Is it the seas or the trees? Modeling the distribution of Marbled Murrelets along the Washington to California coast

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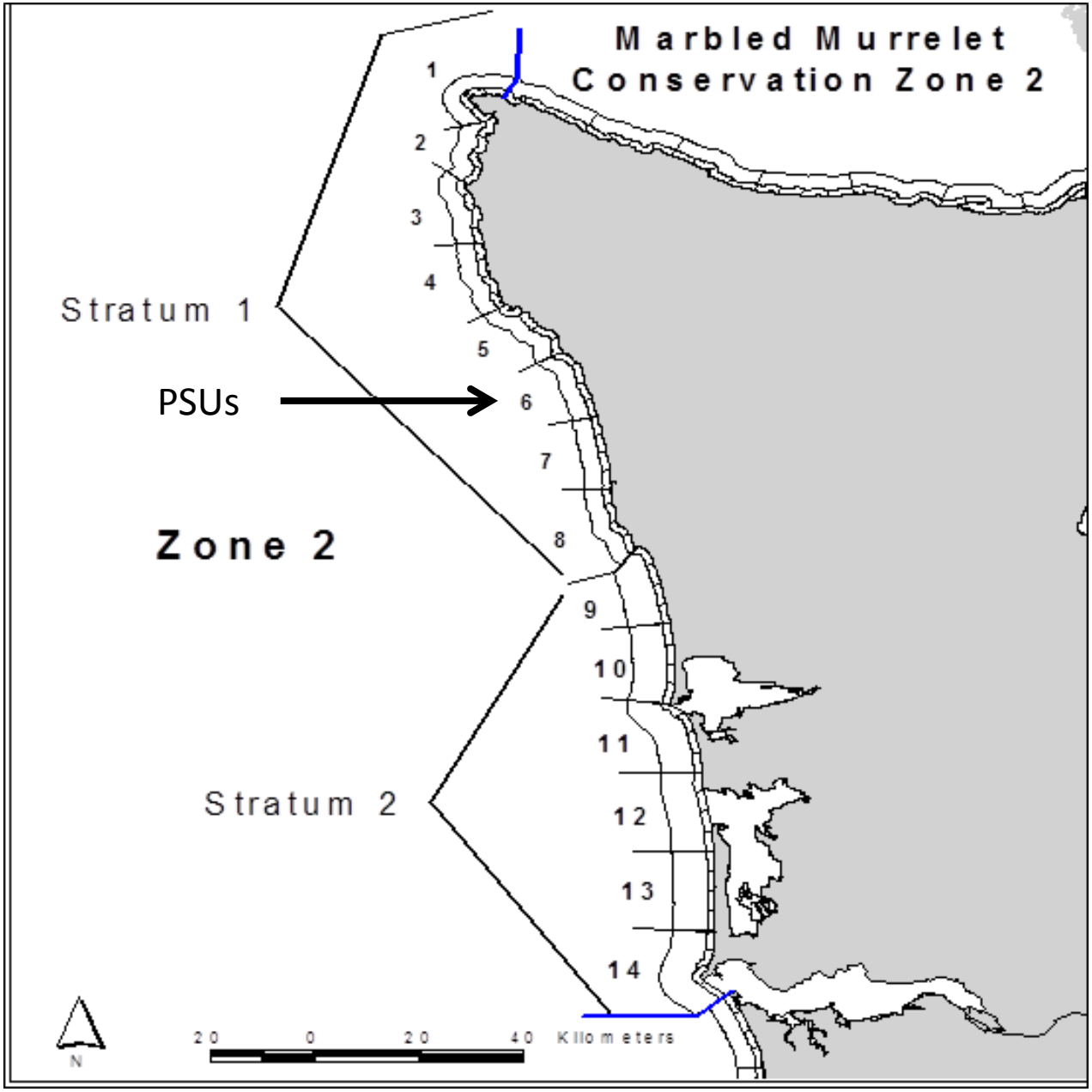
Assessing relative influence of marine and forest habitat attributes

- Document spatial and temporal distribution of marbled murrelets in WA, OR, CA
- Estimate amount and trend of nesting habitat
- Estimate amount and trend of foraging habitat
- Assess relative contributions of marine and terrestrial factors to predict spatial and temporal distribution of murrelets

Murrelet Range in WA, OR, CA

- 6 Conservation Zones (Recovery Plan)
- We survey zones 1 to 5

An Example of Primary Sample Unit (PSU) Layout

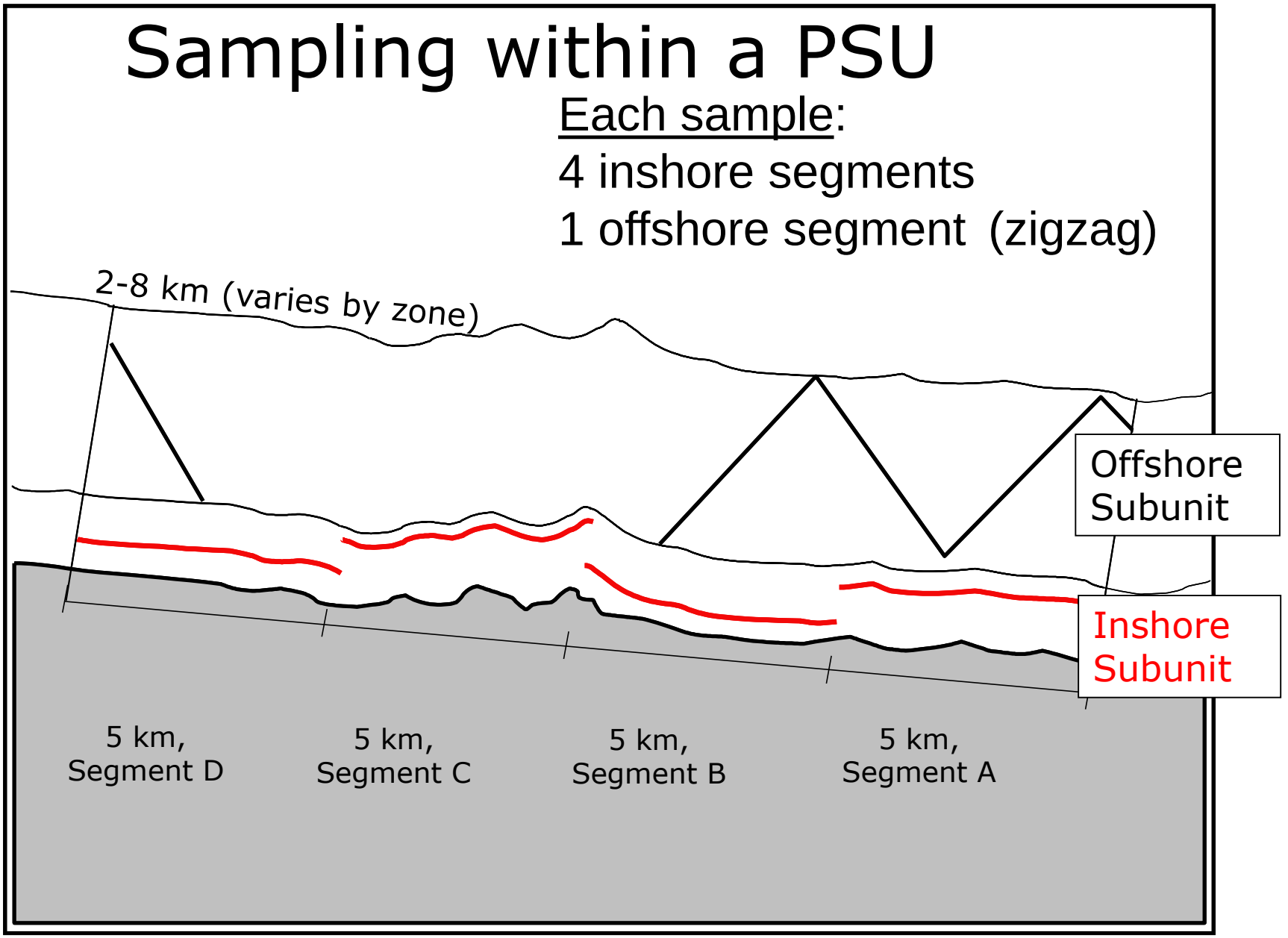


Sampling within a PSU

Each sample:

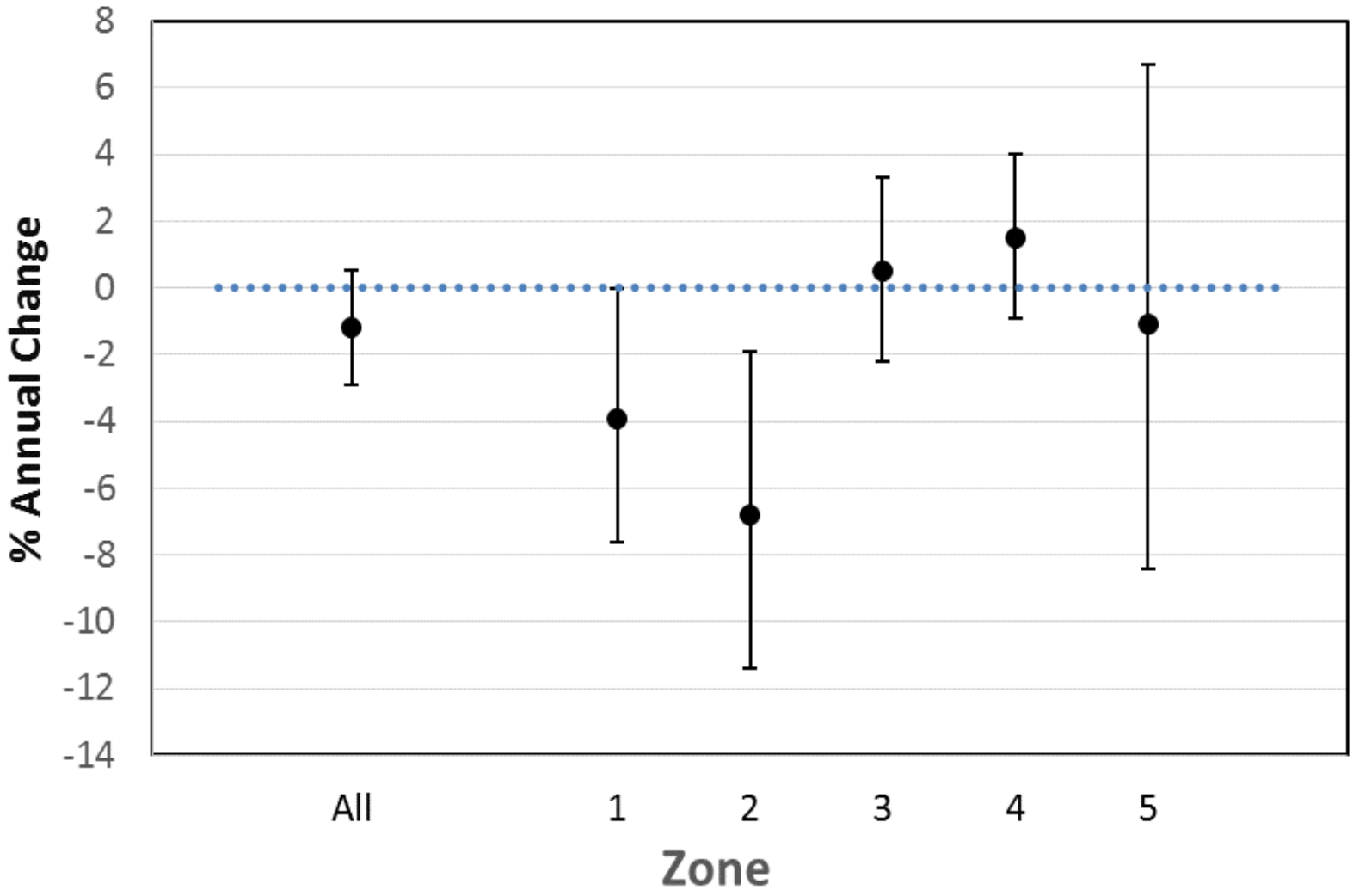
4 inshore segments

1 offshore segment (zigzag)



Average Rate of Annual Change By Zone

(2000-2013, With 95% Confidence Intervals)



Marbled Murrelet Nesting Habitat (2012)

Murrelet Habitat Suitability

Below threshold

- Habitat capable

Above threshold

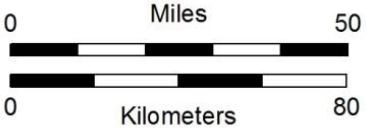
- Class 3 (moderately high suitability)
- Class 4 (highest suitability)

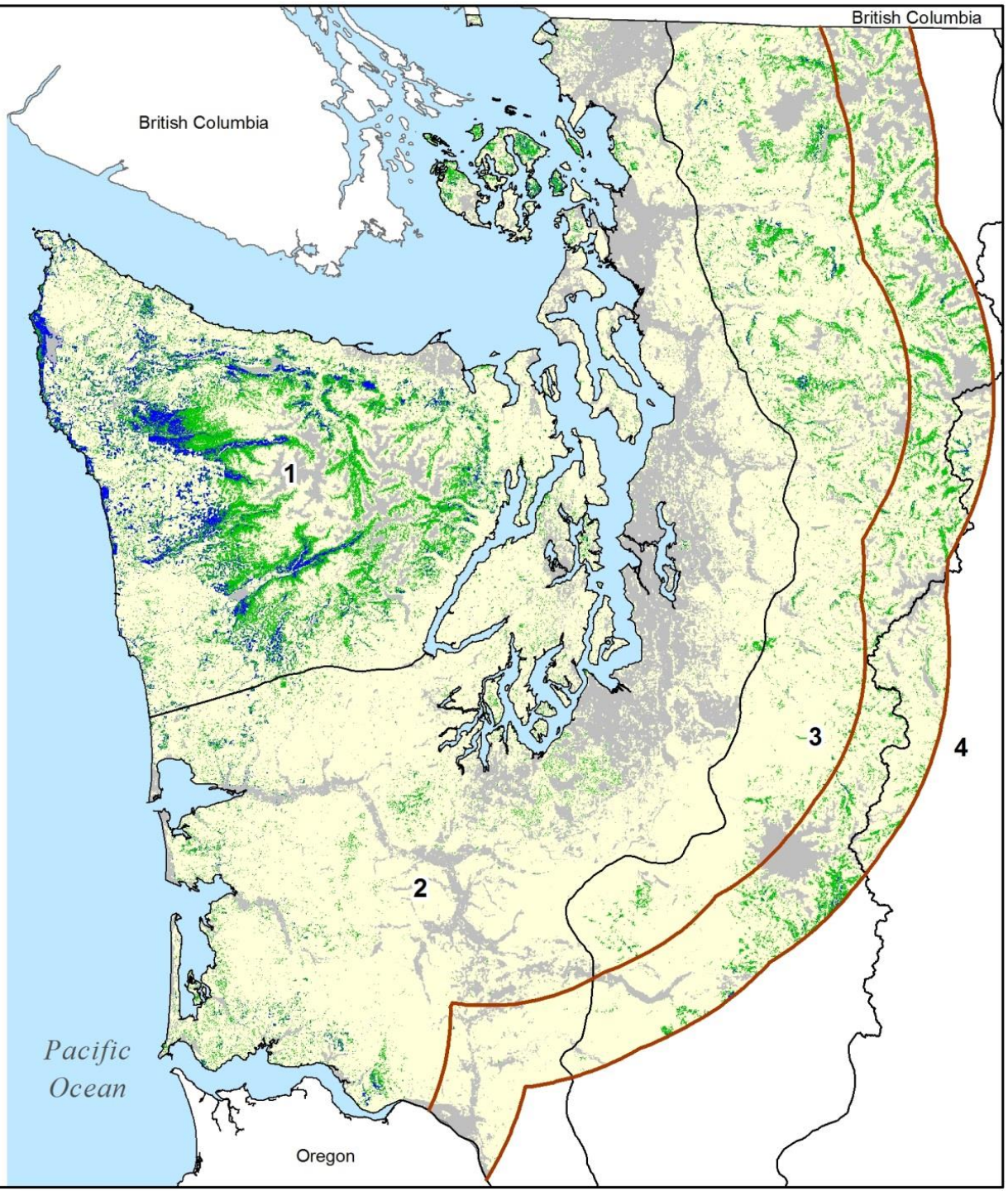
- Not habitat capable

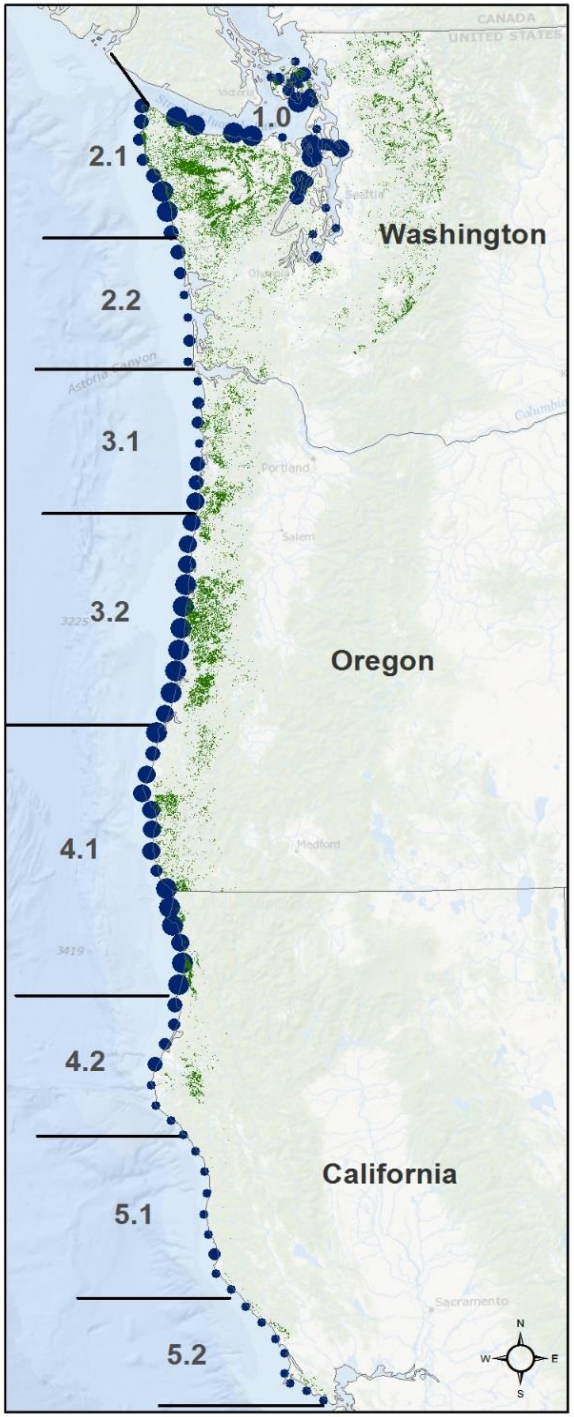
- NWFP Inland Zones

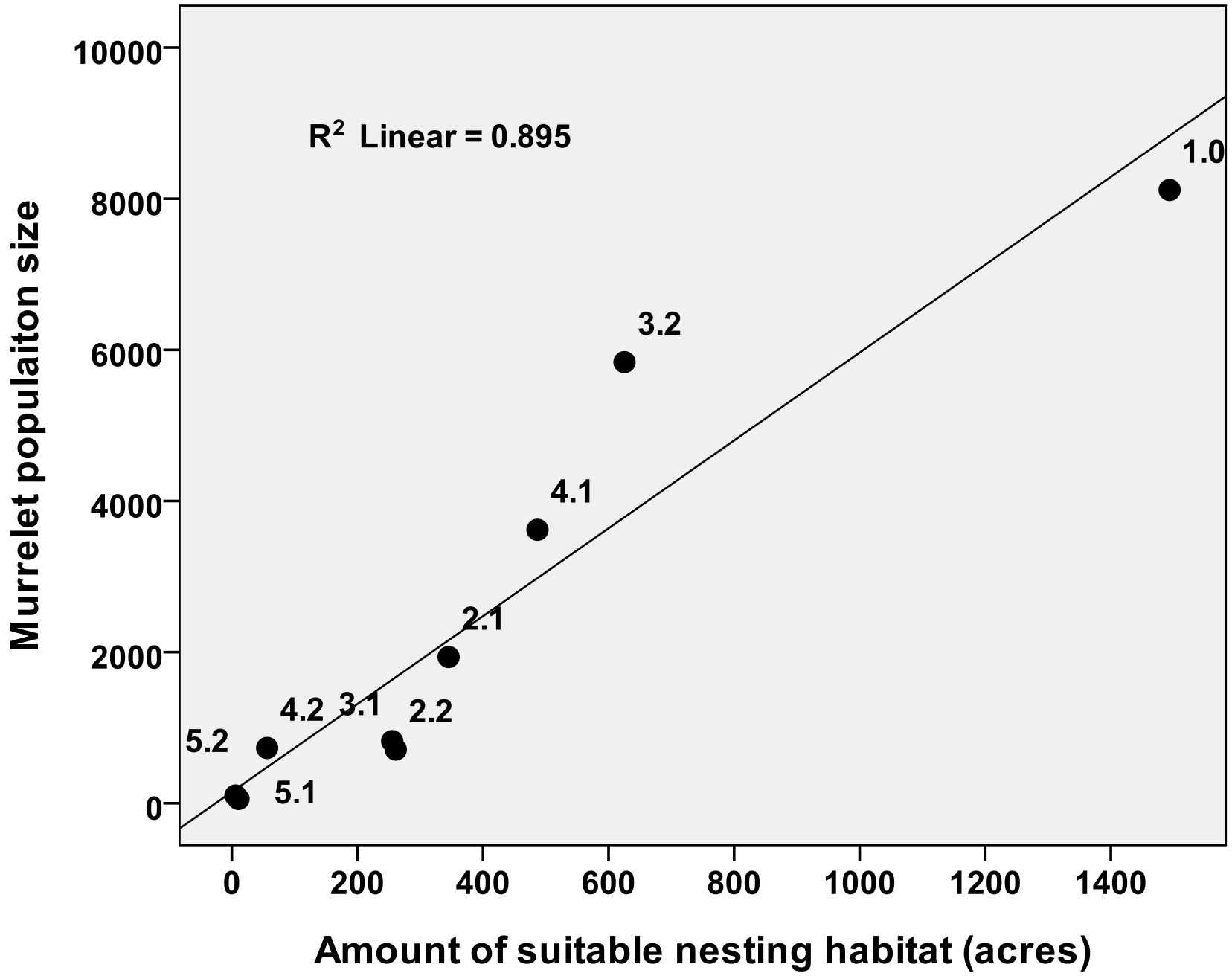
Physiographic Province

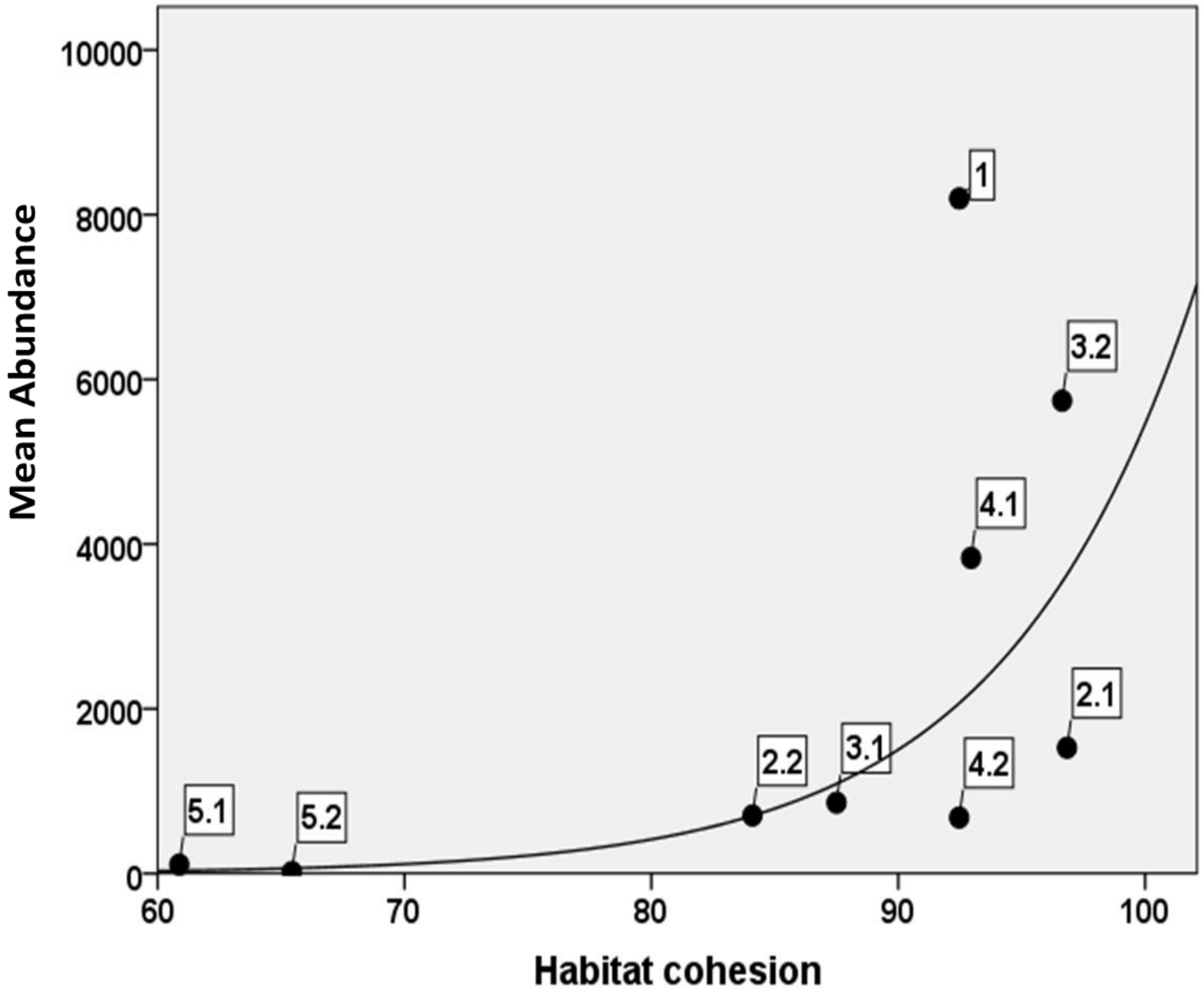
1. Washington Olympic Peninsula
2. Washington Western Lowlands
3. Washington Western Cascades
4. Washington Eastern Cascades



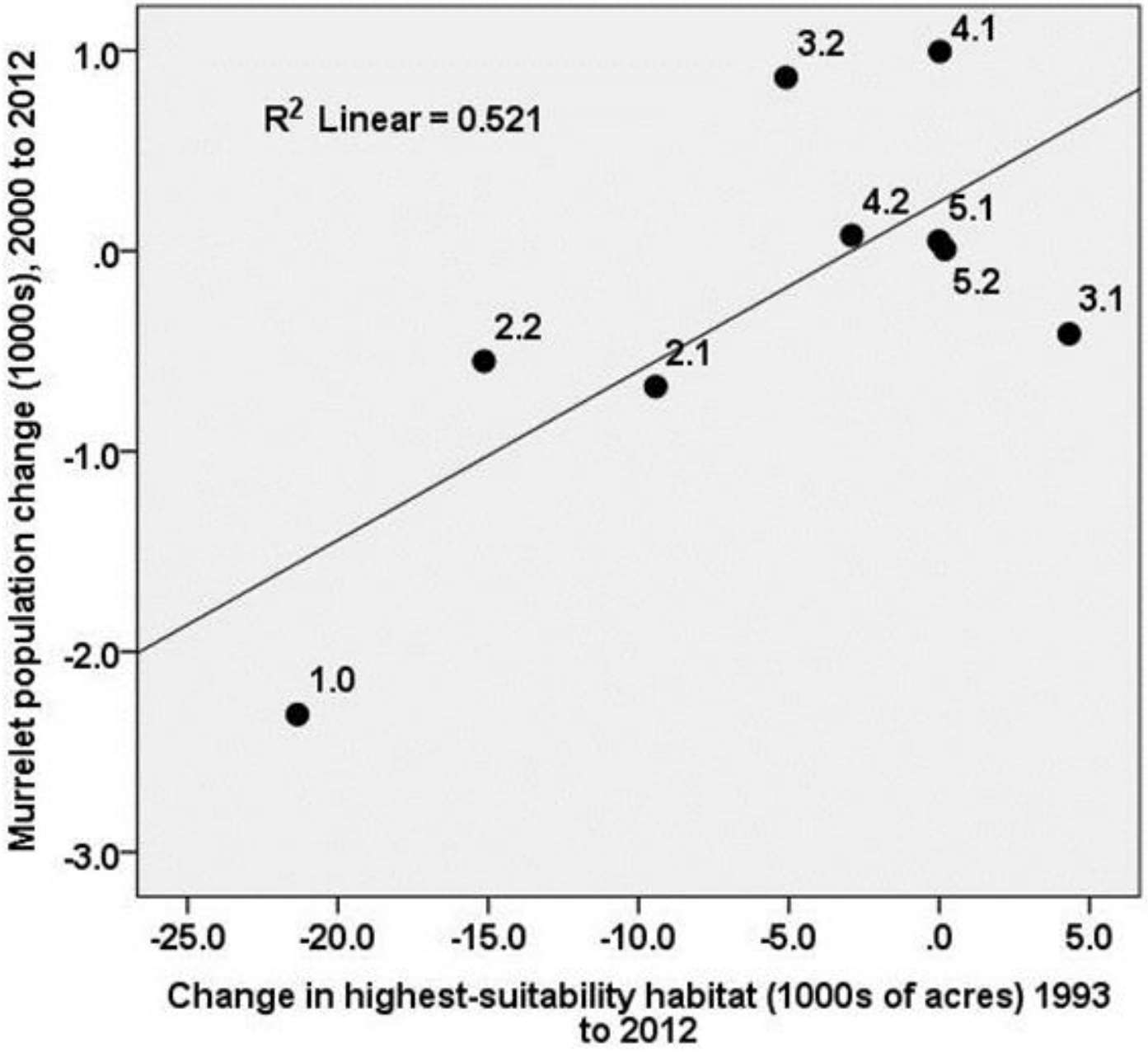



1.0
2.1
2.2
3.1
3.2
4.1
4.2
5.1
5.2
Washington
Oregon
California
Nesting Habitat
Mean Density (birds/sq. mile)
< 1
1 - 3
3 - 5
5 - 10
> 10
Strata Boundaries
0 30 60 120
Miles


Murrelet populaiton size
Amount of suitable nesting habitat (acres)
R2 Linear = 0.895
10000
8000
6000
4000
2000
0
0
200
400
600
800
1000
1200
1400
1.0
3.2
4.1
2.1
4.2
3.1
2.2
5.2
5.1


Mean Abundance
10000
8000
6000
4000
2000
0
60
70
80
90
100
Habitat cohesion
1
3.2
4.1
2.1
2.2
3.1
4.2
5.1
5.2

Murrelet population decline is related to loss of habitat



Nest site abundance and quality

Nest predators, disease

Pollution, oil spills, gill-nets, disease

Oceanographic conditions

Production of young

Prey abundance and distribution

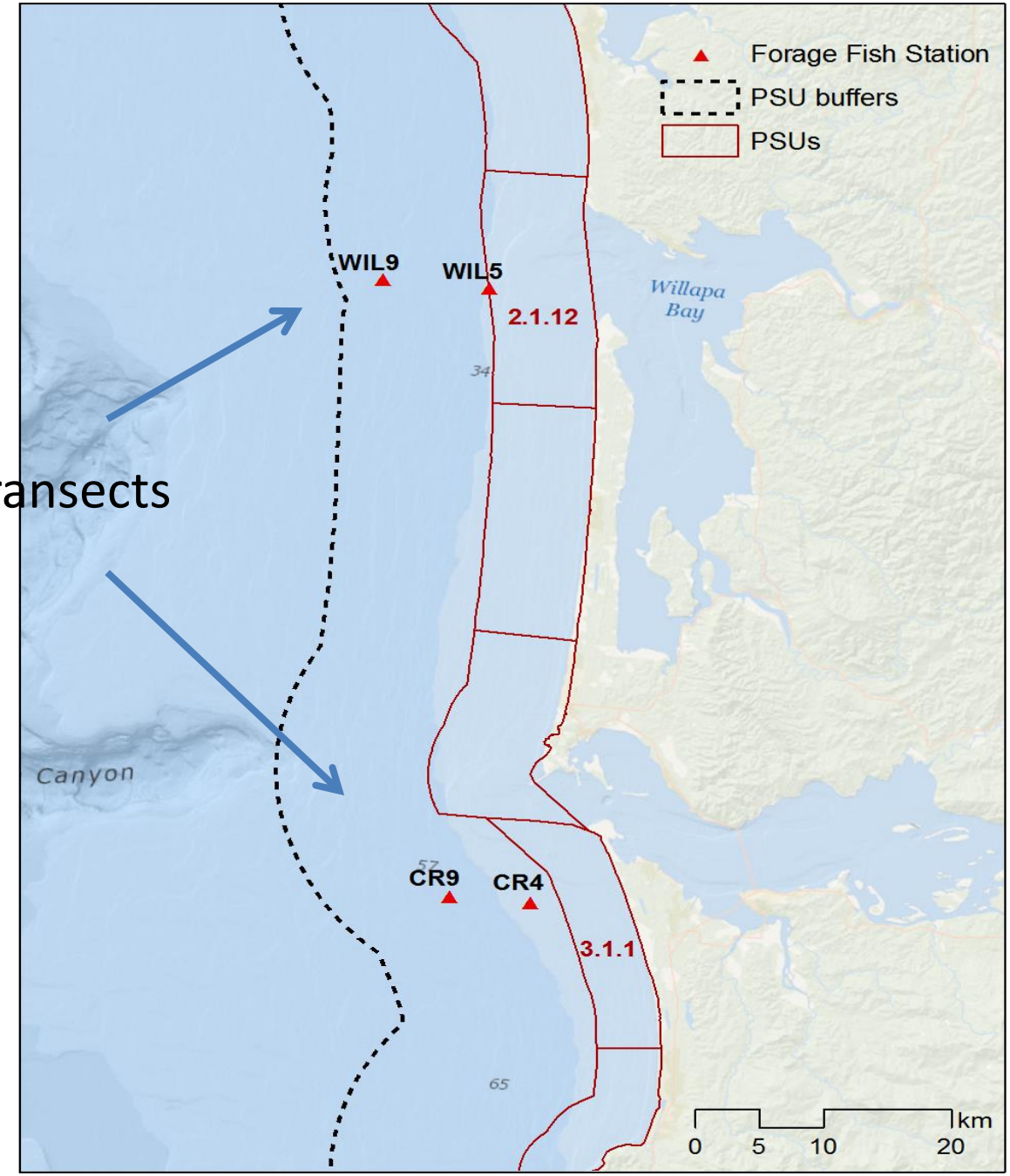
Recruitment

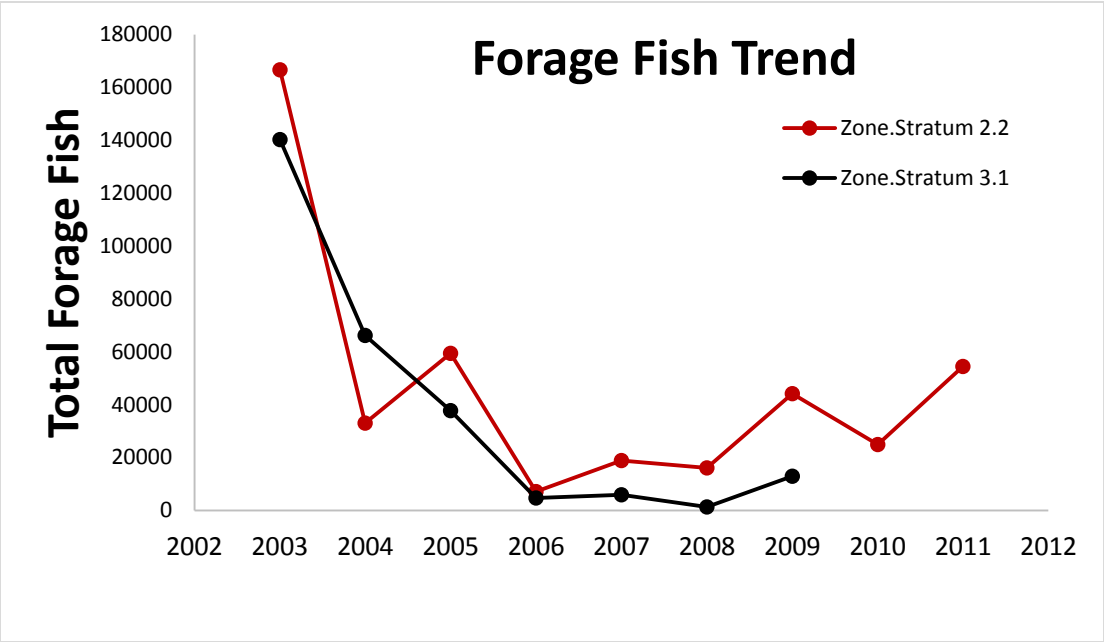
Adult survival

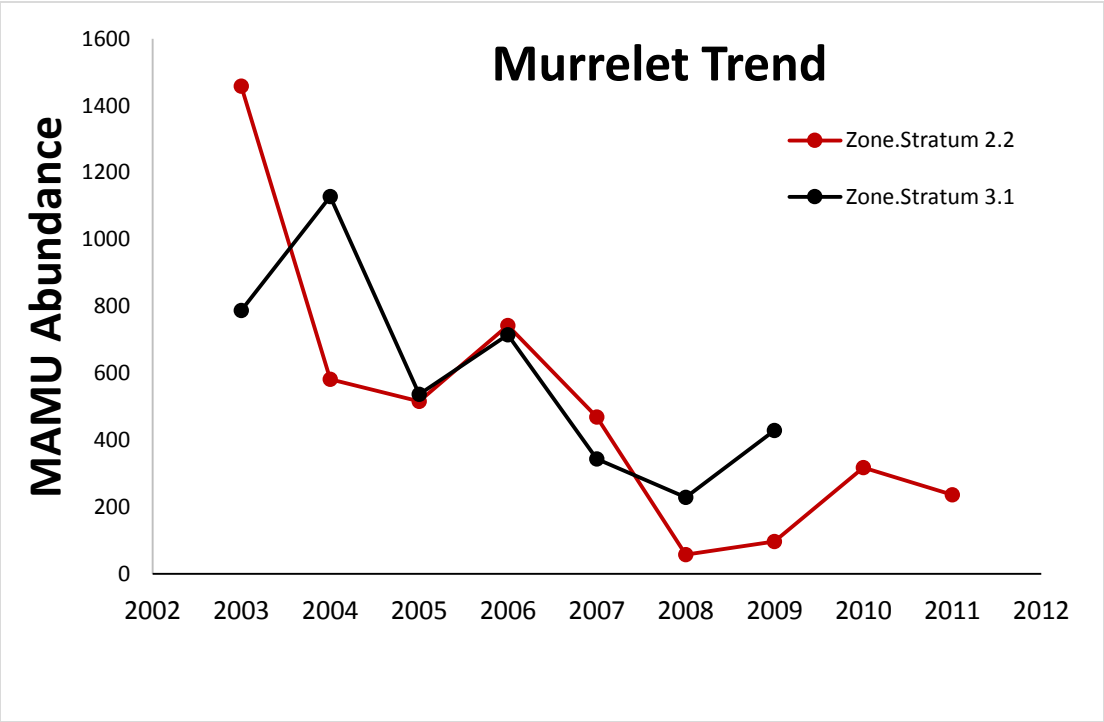
Distribution and movement

Population status and trend

Forage fish transects




Forage Fish Trend
Total Forage Fish
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Zone.Stratum 2.2
Zone.Stratum 3.1


Murrelet Trend
MAMU Abundance
1600
1400
1200
1000
800
600
400
200
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Zone.Stratum 2.2
Zone.Stratum 3.1

Model Covariates

Spatial	Temporal	Spatiotemporal
Distance to Major River	Biological Transition Day	Nesting Habitat (80 km)
Distance to Shore	Spring Physical Transition Day	Nesting Habitat Cohesion
Shoreline Type	Upwelling Anomaly	Summer SST
Mean Depth w/in 10 km	Upwelling Season Duration	Winter SST
Foraging Area w/in 10 km	Winter Oceanic El Nino Index	Summer Chlorophyll A
Marine Human Footprint	Summer Oceanic El Nino Index	Winter Chlorophyll A
Terrestrial Human Footprint	Winter PDO Index	
Residuals Autocorrelation	Summer PDO Index	

Model details

Observational data

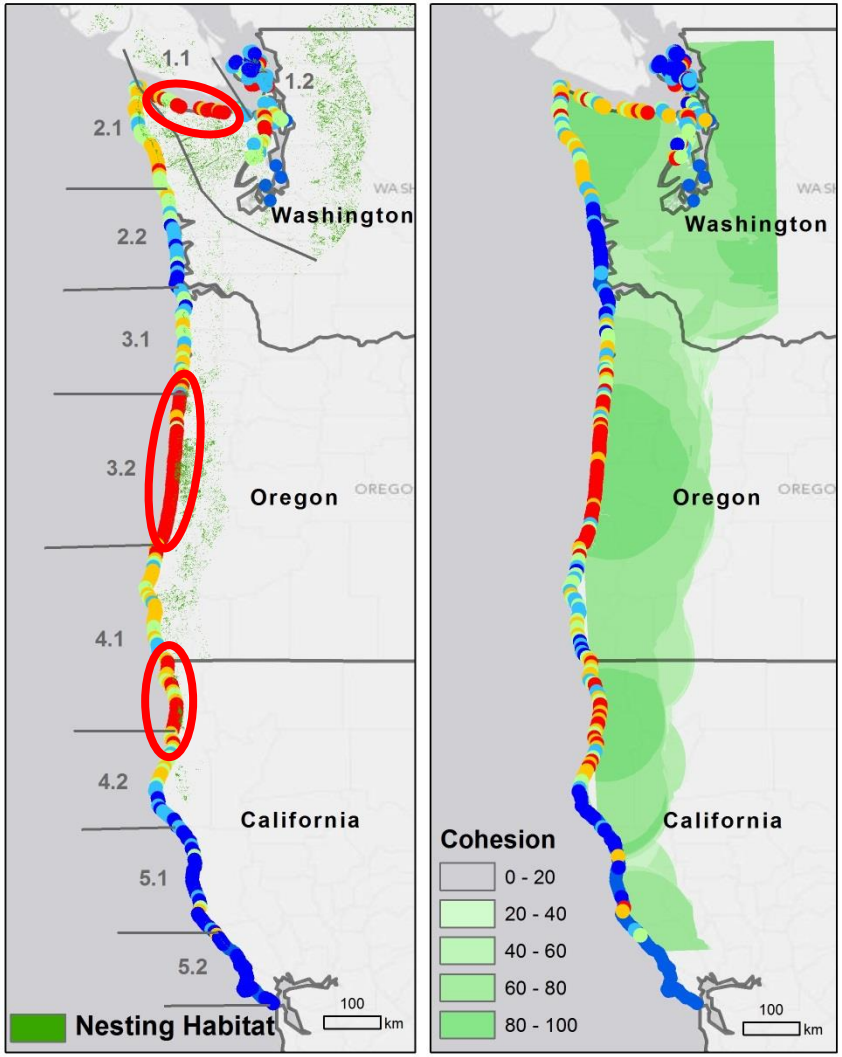
3954 observations (annual counts of a PSU segment)
Years: 2000-2012
Months: May-July

Covariates (21 in initial model, plus autoregression term)

8 temporal covariates
7 spatial covariates
6 spatial and temporal covariates
1 autoregression term

Boosted Regression Tree (implemented via GBM package in R)

Response: mean of replicated PSU segment counts
Family: poisson
Learning rate: 0.01 (weight of each new tree to model fit)
Bag fraction: 0.5 (half the data is used to train the model)
Tree complexity: 5
Crossvalidation folds: 5



Mean Density (birds/km2)

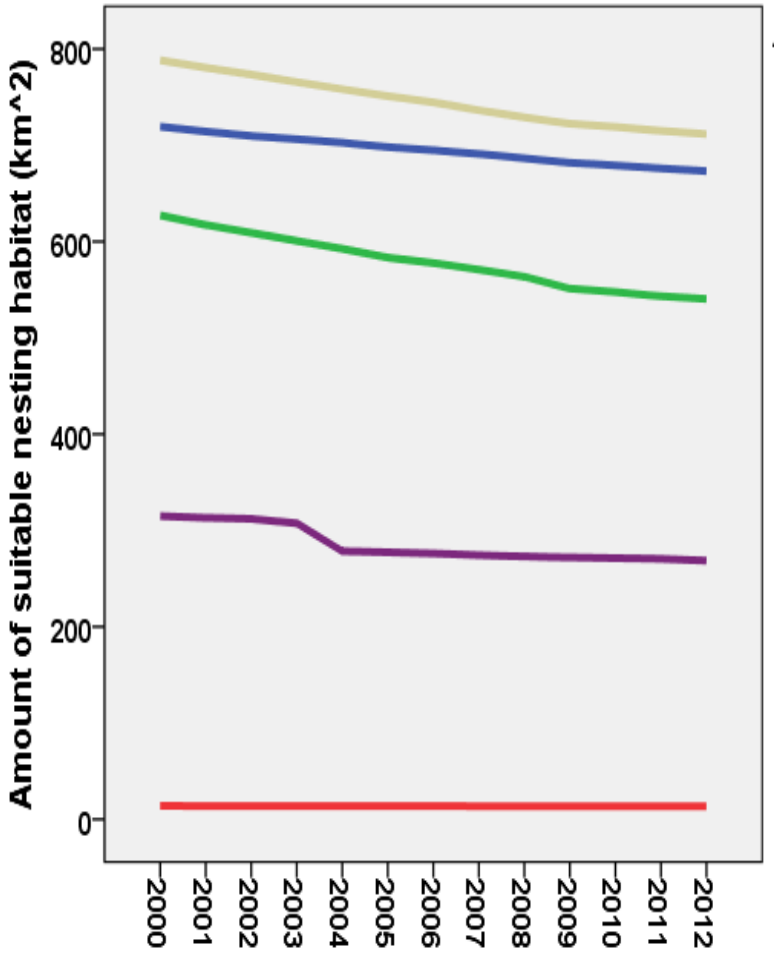
- 0.0 - 0.1
- 0.2 - 0.8
- 0.9 - 2.4
- 2.5 - 8.5
- 8.6 - 51.7

Coefficient of Variation

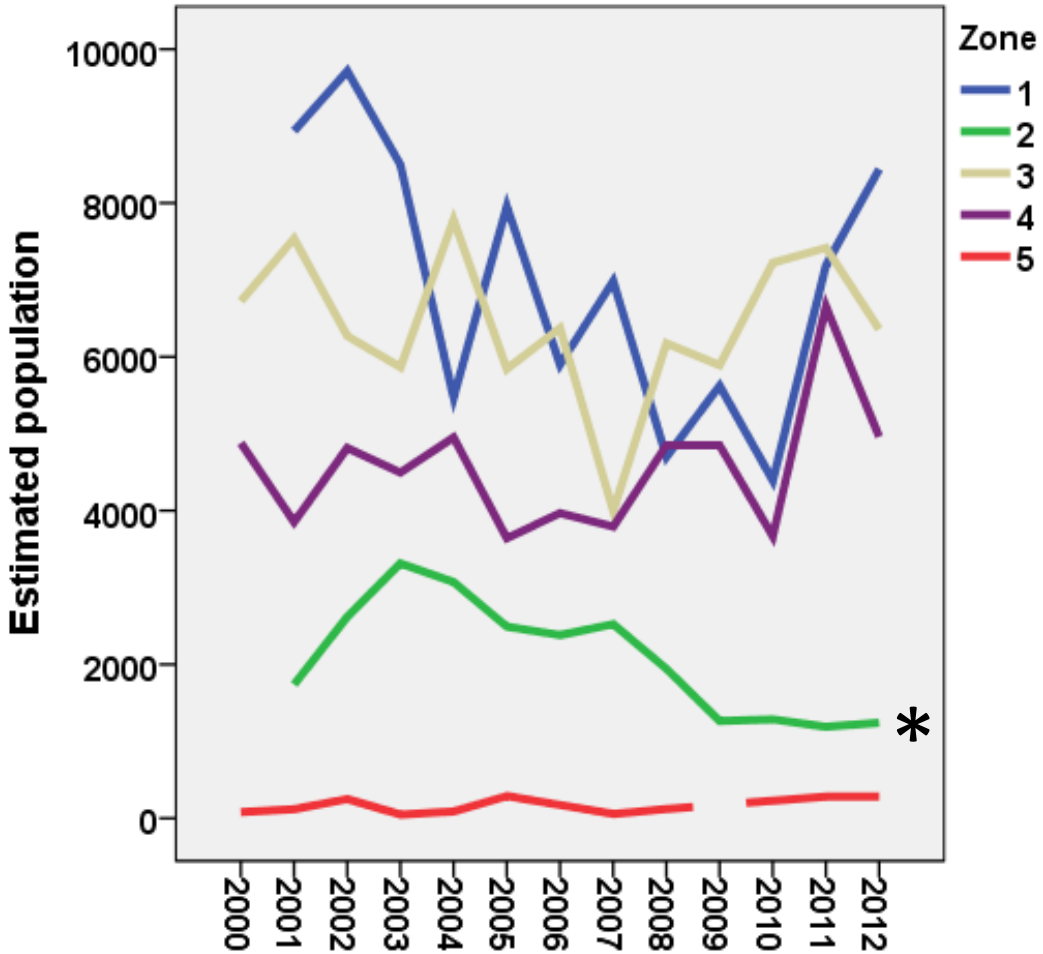
- 41.6 - 87.6
- 87.7 - 111.3
- 111.4 - 148.2
- 148.3 - 214.4
- 214.5 - 360.6

Spatial and temporal variation by Zone

Amount of nesting habitat

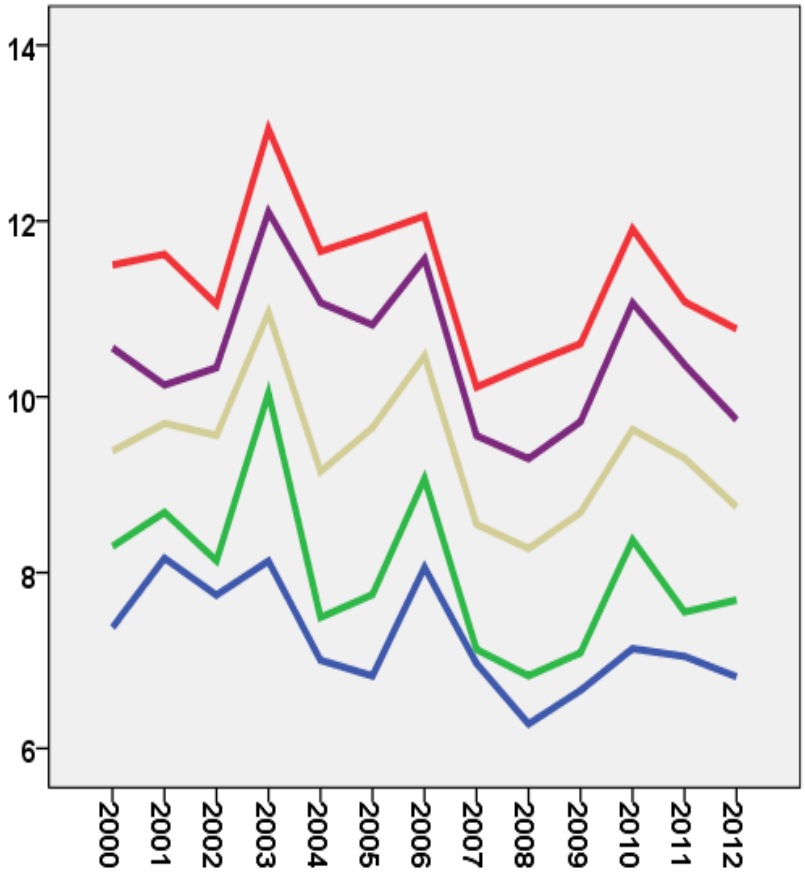


Murrelet population size



Sea surface temperature (°C)

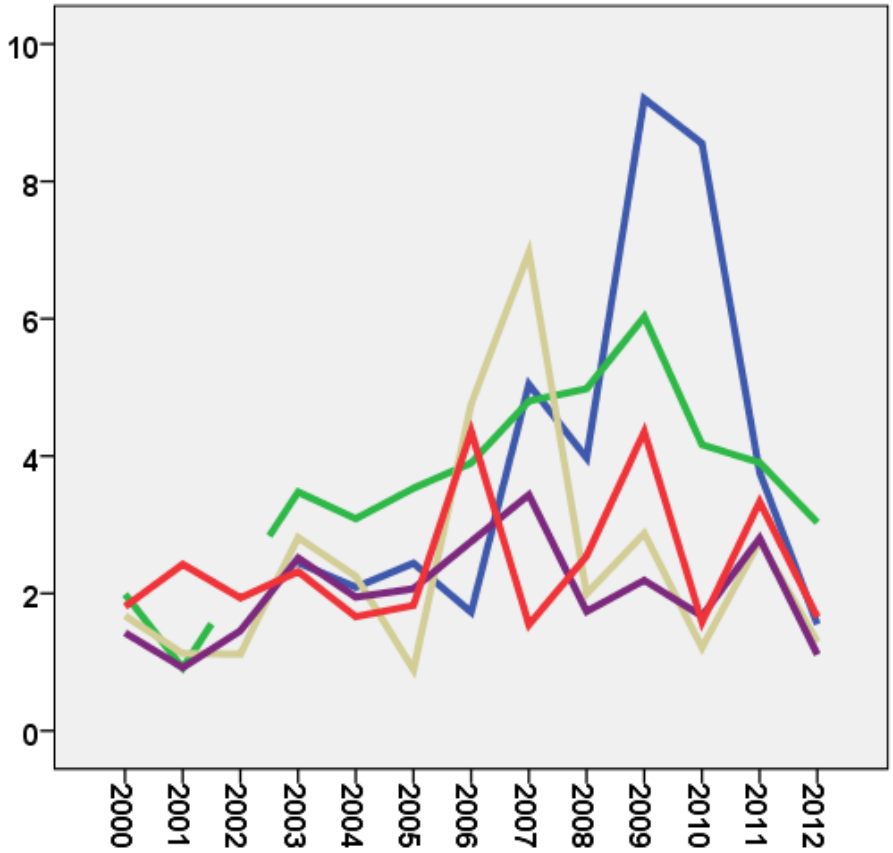
Winter



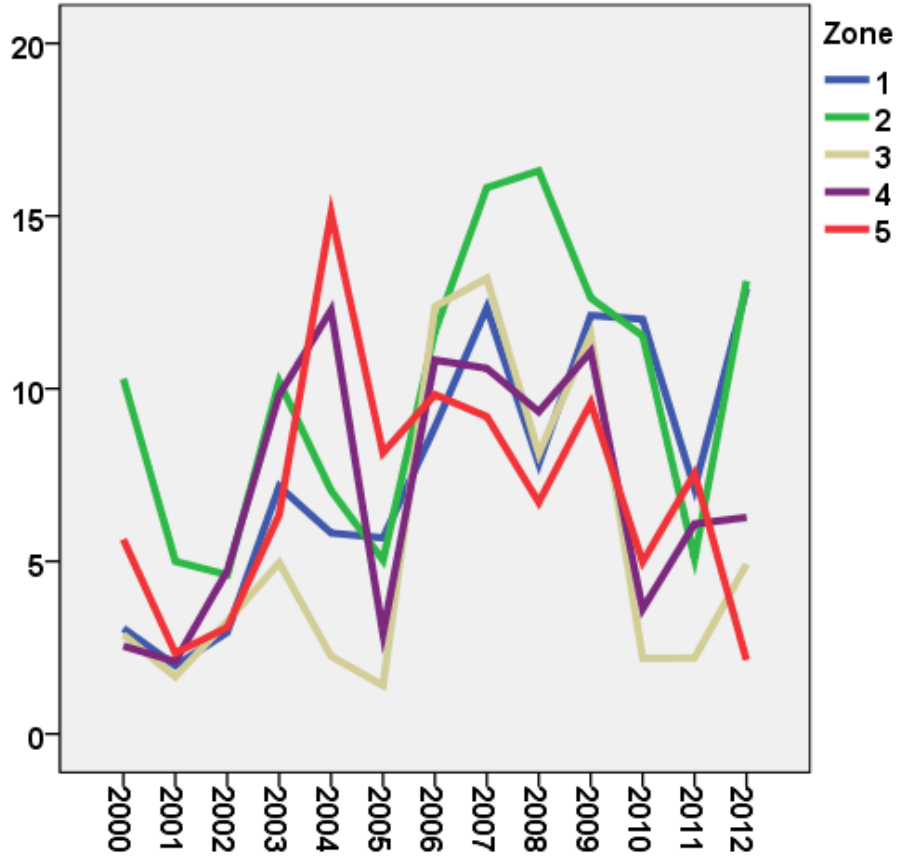
Summer

Chlorophyll A (mg/m^3)

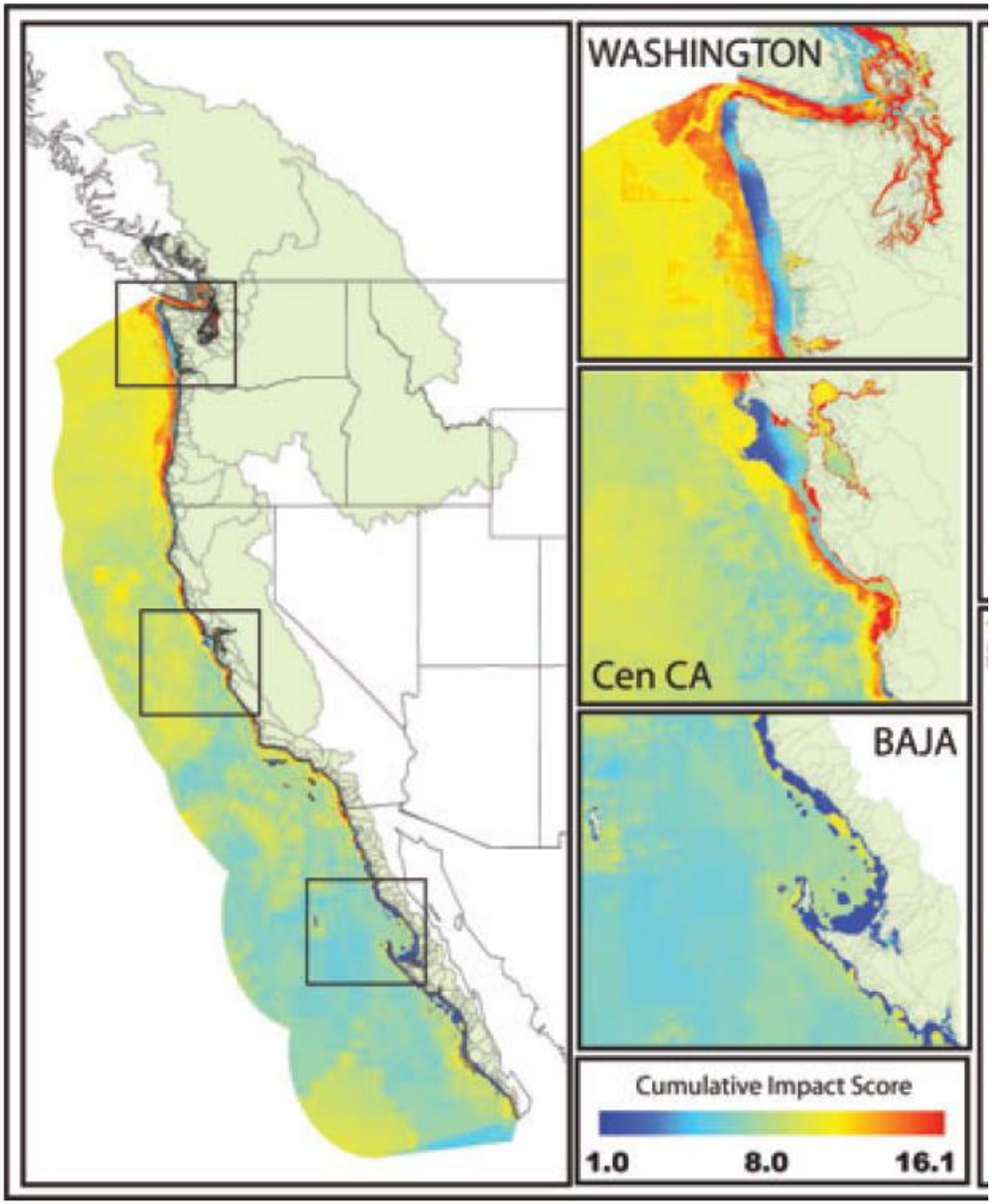
Winter

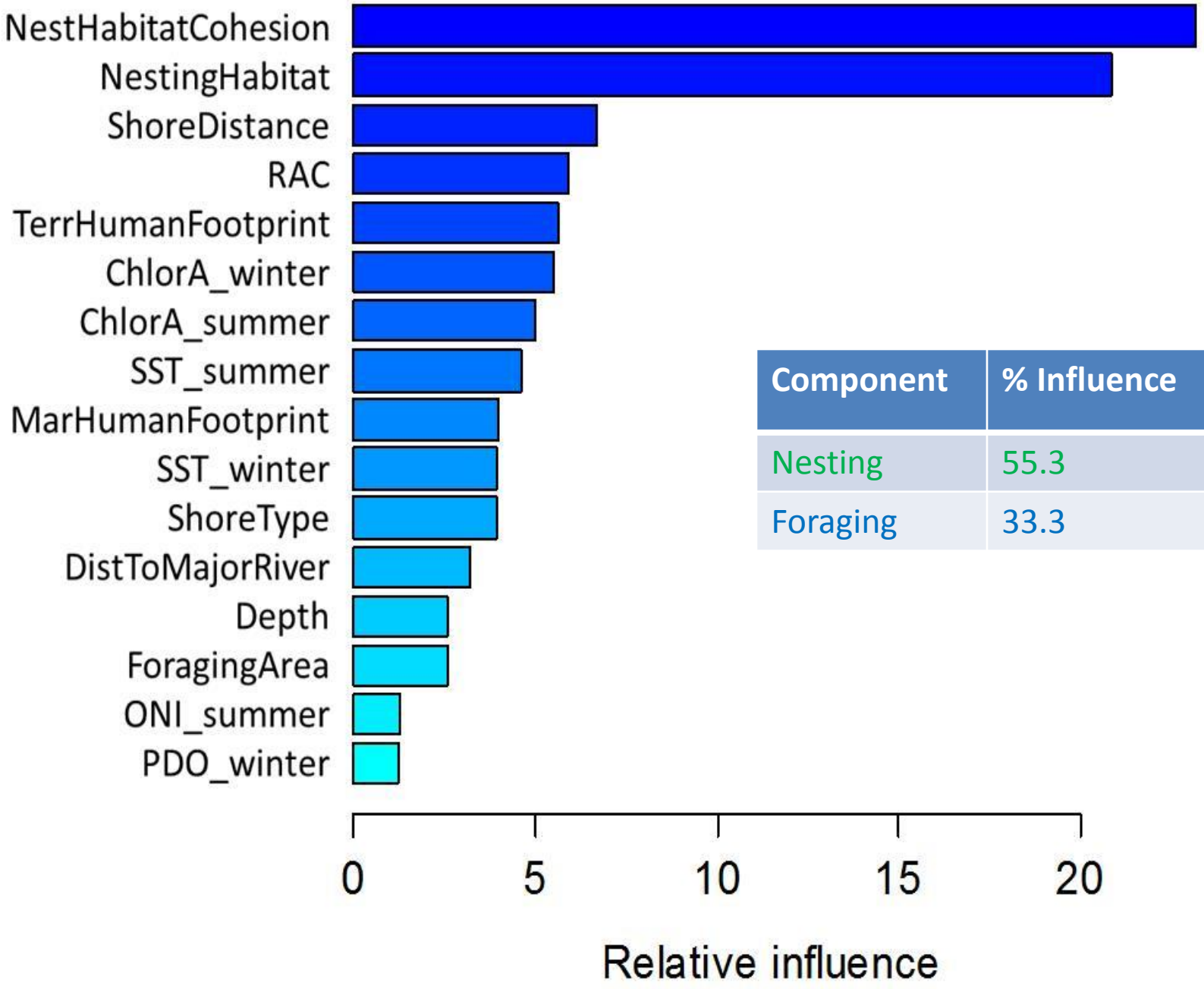


Summer



Marine Human Footprint (Halpern et al. 2009)

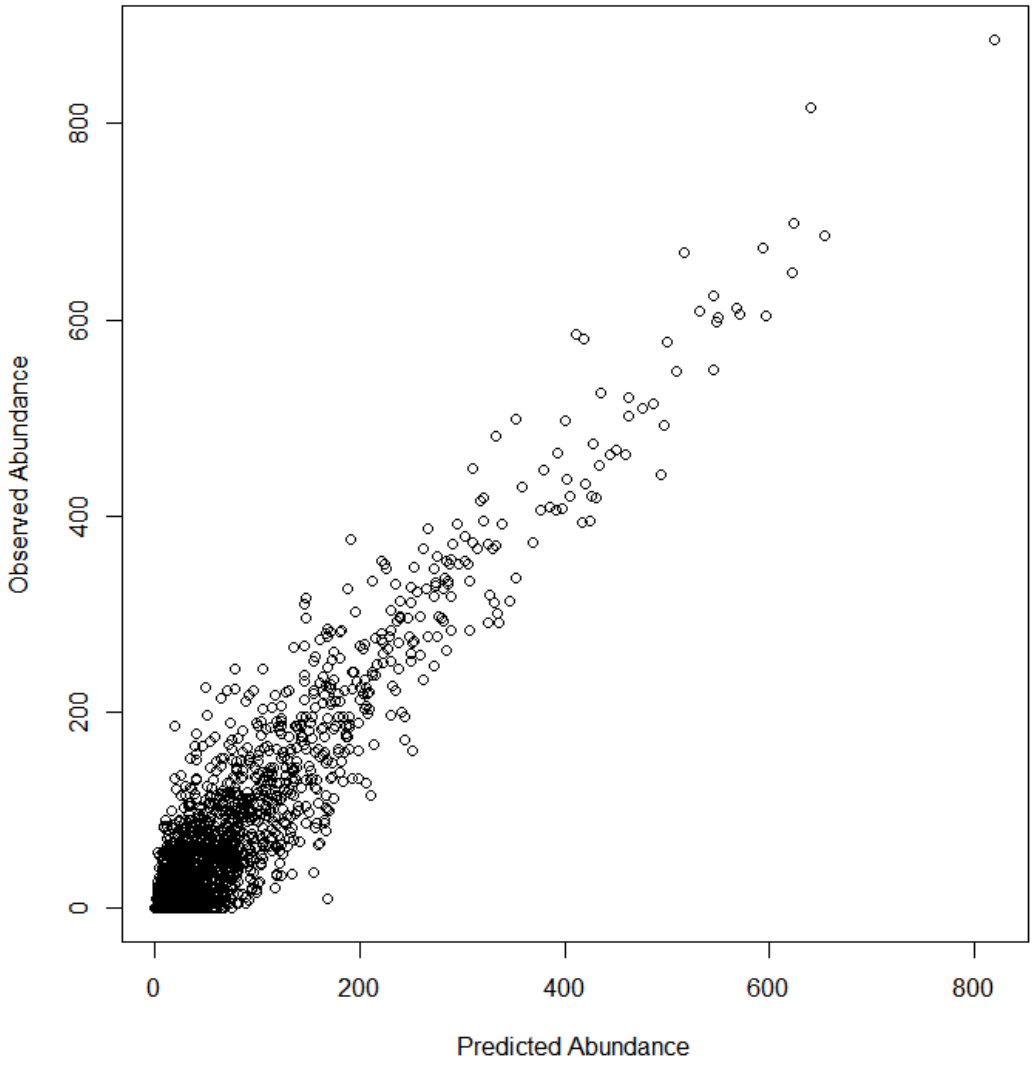




Component	% Influence
Nesting	55.3
Foraging	33.3

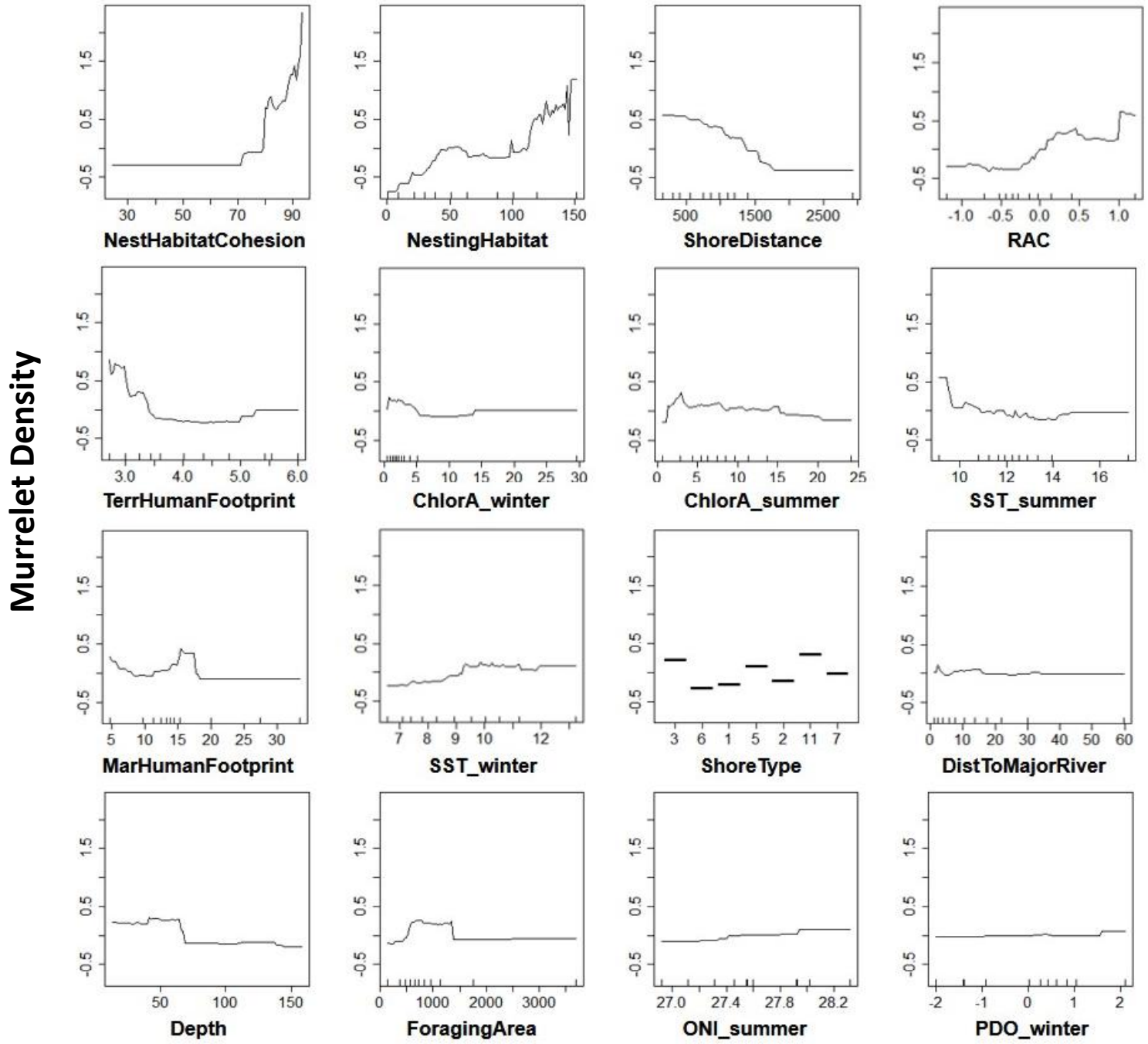
Predictive performance

Most parsimonious model

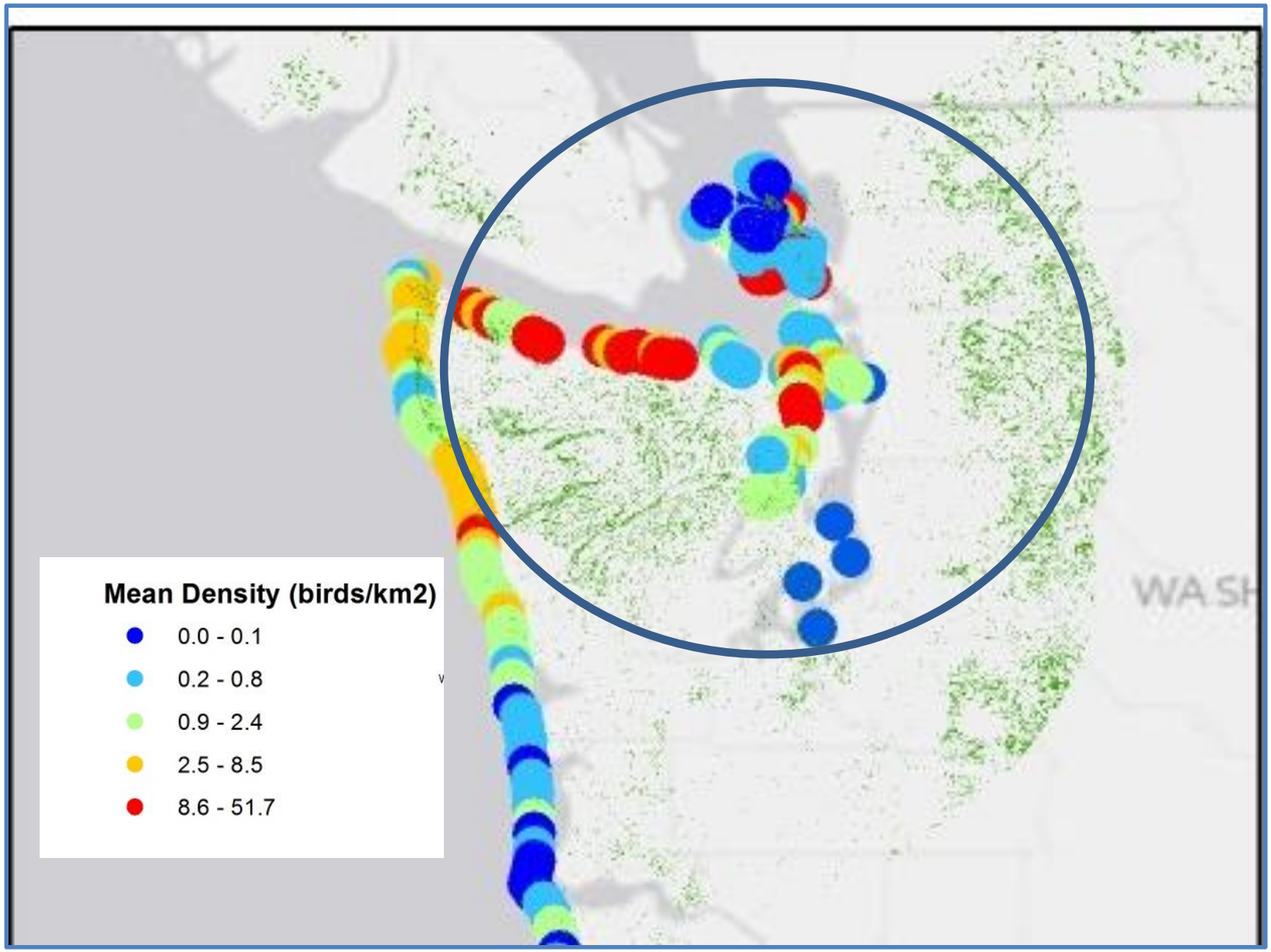


% Deviance explained – 82.7%

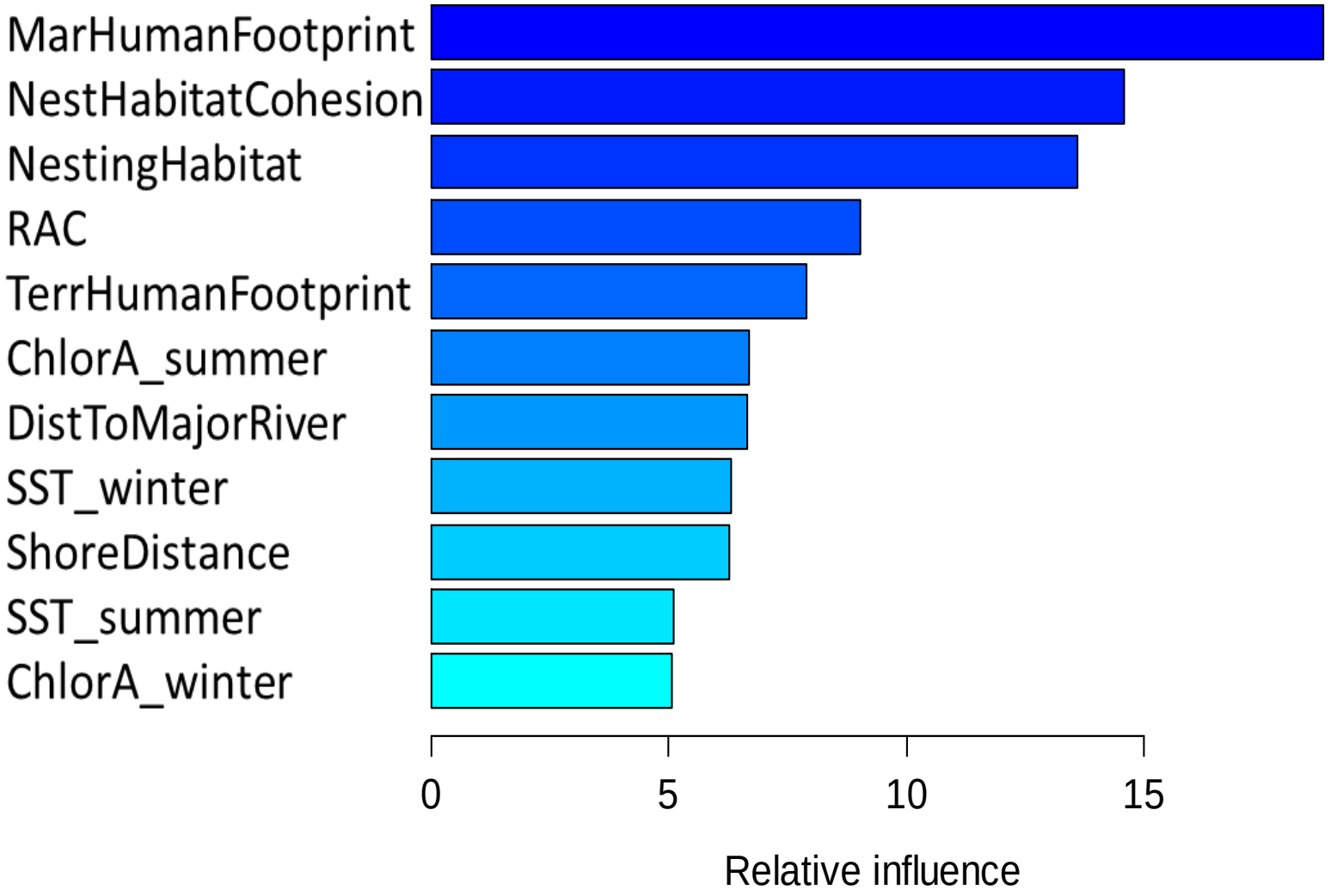
% Deviance explained (crossvalidated) – 63.3%


Murrelet Density
NestHabitatCohesion
NestingHabitat
ShoreDistance
RAC
TerrHumanFootprint
ChlorA_winter
ChlorA_summer
SST_summer
MarHumanFootprint
SST_winter
ShoreType
DistToMajorRiver
Depth
ForagingArea
ONI_summer
PDO_winter

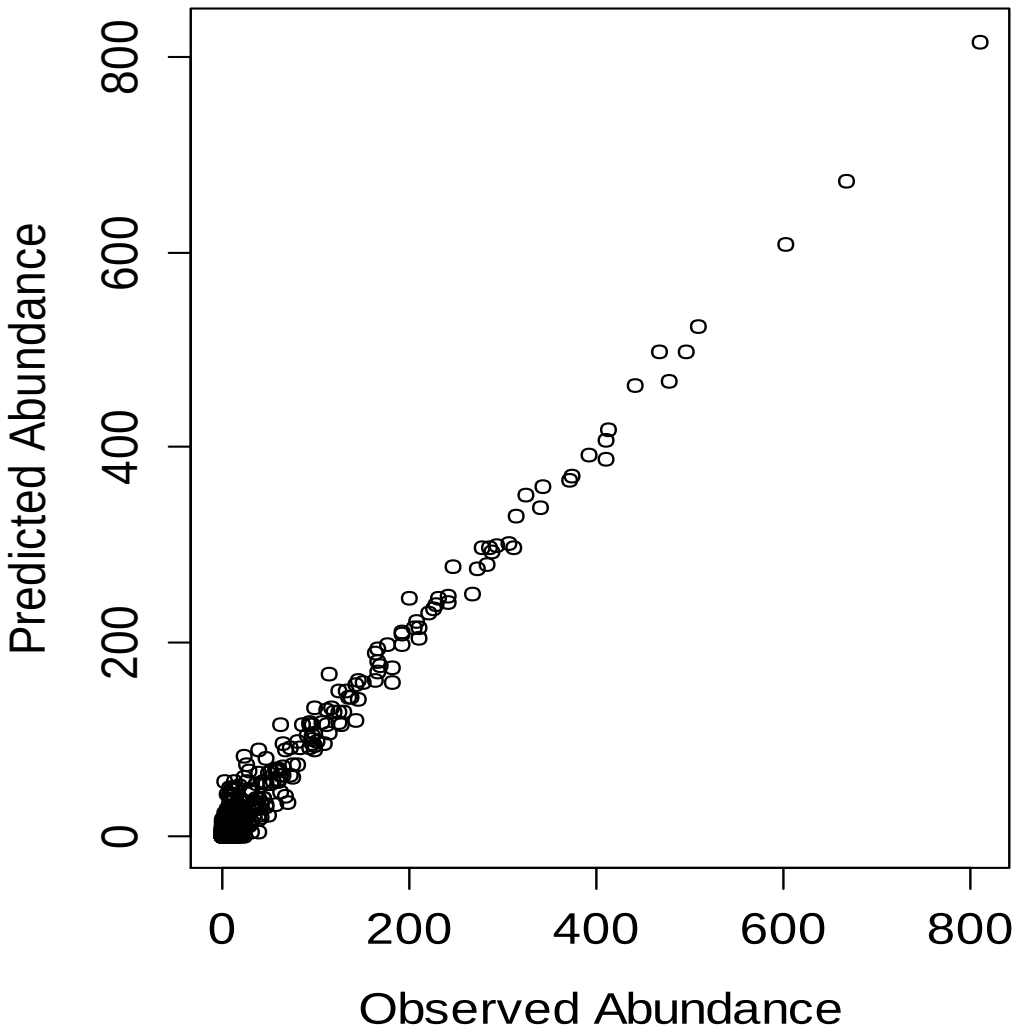
Samples in Zone 1 (southern Salish Sea)



Zone 1 – southern Salish Sea



Zone 1 – Salish Sea



% Deviance explained – 93%

% Deviance explained (crossvalidated) – 79%

Summary

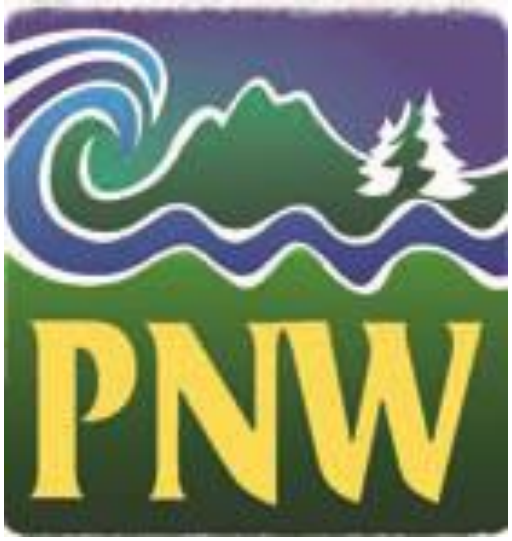
- Spatial distribution of nesting habitat is strongest predictor of murrelet distribution during breeding season
- Marine covariates contribute to prediction to a lesser degree along coast
- Marine human footprint is strongest contributor in Salish Sea
- Murrelet status and trend are therefore best predicted by the amount and pattern of adjacent nesting habitat at large scale
- Marine conditions affect short term and local abundance and trend
- **AND** - if prey data become available, marine models may improve

Is nesting habitat the limiting factor?

- Circumstantial evidence suggests it is
  - Amount of nesting habitat predicts offshore abundance
  - Decline of habitat is correlated with population decline
- However: our study is correlational – we have not established cause-effect relationships
- The big test will come as amounts of habitat increase in future
- We predict a murrelet population increase if our working hypothesis is true

Thanks to

- PNW Research Station and US Fish and Wildlife Service for funding
- Members of the Marbled Murrelet Effectiveness Monitoring team
- Field crews



For more information

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