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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
- Nest predators, disease
- Production of young
- Recruitment
- Adult survival

Foraging Habitat

- Pollution, oil spills, gill-nets, disease
- Oceanographic conditions
- Prey abundance and distribution
- 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

0 25 50 Miles
0 40 80 Kilometers
Murrelet population decline is related to loss of habitat.
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

## Spatial
- Distance to Major River
- Distance to Shore
- Shoreline Type
- Mean Depth w/in 10 km
- Foraging Area w/in 10 km
- Marine Human Footprint
- Terrestrial Human Footprint
- Residuals Autocorrelation

## Temporal
- Biological Transition Day
- Spring Physical Transition Day
- Upwelling Anomaly
- Upwelling Season Duration
- Winter Oceanic El Nino Index
- Summer Oceanic El Nino Index
- Winter PDO Index

## Spatiotemporal
- Nesting Habitat (80 km)
- Nesting Habitat Cohesion
- Summer SST
- Winter SST
- Summer Chlorophyll A
- Winter Chlorophyll A
- Winter PDO Index
- Summer PDO Index
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 by zone over different years.]
Sea surface temperature (°C)

Winter

Summer

Zone
1
2
3
4
5
Chlorophyll A (mg/m³)

Winter

Summer

Zones: 1, 2, 3, 4, 5
Marine Human Footprint  (Halpern et al. 2009)
Component | % Influence
----------|-------------
NestHabitatCohesion | 55.3
NestingHabitat | 
ShoreDistance | 
RAC | 
TerrHumanFootprint | 
ChlorA_winter | 
ChlorA_summer | 
SST_summer | 
MarHumanFootprint | 
SST_winter | 
ShoreType | 
DistToMajorRiver | 
Depth | 
ForagingArea | 
ONI_summer | 
PDO_winter | 
Foraging | 33.3

Relative influence

Component: Nesting and Foraging
% Influence: Nesting 55.3, Foraging 33.3
Predictive performance
Most parsimonious model

% Deviance explained – 82.7%
% Deviance explained (crossvalidated) – 63.3%
Murrelet Density vs. various factors:

- 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)

Mean Density (birds/km²)
- 0.0 - 0.1
- 0.2 - 0.8
- 0.9 - 2.4
- 2.5 - 8.5
- 8.6 - 51.7
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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