Population Trends:  
Eldorado Study Area 

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Sierra Nevada Owl Population Studies

- CASPO (Noon et al. 1992)
- Seamans et al. 2001
- Franklin et al. 2004
- Seamans and Gutiérrez 2007
- Blakesley et al. 2010
- Connor et al. 2013
- Tempel and Gutiérrez 2013
Population Trends: Eldorado Density Study Area (EDSA)

1) Compared population trends from occupancy and mark-recapture data on the EDSA (1993-2010).
2) Developed an integrated population model (IPM) to assess population trends using all data collected on EDSA (1990-2012).

Eldorado Density Study Area (EDSA)

- 35,500 ha on Eldorado National Forest.
- Elevations from 360 to 2,400 m.
- Primary vegetation is mixed-conifer forest.
- Land ownership is 60% public, 40% private.
- Entire EDSA was surveyed regardless of topography and ownership.
Survey Coverage of EDSA

- Funding constraints in early years of study prevented complete survey coverage.
- Assessed coverage in ArcGIS from 1990-2010:
  - Placed buffers around nocturnal survey locations and nest/roost locations.
  - 1993 was first year with > 90% coverage of EDSA and surveys at > 90% of owl territories.

Part 1: Occupancy and Abundance

- Detection-nondetection studies are less expensive than mark-recapture studies (Noon et al. 2012).
- Recent statistical advances: imperfect detection, site- and survey-specific covariates, multiple seasons, and multiple states (MacKenzie et al. 2006).
- Theory suggests fundamental relation between occupancy and abundance.

Occupancy Results

• Within-year $p$
  – Top model had 100.0% AIC weight.
  – $p$ increased after initial detection of owls.
  – $p$ was higher at territories with nesting owls.

• Annual variation in $\varepsilon_t$, $\gamma_t$, $p_t$
  – Considerable model selection uncertainty so I used model averaging.
  – Parameter estimates always showed increasing $\varepsilon$ and decreasing $\gamma$. 
Mark-Recapture Results

- **Annual $p$**
  - Top model had 35.7% AIC weight.
  - $p$ was higher for males.
  - $p$ was higher with increased survey effort.

- **Annual variation in $\lambda_t$, $\phi_t$, $f_t$**
  - Considerable model selection uncertainty so I used model averaging.
  - Survival was nearly constant; $\lambda$ and recruitment declined.

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**Annual Variation in $\lambda_t$, $\phi_t$, $f_t$**

- Rate of population change
- Survival
- Recruitment
Part 1: Conclusions

• Occupancy monitoring suitable as cost-effective alternative for monitoring spotted owl population trends.

• Important caveats:
  – Results do not necessarily extend to non-territorial species.
  – Mark-recapture studies provide information that occupancy studies do not (life-history).
Part 2: Integrated Population Models (IPM)

- Multiple data sources.
- Population size is linked to demographic rates (e.g., Leslie matrix).
- Individual data sets are modeled.
- Inference is based on the joint likelihood (i.e., multiplication of individual likelihoods).


Potential Benefits of IPM

- Increased precision of parameter estimates.
- Estimate parameters for which no specific data were collected.
- Account for all sources of uncertainty in the parameter estimates.
IPM for Spotted Owls

Data:

- $y$ = no. of adult owls detected
- $J$ = no. of juveniles detected
- $R$ = no. of adults assessed for reproduction
- $m$ = individual capture histories (juveniles, adults)

Population parameters:

- $N$ = no. of adults in population with two age classes (1 year old, ≥ 2 years old)
- $f$ = reproductive output (juveniles per adult)
- $imm$ = immigration rate (immigrants per adult)
- $\phi_{juv}$ = apparent juvenile survival
- $\phi_{ad}$ = apparent adult survival
- $p$ = recapture probability
Analyses for Multi-state Occupancy and IPM

• Markov Chain Monte Carlo (MCMC) to obtain parameter estimates within a Bayesian framework.
• All parameters modeled as random effects.
• Conducted analyses in WinBUGS and OpenBUGS.

Multi-State Occupancy Model
(MacKenzie et al. 2007)

• Obtained estimates of $y$ and $J$ that accounted for imperfect detection.
• Territory states:
  0 = no owls present
  1 = one owl present
  2 = pair of owls present, no young produced
  3 = pair of owls present, 1 young produced
  4 = pair of owls present, 2 young produced
“Counts” from Occupancy Model

IPM Results: Apparent Survival
IPM Results: Rate of Population Change

\( \lambda = 0.969 \), 95% CRI 0.957—0.980

IPM Results: Realized Population Change

\( J_{2012} = 0.501 \), 95% CRI 0.384—0.642
Correlations Between $\lambda$ and Demographic Rates

**Part 2: Conclusions**

- Population has declined by 50% since 1990.
- Increased precision compared to analyses of individual data sets.
- Immigration important for this population.
- Further research needed on causes of population decline.
Retrospective Analysis: Effects of Timber Harvest and Fire

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Historic Information

- CSO potentially different than NSO in terms of logging and fire effects
- Lack of clear cut logging on public land in the Sierra Nevada and no gaps in distribution
- CASPO predicated on examining harvest effects
- Seamans and Gutiérrez 2007
- Tempel et al. In Press
Predicted Short vs Long-term Risk of SPLATS

30 years after a high-severity fire, more habitat with SPLATs than without SPLATs.

30 years after a high-severity fire, same habitat amount with and without SPLATs.

Short-term Effects of Timber Harvest and Fire on Spotted Owls

1) Retrospective analysis of data from the Eldorado Density, Regional, and Last Chance (SNAMP).
2) Developed annual vegetation maps for 74 owl territories.
3) Modeled the relationships between habitat/treatment and owl demographic and occupancy rates.

Modified Study Design

- Insufficient treatment territories in Last Chance → Expansion to Eldorado Study Area
- Delay in treatments/low power → Retrospective analysis (1993-2012); n = 74 territories
- “Quasi-experimental” evaluation of SPLATs → Correlative assessment of many treatments types
Map of Habitat and Habitat Change

400 ha analysis circle

1993

2009

Vegetation Classes

Hardwood

Pole-sized forest

Clearcut/Brush/Sapling

12-24" dbh

30-70% CC

Veg class 1

Veg class 3

Veg class 2

Veg class 4
Timber Harvest Categories

- **Heavy**
  - Clear cut, overstory removal, seed tree removal, seed tree cut, shelterwood removal/commercial thin, shelterwood seed step

- **Medium (with and without understory removal)**
  - Commercial thin, selection, single-tree selection, group selection, thinning for hazardous fuels removal, fuel break, SPLATS

- **Light**
  - Pre-commercial thin, sanitation salvage
Analytical Approach

• **Dependent variables**: Reproductive output, survival, and occupancy (extinction and colonization)

• Development of *a priori* models with *explanatory variables*:
  - Stage 1: owl nesting/roosting habitat
  - Stage 2: other habitat-related variables
  - Stage 3: timber harvest, fire

• 3-, 6-, and 9-year “moving windows” for stage 3 variables

Analytical Approach

• Conducted sensitivity analyses for population growth rate and equilibrium occupancy.

• Used explanatory variables in top-ranked models for reproduction and survival to estimate population growth rate.

• Used explanatory variables in top-ranked models for territory extinction and colonization to estimate equilibrium occupancy.
Explanatory Variables

• Owl habitat
  • Forest dominated by trees ≥ 12” dbh with high canopy cover (≥ 70%) *(classes 5 and 7)*
  • Forest dominated by trees ≥ 24” dbh with lower canopy cover (≥ 30%) *(classes 6 and 7)*

• Other habitat-related variables
  • Hardwood forest
  • Edge between owl nesting/roosting habitat and shrubs/saplings
  • Mean patch size of owl nesting/roosting habitat
  • Habitat diversity (Shannon-Wiener index)
  • Private land

• Timber harvest, fire
  • High-intensity timber harvest
  • Medium-intensity harvest
  • Medium-intensity harvest with understory removal
  • Low-intensity timber harvest
  • Wildfire
  • Interaction between owl nesting/roosting habitat and timber harvest/wildfire

Top-ranked Overall Models

• Reproductive output
  – Adult females had higher reproduction
  – Negatively correlated with hardwoods and medium-intensity timber harvest

• Survival
  – Adults and males had higher survival
  – Positively correlated with log(57) and edge

• Territory extinction
  – Negatively correlated with 57 and high-intensity timber harvests
  – Positively correlated with habitat diversity

• Survival
  – Positively correlated with 57 and habitat diversity
  – Negatively correlated with wildfire
Territories Impacted by 2001 Star Fire

- RSTAR, CHPMK vacated and never recolonized.
- NFKLC, SPHOL colonized once.
- Other territories never vacated, so could not be colonized.

Sensitivity Analyses for Population Growth

- (a) Area (ha) of vegetation classes 5 – 7 ($R^2 = 0.74$)
- (b) Amount (km) of habitat edge ($R^2 = 0.32$)
- (c) Area (ha) of medium-intensity harvests ($R^2 < 0.01$)
- (d) Area (ha) of hardwood forest ($R^2 = 0.02$)
Sensitivity Analyses for Equilibrium Occupancy

Caveats

- Characterizing the effect of habitat change and treatments on CSO demography challenged by:
  - Correlative rather than experimental nature of study
  - Broad range of treatments and disturbances
  - Resolution of habitat map
    - Coarse and subjective binning of habitat classes
    - Large and residual trees not mapped
    - Understory characteristics not mapped
  - Timing of treatments
  - Variability in “quality” among individual owls
Conclusions

• High-canopy forest (≥ 70%, classes 5 and 7) was primary correlate of owl population growth and occupancy at the territory scale.

• High-canopy forest declined by 7.4% during our study, which may have contributed to declines in abundance from 1993-2012.

• Timber harvest was not strongly correlated with territory-scale dynamics, but > 90% of medium-intensity harvests within high-canopy forests converted them to lower canopy cover class.

• Some evidence that high-intensity fire can negatively impact territory occupancy.

Recommendations

• Target forests with lower canopy cover for fuel treatments.
  – 40.7% of medium-intensity harvests occurred in class 4.
  – 10.6% of medium-intensity harvests occurred in class 6.

• Fuel treatments should retain focus on removal of ladder fuels and smaller trees, while maintaining higher canopy cover.
Owl Habitat Metrics

- **Fireshed Scale**
  - Nesting habitat quality on continuous scale based on canopy cover, large tree density, and vertical structure (Gini coefficient)

- **PAC Scale**
  - Change in nesting habitat quality within PACs

- **Territory Scale (400 ha)**
  - Forested area with >70% canopy and >12 inch trees (for demographic analysis)

Owl Habitat Metric: Probability of Forest Being Owl Nesting Habitat

- Used veg plots from Eldorado Density Study Area at nest sites and random sites in classes 4, 5, 6, and 7.
- Recorded canopy cover and all trees ≥6” dbh within 20 x 100 m plots.
- Performed a logistic regression for owl nesting vs. available habitat using:
  - 22 nest plots.
  - 21 plots in Class 4.
  - 3 plots in Class 5.
  - 7 plots in Class 6.
  - 5 plots in Class 7.
- Explanatory variables were large tree density, canopy cover, and Gini coefficient.
Probability of Nesting Habitat

Owl Demographic Metrics

- Demographic Metrics
  - Reproduction, survival, territory extinction and colonization
  - Composite demographic metrics
    - Population growth rate ($\lambda$) from matrix model parameterized with survival and reproductive rates.
    - Equilibrium occupancy parameterized with territory extinction and colonization.
- Scale of Demographic Metrics
  - Owl territories (400 ha) in Last Chance
Fire-Owl Habitat/Demography Modeling

Owl Territories and PACs at Last Chance

- Six occupied territories have ≥40 % of their area within Lidar footprint.
- Ten PACs with at least partial overlap of the Lidar footprint.
- Quantify change in habitat within entire footprint and within PACs only.
- Quantify change in habitat within owl territories, then estimate population growth and equilibrium occupancy at those territories.
Methods

• Spatial and FFEH Teams developed base vegetation maps for Last Chance (pre- and post-SPLAT).
• FFEH Team simulated fire under extreme weather conditions in year 2013.
• FFEH Team simulated forest growth in 10-year increments 30 years into the future (2023, 2033, 2043).
• Vegetation maps to year 2043 have been generated under 4 scenarios:
  • No SPLAT, no fire.
  • No SPLAT, fire.
  • SPLAT, no fire.
  • SPLAT, fire.
• Initial examination of vegetation maps suggest that resolution of habitat variables may not of sufficient resolution to use “thresholds” for owl nesting habitat.

Methods

• Use the Last Chance veg maps under the four scenarios.
• Use logistic regression equation to predict probability that each stand with ≥ 30 % canopy cover contains suitable owl nesting habitat.
• Any stand with ≤ 30 % canopy cover has zero probability of being owl nesting habitat.
• Owl habitat quality = sum of the probability of nesting habitat across all polygons.