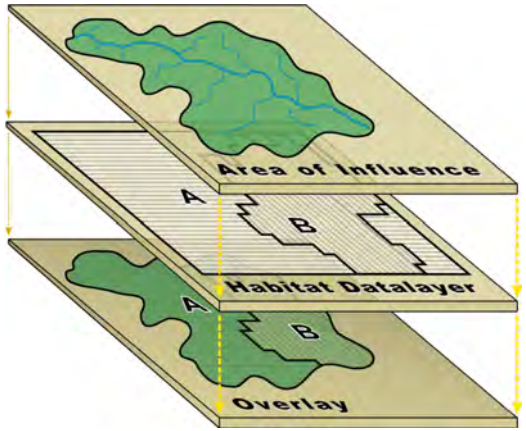
Coho Mortality Predictions

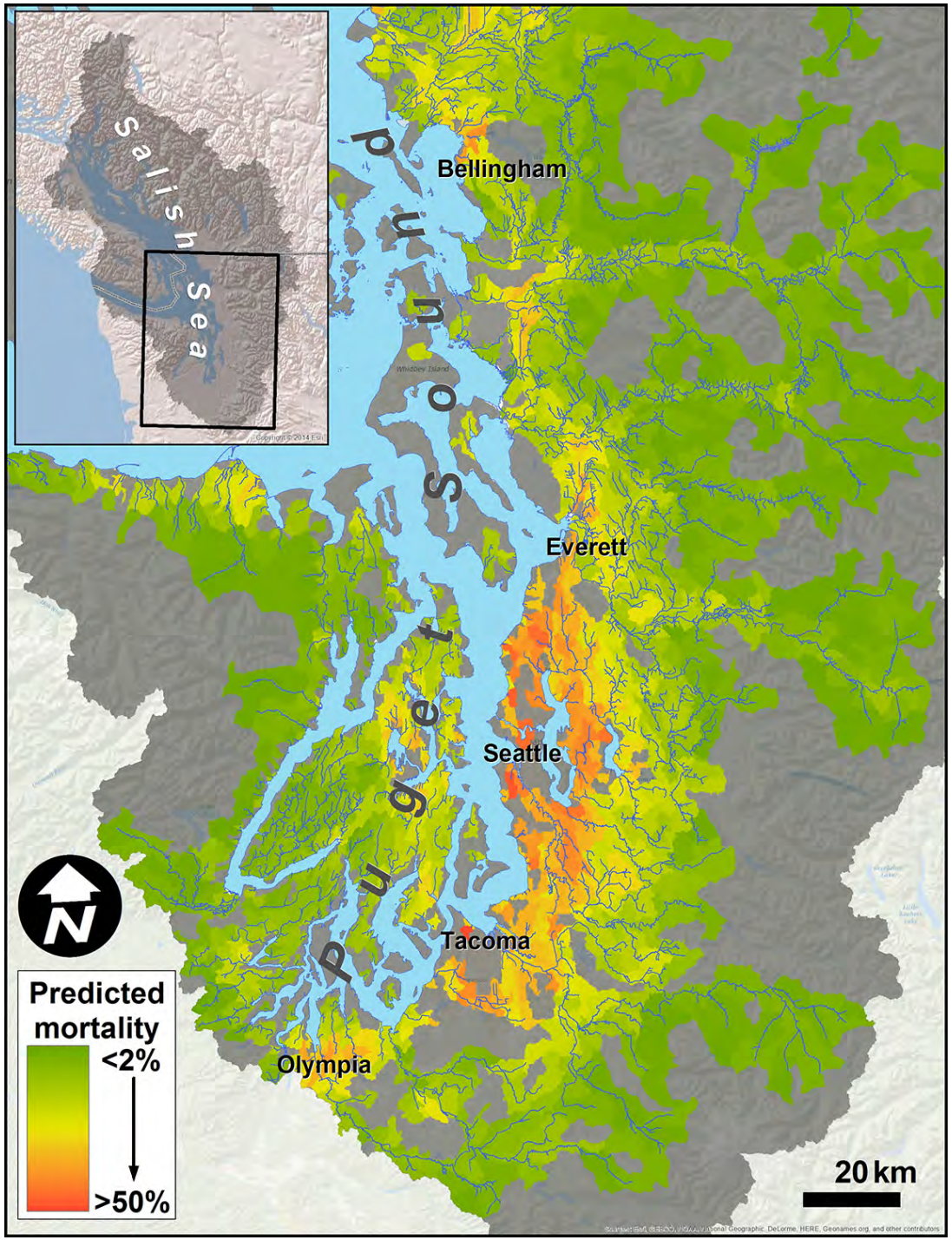
- WADOE Puget Sound Watershed Characterization Project basins
- Limit to coho basins



Coho Mortality Predictions

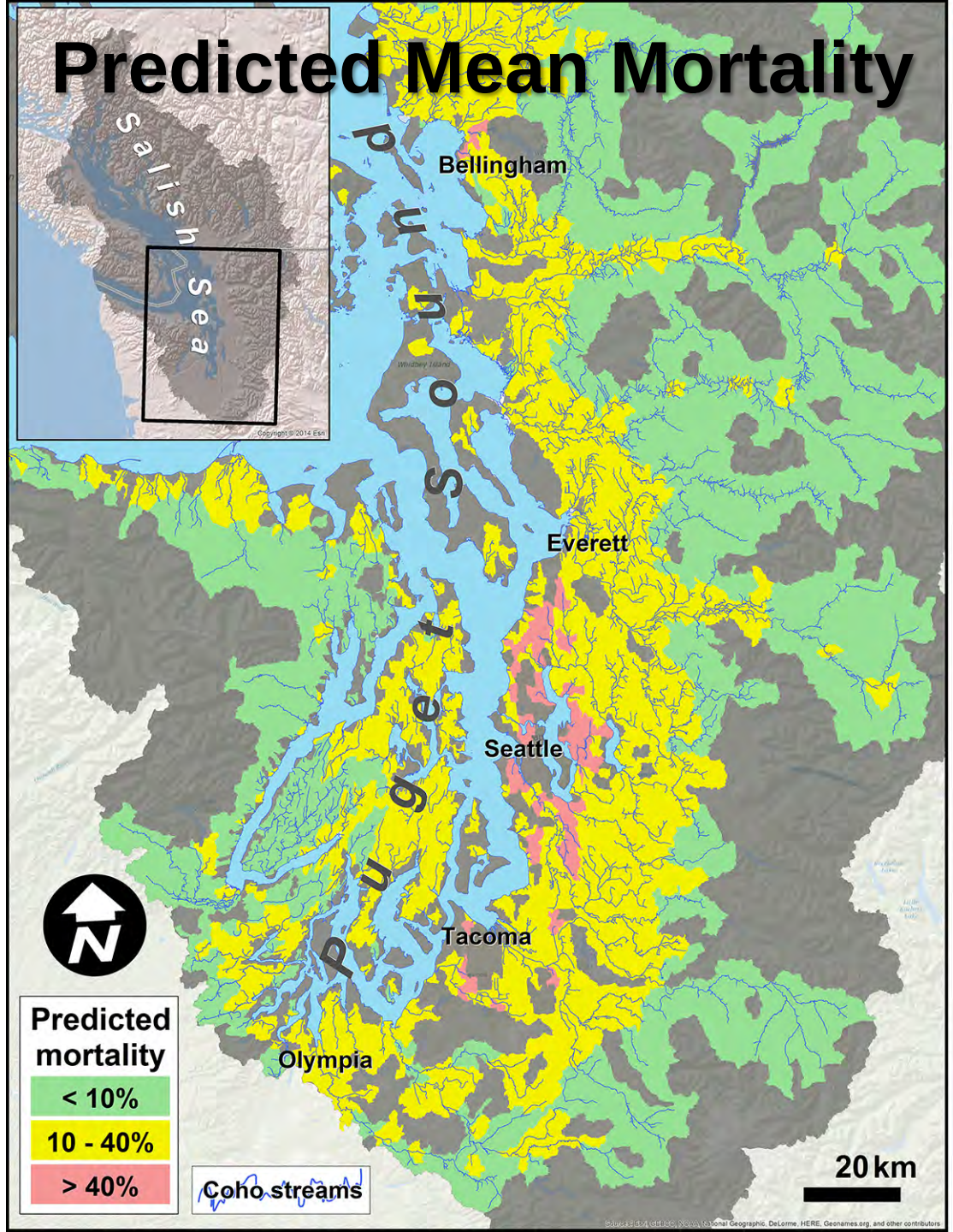
- WADOE Puget Sound Watershed Characterization Project basins
- Limit to coho basins
- Spatial analysis

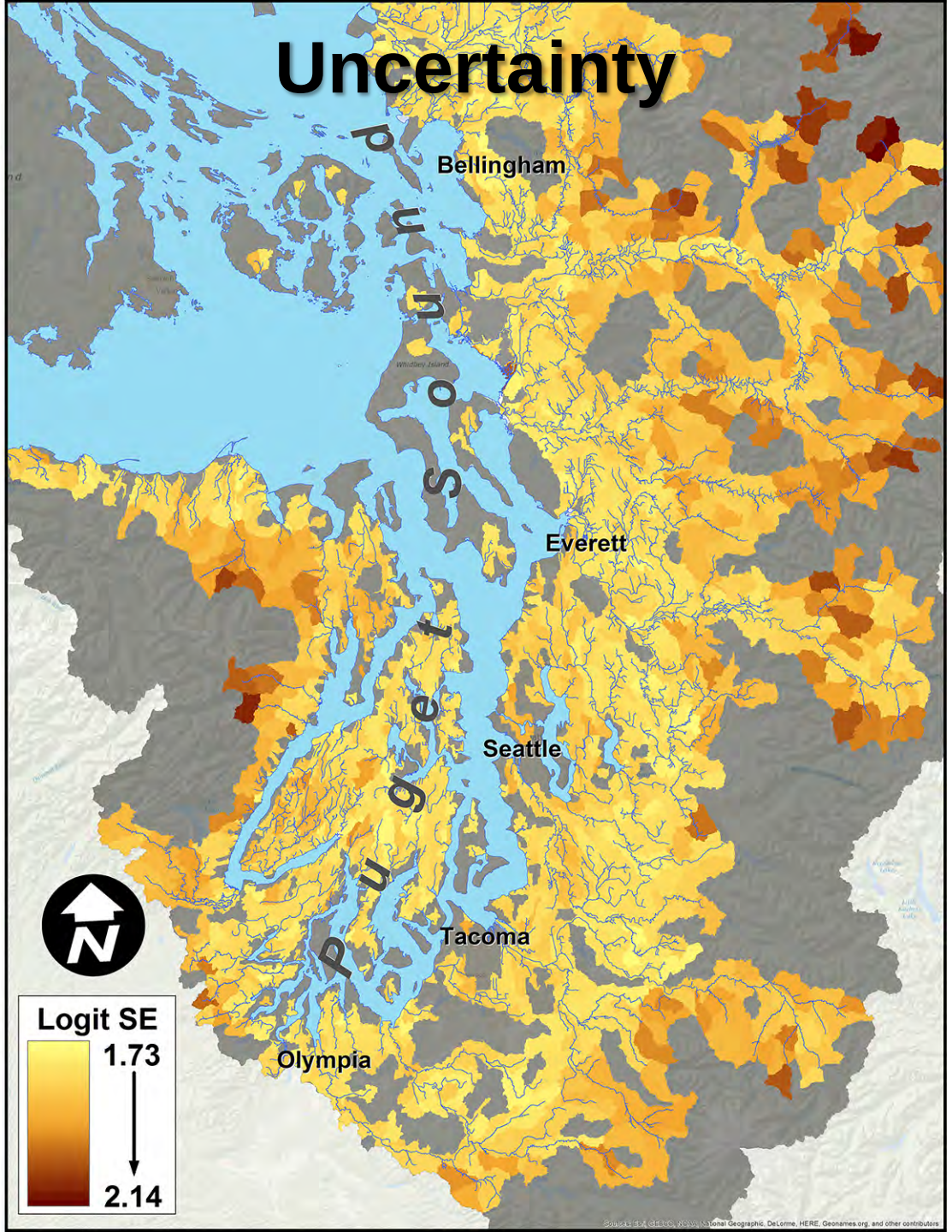




Coho Mortality Predictions

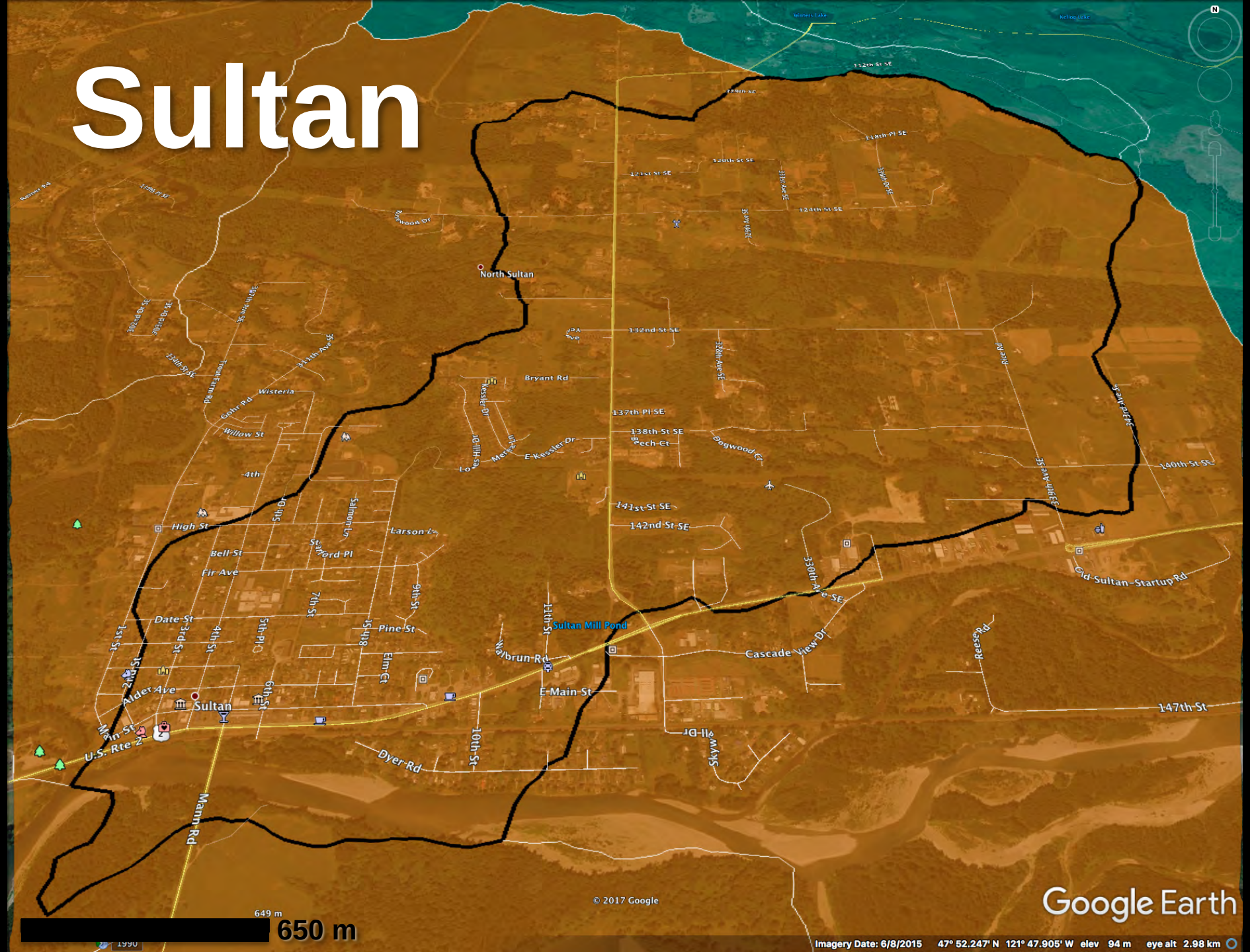
- WADOE Puget Sound Watershed Characterization Project basins
- Limit to coho basins
- Spatial analysis
- Predict the probability of coho mortality in unsampled basins and the associated uncertainty in those predictions


Predicted Mean Mortality
Salish Sea
Puget Sound
Bellingham
Everett
Seattle
Tacoma
Olympia
N
Predicted mortality
< 10%
10 - 40%
> 40%
Coho streams
20 km


Uncertainty
Puget Sound
Bellingham
Everett
Seattle
Tacoma
Olympia
N
Logit SE
1.73
2.14

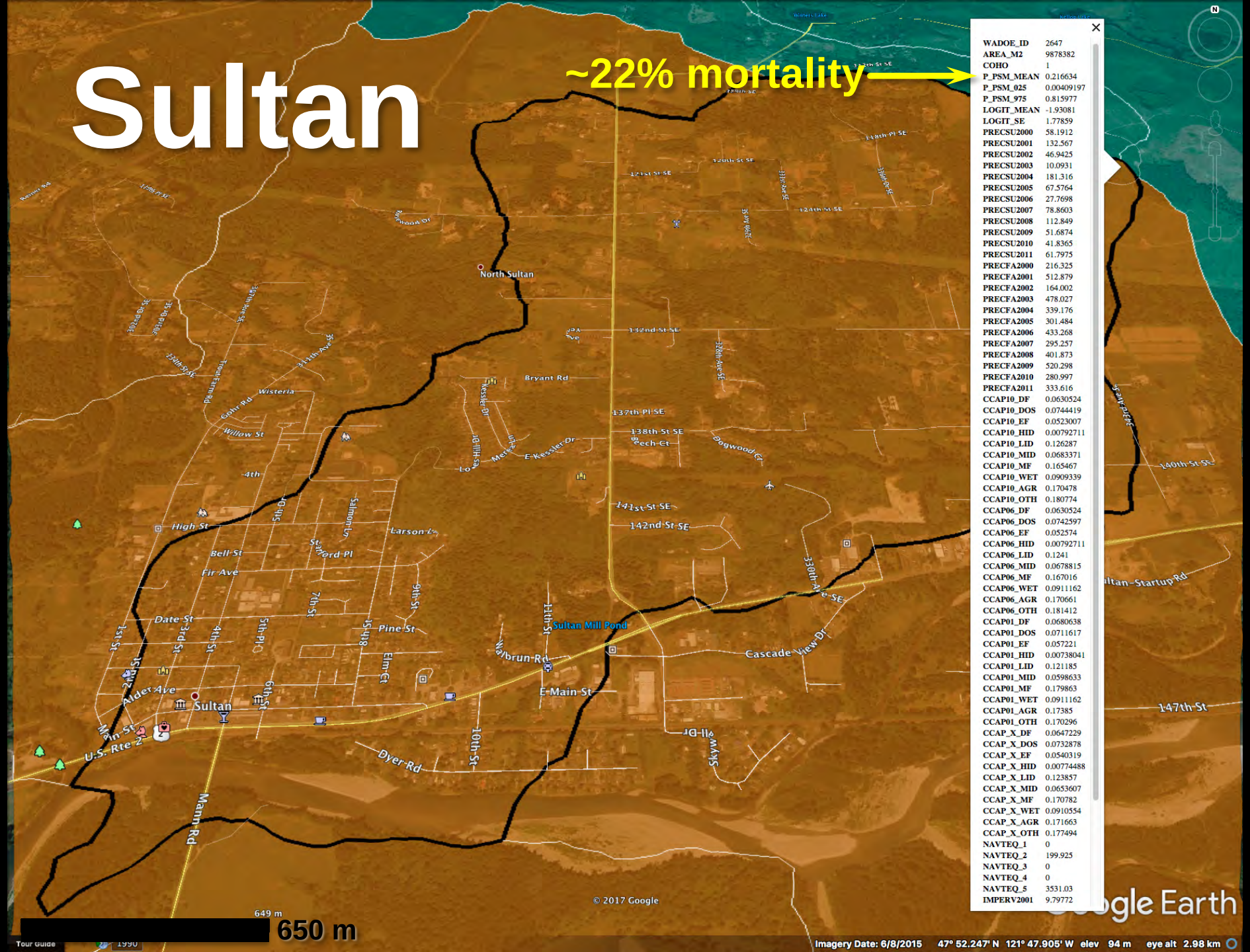
What’s it good for?

Sultan


North Sultan
Bryant Rd
137th Pl SE
138th St SE
Beech Ct
Dogwood Ct
E Kessler Dr
141st St SE
142nd St SE
330th Ave SE
Old Sultan-Startup Rd
Cascade View Dr
Reese Rd
147th St
Sultan Mill Pond
Walbrun Rd
E Main St
Skyline Dr
Dyer Rd
Mann Rd
Sultan
Main St
U.S. Rte 2
Aldet Ave
High St
Bell St
Fir Ave
Date St
Pine St
Elm Ct
Larson Ln
Salmon Ln
Stanford Pl
Wisteria
Willow St
Gohr Rd
Tower Farm Rd
Rivwood Dr
Metcalf
Lo
Hill Dr
Kessler Dr
1st St
2nd St
3rd St
4th St
5th St
6th St
7th St
8th St
9th St
10th St
11th St
Pl
4th
© 2017 Google
Google Earth
649 m
650 m
Imagery Date: 6/8/2015 47° 52.247' N 121° 47.905' W elev 94 m eye alt 2.98 km

Sultan

~22% mortality



WADOE_ID	2647
AREA_M2	9878382
COHO	1
P_PSM_MEAN	0.216634
P_PSM_025	0.00409197
P_PSM_975	0.815977
LOGIT_MEAN	-1.93081
LOGIT_SE	1.77859
PRECSU2000	58.1912
PRECSU2001	132.567
PRECSU2002	46.9425
PRECSU2003	10.0931
PRECSU2004	181.316
PRECSU2005	67.5764
PRECSU2006	27.7698
PRECSU2007	78.8603
PRECSU2008	112.849
PRECSU2009	51.6874
PRECSU2010	41.8365
PRECSU2011	61.7975
PRECFA2000	216.325
PRECFA2001	512.879
PRECFA2002	164.002
PRECFA2003	478.027
PRECFA2004	339.176
PRECFA2005	301.484
PRECFA2006	433.268
PRECFA2007	295.257
PRECFA2008	401.873
PRECFA2009	520.298
PRECFA2010	280.997
PRECFA2011	333.616
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CCAP10_DOS	0.0744419
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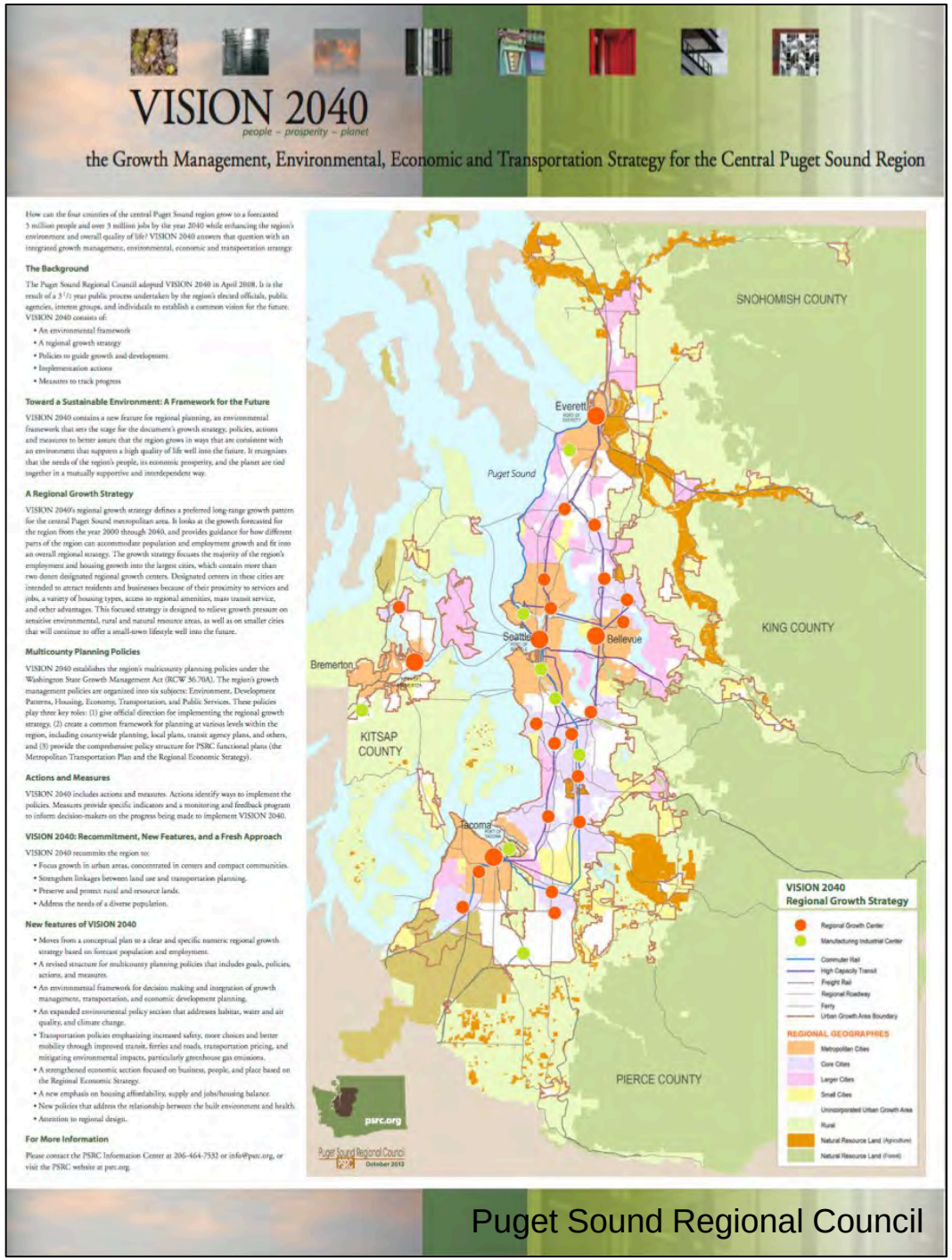
CCAP_X_AGR	0.171663
CCAP_X_OTH	0.177494
NAVTEQ_1	0
NAVTEQ_2	199.925
NAVTEQ_3	0
NAVTEQ_4	0
NAVTEQ_5	3531.03
IMPERV2001	9.79772



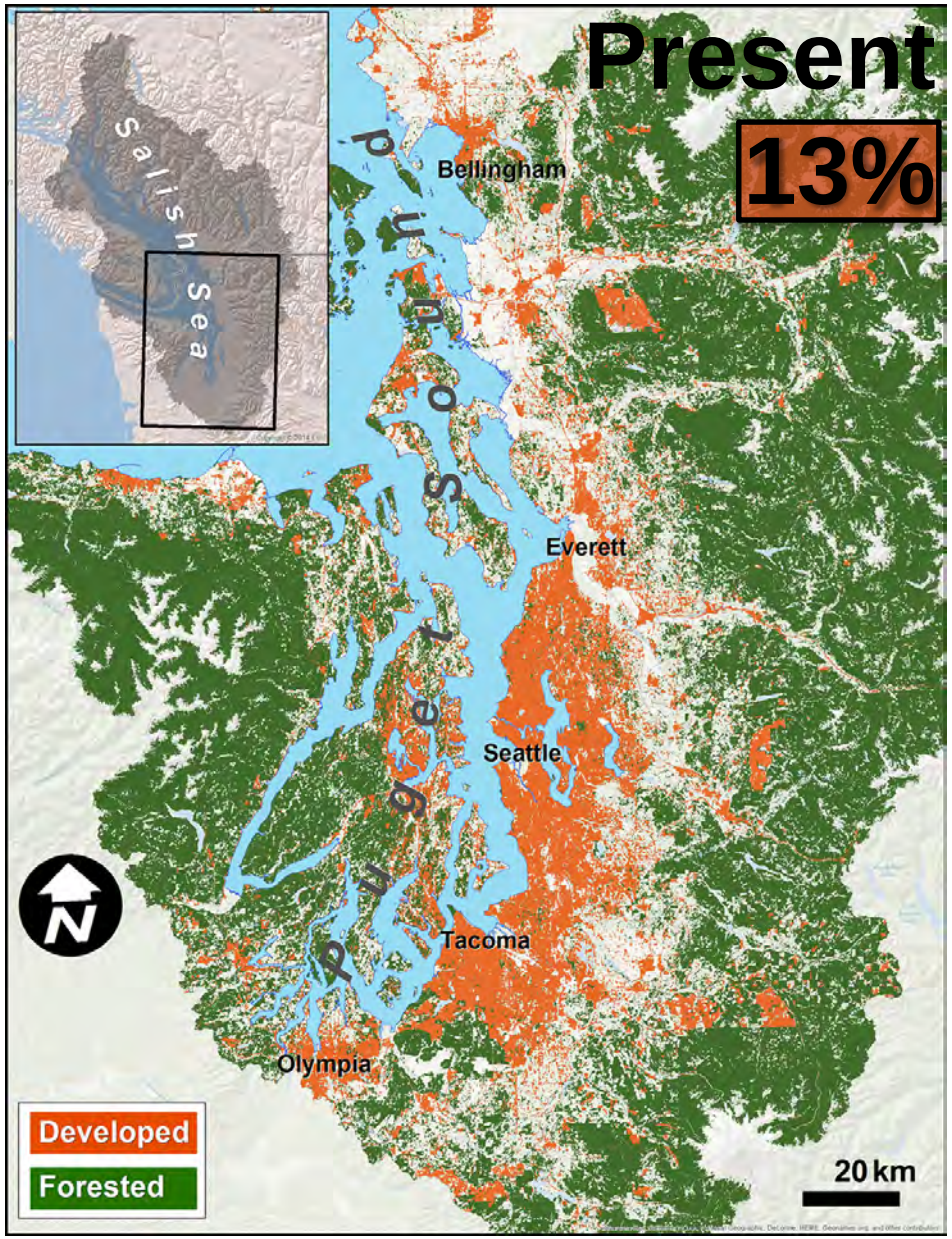
Puget Sound Regional Council

Population Growth and Future Threats

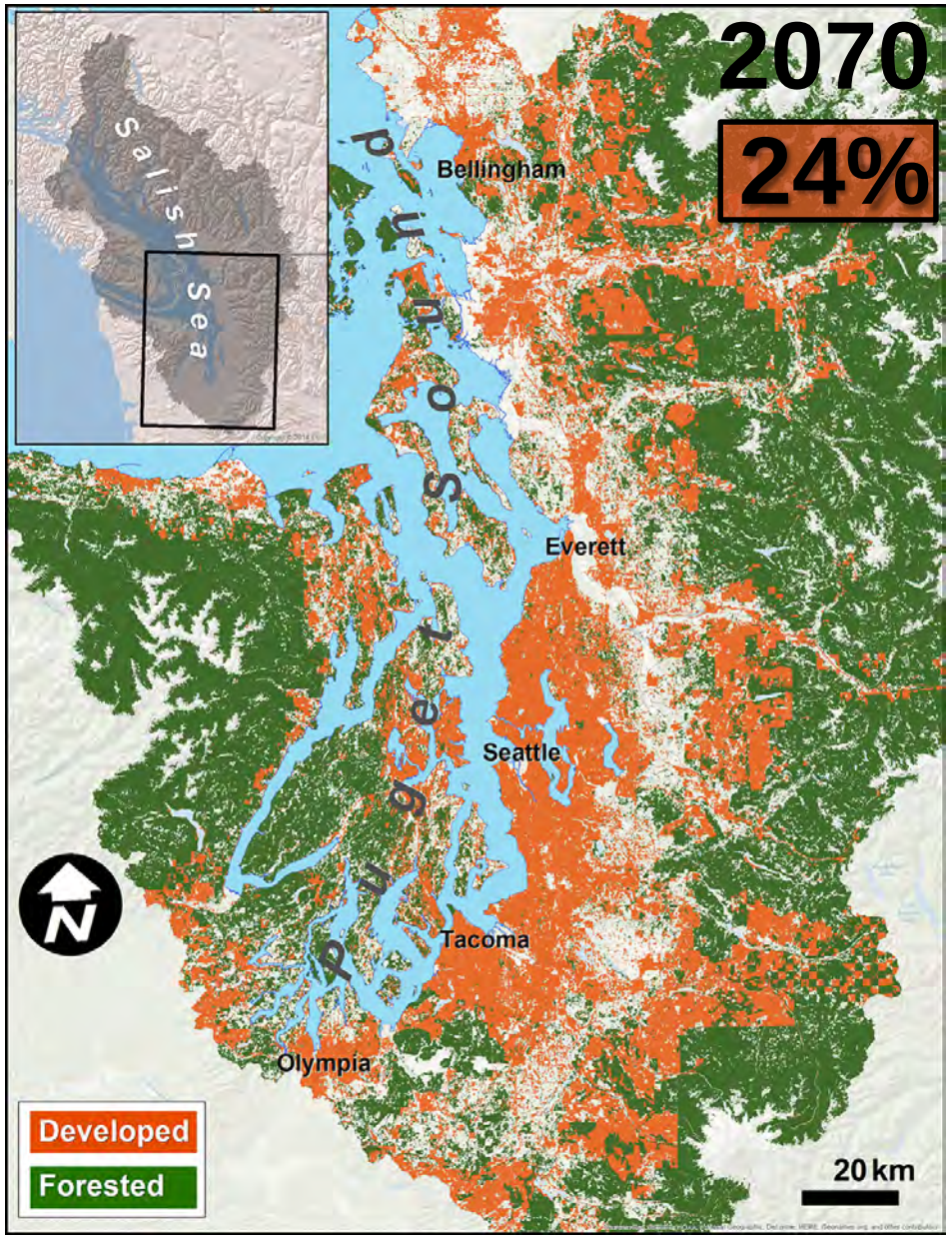
- Where will coho populations be most vulnerable in the future?
- Where is the tipping point for regional coho population extinction?

Future Development in Puget Sound

NOAA 2013 Coastal Change Analysis Program



Bolte & Vache 2010 Envisioning Puget Sound Alternative Futures

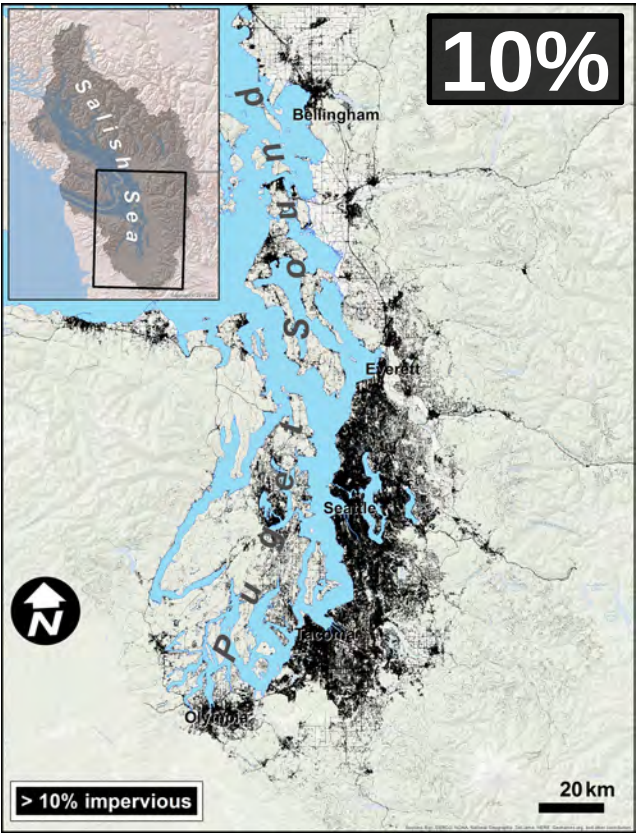


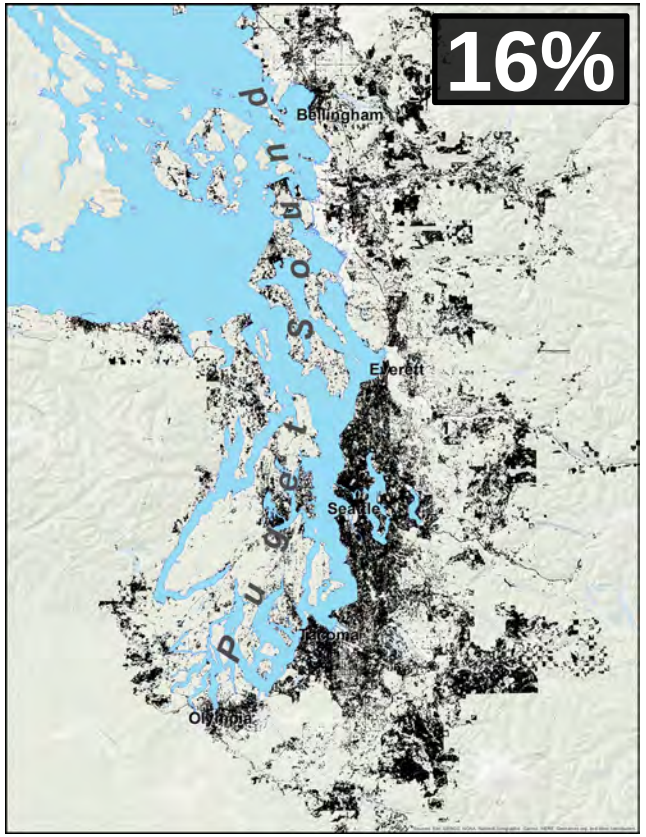
First Order Approximation of Future Mortality

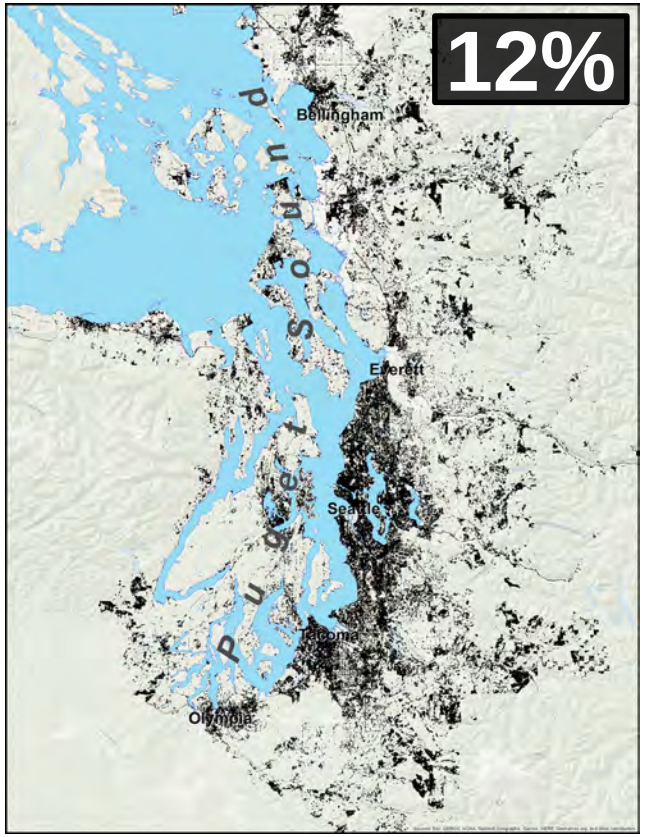
- Generate an equation that represents the relationship between imperviousness and predicted coho mortality (current model)
- Apply that equation to basins using their predicted imperviousness in 2070 (3 scenarios):

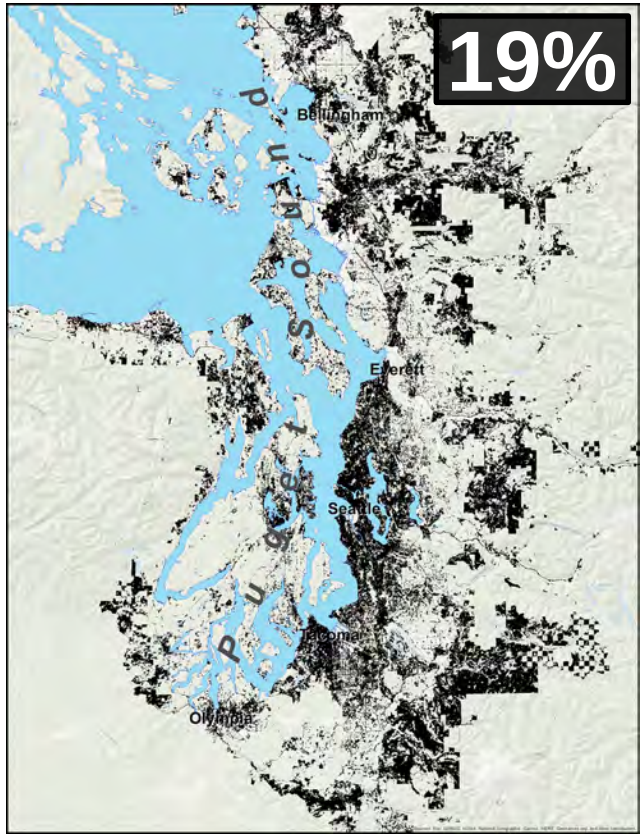
Future Scenarios - Imperviousness

Present	Year 2070 **Status Quo**	Year 2070 **Managed Growth**	Year 2070 **Unconstrained Growth**









USGS 2014 National Landcover Database

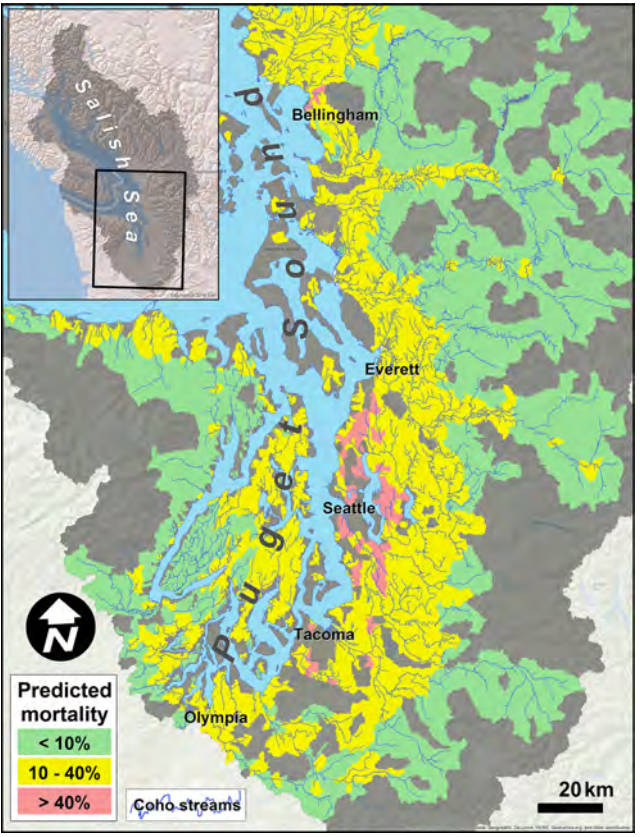
Bolte & Vache 2010 Envisioning Puget Sound Alternative Futures

First Order Approximation of Future Mortality

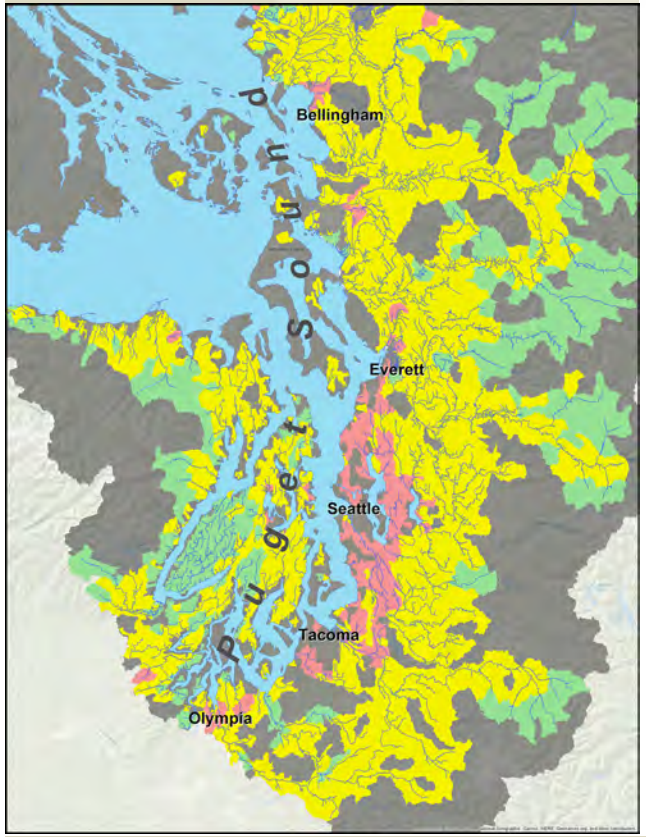
- Generate an equation that represents the relationship between imperviousness and predicted coho mortality (current model)
- Apply that equation to basins using their predicted imperviousness in 2070 (3 scenarios)
  - Status quo
  - Managed growth
  - Unconstrained growth
- Predict coho mortality in 2070

Future Scenarios – Predicted Mortality

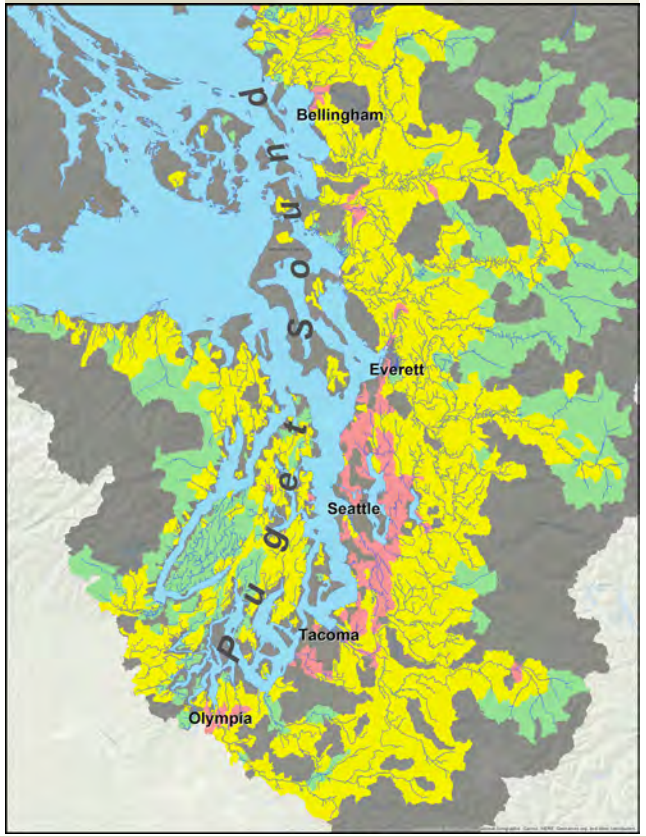
Present 40% 2%



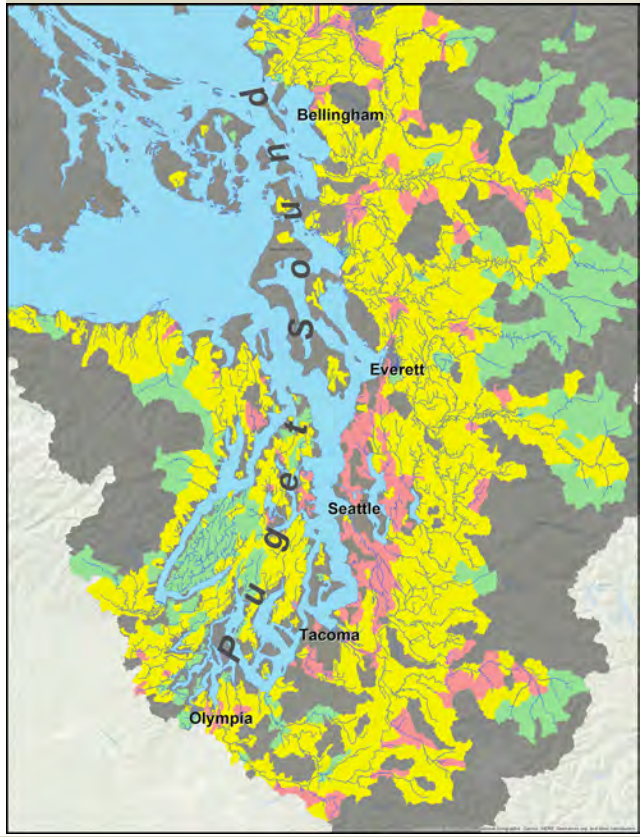
2070: **Status Quo** 66% 6%



2070: **Managed Growth** 64% 5%



2070: **Unconstrained** 65% 11%



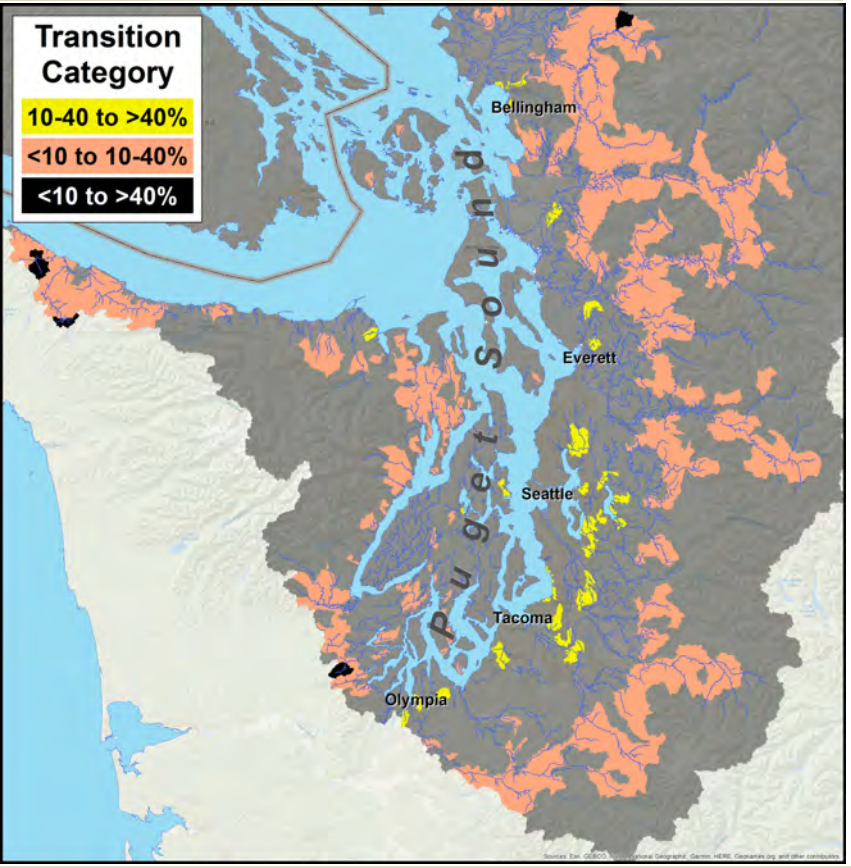
Feist et al. 2017

Bolte & Vache 2010 Envisioning Puget Sound Alternative Futures

Future Scenarios – Mortality Transitions

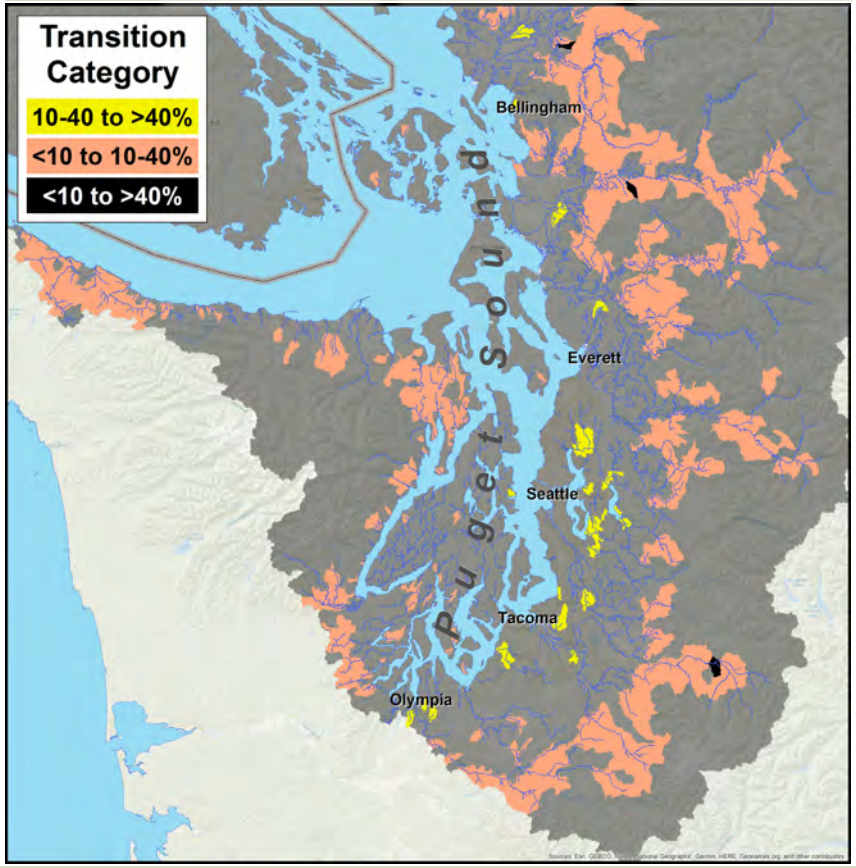
2070: **Status Quo**

2.0% **36%** **0.5%**



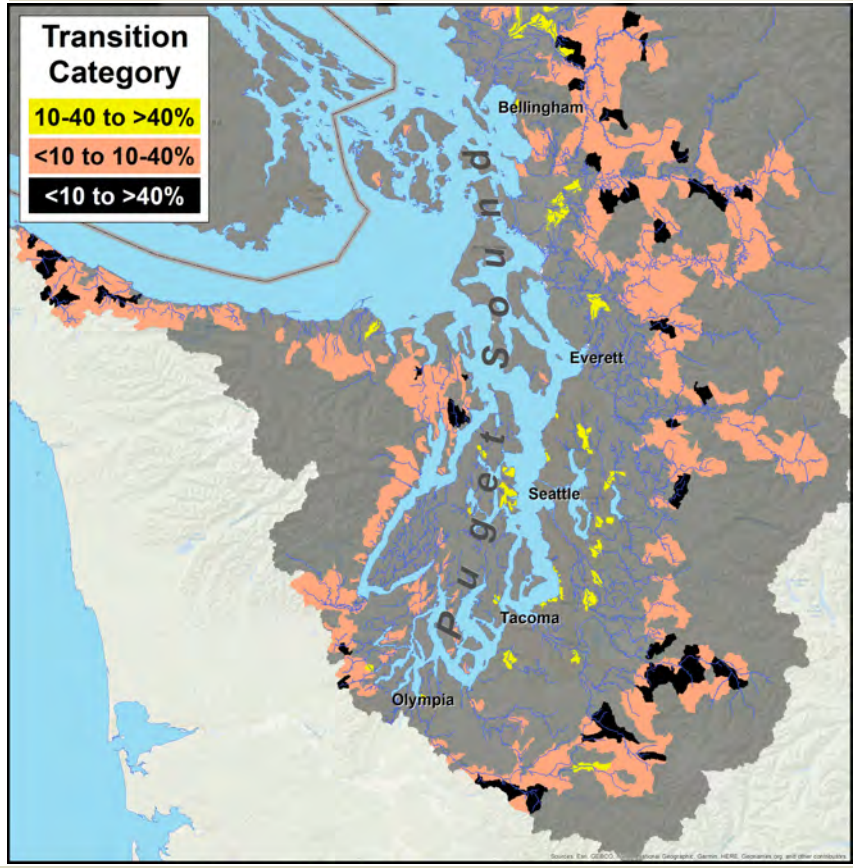
2070: **Managed Growth**

1.4% **36%** **0.2%**



2070: **Unconstrained Growth**

1.9% **34%** **5.6%**



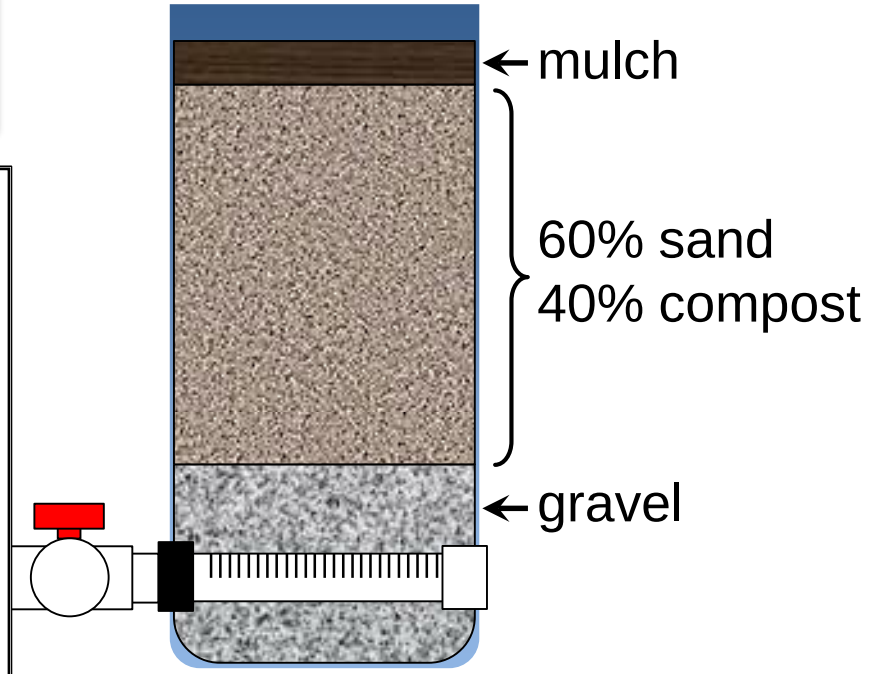
Bolte & Vache 2010 Envisioning Puget Sound Alternative Futures

Even with managed growth, things get worse for coho in the future

Game over, man,
GAME OVER!!!

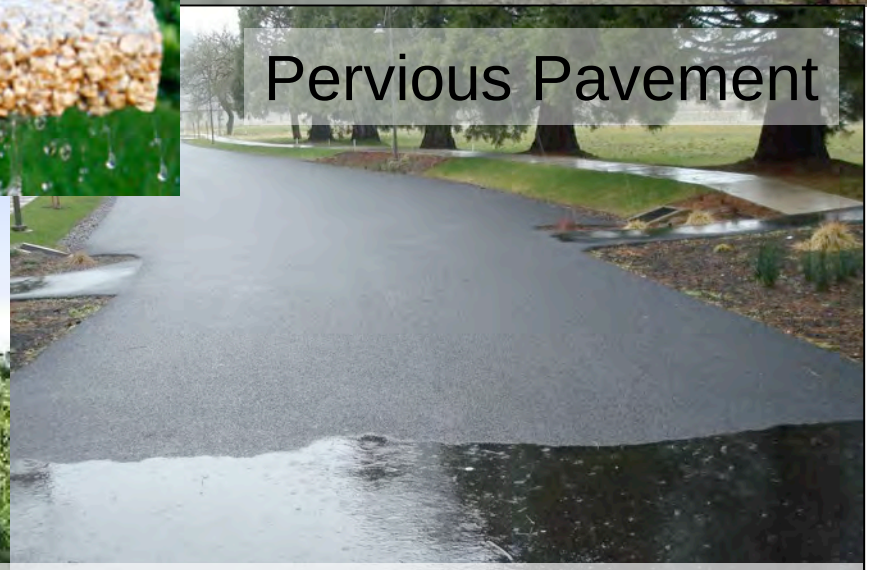
Pass stormwater through ordinary household materials and it's no longer toxic to coho

Bioretention Column



Spromberg et al. 2016 J. Appl. Ecol.

Green Stormwater Infrastructure



Emerging technologies for the built landscape may be less harmful to salmon and other aquatic animals

Conclusions and Applications

- Coho salmon are sensitive to something in stormwater that washes into their spawning streams
- Landscape analyses suggest that degree of urbanization and amount of heavily used roads positively correlated with coho spawner mortality
- Predictive models from landscape analyses:
  - can inform regional urban growth scenarios and identify coho populations at risk (currently and in the future)
  - can be used to prioritize GSI placement, which can ameliorate stormwater toxicity
- Given human populations aren’t going to decline, removing toxics at their source or neutralizing them using GSI treatment are essential if we wish to reduce coho mortality

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Roads to ruin: conservation threats to a sentinel species across an urban gradient

Blake E. Feist, Eric R. Buhle, David H. Baldwin, Julann A. Spromberg, Steven E. Damm, Jay W. Davis, Nathaniel L. Scholz

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Figures References Related Information

Metrics

Am score 103

Check out the Esri Story Map!

https://arcg.is/0SivbL

Postscript

- Online release of paper was intentionally synchronized with local and national media coverage

The Seattle Times

The Olympian

the johns hopkins NEWS-LETTER

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Stormwater pollution killing coho before they can spawn

PUGET SOUND BASIN

40% of home range a toxic stew that may drive extinction

By LYNDA V. MAPES
Seattle Times environment reporter

The sweet seep of autumn rain is bringing coho salmon back home to their natal streams all over the Puget Sound basin — where too often they encounter a bitter truth: pollution in a shocking 40 percent of their home range so bad it can inflict a swift death.

The culprit is stormwater, and it is causing death rates so high, some populations of wild coho are at risk of local extinction, researchers found.

Yet there also are surprisingly simple and cheap solutions at hand, the researchers wrote in their paper, published Wednesday by the Ecological Society of America in the scientific journal Ecological Applications.

Researchers at NOAA's Northwest Fisheries Science Center in Seattle worked with collaborators, including the U.S. Fish and Wildlife Service, local tribes and the Wild Fish Conservancy, to survey 51 sites from 2000 to 2011 in streams all over the Puget Sound basin. They used the survey data with a new computer model to map predicted coho death rates. The results show that in an estimated 40 percent of their range in the Puget

See > COHO, A4

NOAA FISHERIES

Coho salmon, including females full of eggs, are dying before they can spawn in Puget Sound streams polluted with stormwater runoff.

Postscript

- Online release of paper was intentionally synchronized with local and national media coverage
- Serendipitously synchronized with fall runs of Puget Sound coho
- Citizens keyed in on the newspaper coverage and noticed mortality phenomena themselves
- Currently developing a citizen science portal
  - Outreach
  - Data dissemination
  - Citizen science data input