Spatio-temporal dynamics of Marbled Murrelet hotspots during nesting in nearshore waters along the Washington to California coast

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Spatio-temporal dynamics of Marbled Murrelet hotspots during nesting along the Washington to California coast

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Nesting Habitat

Nest site abundance and quality

Production of young

Recruitment

Nest predators, disease

Adult survival

Foraging Habitat

Pollution, oil spills, gill-nets, disease

Prey abundance and distribution

Oceanographic conditions

Distribution and movement

Population status and trend
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)

2-8 km (varies by zone)
Marbled Murrelet Nesting Habitat (1996)

Murrelet Habitat Classes

- Class 1 (low)
- Class 2
- Class 3
- Class 4 (high)

Not habitat capable
Plan murrelet zones

Physiographic provinces
1. Washington Olympic Peninsula
2. Washington Western Lowlands
3. Washington Western Cascades
4. Washington Eastern Cascades
The scatter plot shows the relationship between the amount of suitable nesting habitat (in acres) and the murrelet population size. The equation of the trend line is given as:

$$ y = 0.12x + 1.0 $$

The coefficient of determination, $R^2$, is 0.895, indicating a strong linear relationship. The data points are plotted on the graph, with each point representing a year's data.
Murrelet population decline is related to loss of habitat.
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
## Model Covariates

<table>
<thead>
<tr>
<th>Spatial</th>
<th>Temporal</th>
<th>Spatiotemporal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to Major River</td>
<td>Biological Transition Day</td>
<td>Nesting Habitat (80 km)</td>
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<tr>
<td>Distance to Shore</td>
<td>Spring Physical Transition Day</td>
<td>Nesting Habitat Cohesion</td>
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<tr>
<td>Shoreline Type</td>
<td>Upwelling Anomaly</td>
<td></td>
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<td>Mean Depth w/in 10 km</td>
<td>Upwelling Season Duration</td>
<td>Summer SST</td>
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<td>Foraging Area w/in 10 km</td>
<td>Winter Oceanic El Nino Index</td>
<td>Winter SST</td>
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<td>Marine Human Footprint</td>
<td>Summer Oceanic El Nino Index</td>
<td>Summer Chlorophyll A</td>
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<td>Terrestrial Human Footprint</td>
<td>Winter PDO Index</td>
<td>Winter Chlorophyll A</td>
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<tr>
<td>Residuals Autocorrelation</td>
<td>Summer PDO Index</td>
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Spatial and temporal variation by Zone

Amount of nesting habitat

Murrelet population size

[Graphs showing trends in amount of nesting habitat and murrelet population size over time by zone.]
Sea surface temperature (°C)

Winter

Summer
Chlorophyll A (mg/m$^3$)

Winter

Summer
Marine Human Footprint  (Halpern et al. 2009)
Predictive performance
Most parsimonious model

% Deviance explained – 82.7%
% Deviance explained (crossvalidated) – 63.3%
Samples in Zone 1 (southern Salish Sea)
Zone 1 – southern Salish Sea

- MarHumanFootprint
- NestHabitatCohesion
- NestingHabitat
- RAC
- TerrHumanFootprint
- ChlorA_summer
- DistToMajorRiver
- SST_winter
- ShoreDistance
- SST_summer
- ChlorA_winter

Relative influence
Zone 1 – southern Salish Sea

% Deviance explained – 93%
% Deviance explained (crossvalidated) – 72%
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 hotspots are therefore best predicted by the amount and pattern of adjacent nesting habitat
• **BUT** - we need to look at non-breeding (winter) distribution
• **AND** - as prey data become available, models may improve
For more information

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