Using landscape-scale passive acoustic monitoring to inform forest management across California's Sierra Nevada

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FHRP
July 26, 2023

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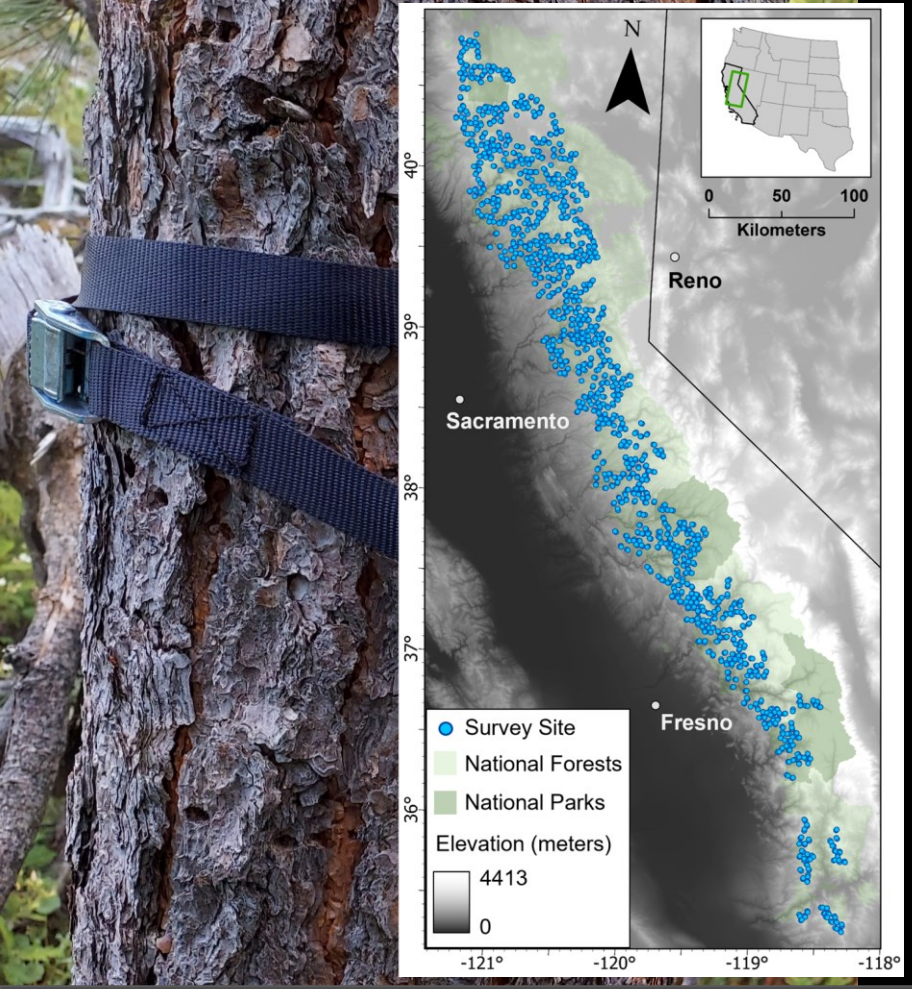
Funding

CAL FIRE SINCE 1885
FRAP Fire and Resource Assessment Program California Department of Forestry and Fire Protection
California Climate Investments Cap and Trade Dollars at Work
Forest Service U.S. Department of Agriculture
National Park Service
NASA
Biological Diversity & Ecological Conservation

Passive acoustic monitoring

- Surveying and monitoring wildlife and environments using sound recorders (autonomous recording units, ARUs)
- Systematically surveying acoustically-active species across the Sierra Nevada

1,702 ARUs deployed across 22,000 km^2 in the Sierra Nevada, CA



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Each records continuously between 6pm and 9am

Each unit is deployed for 5 weeks

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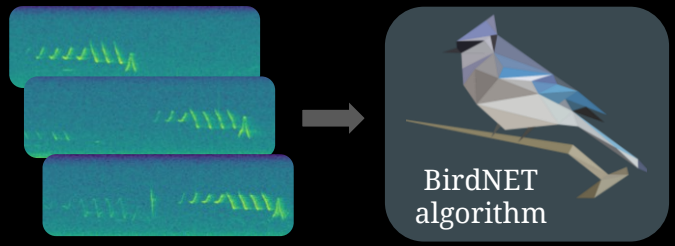
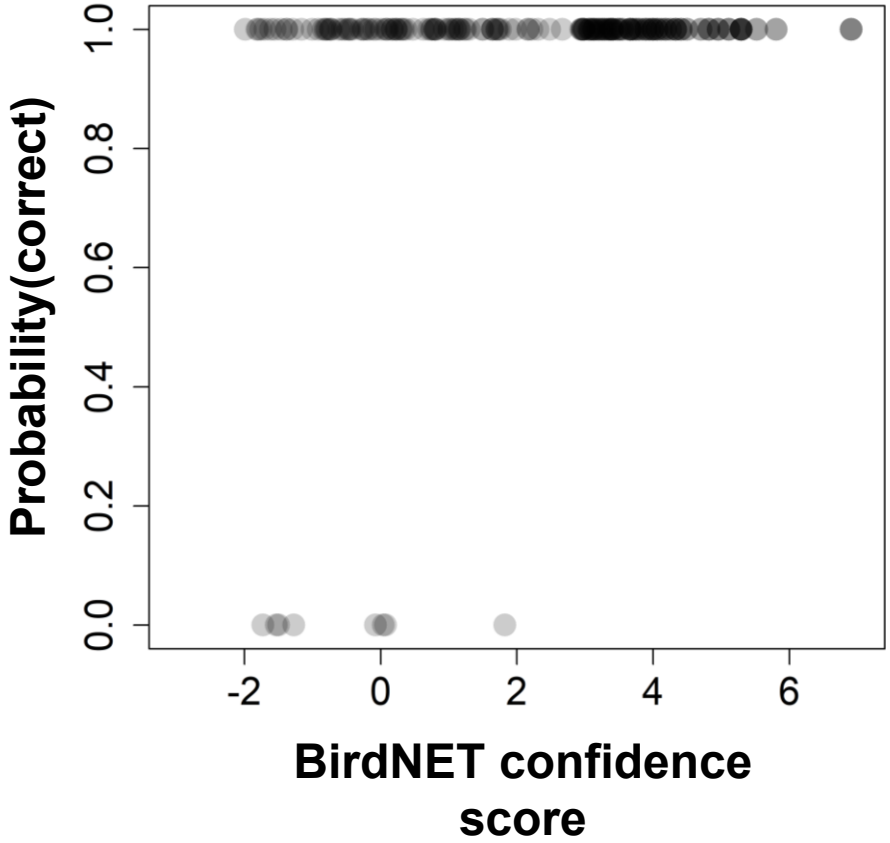


Process recordings using BirdNET to identify target species signals

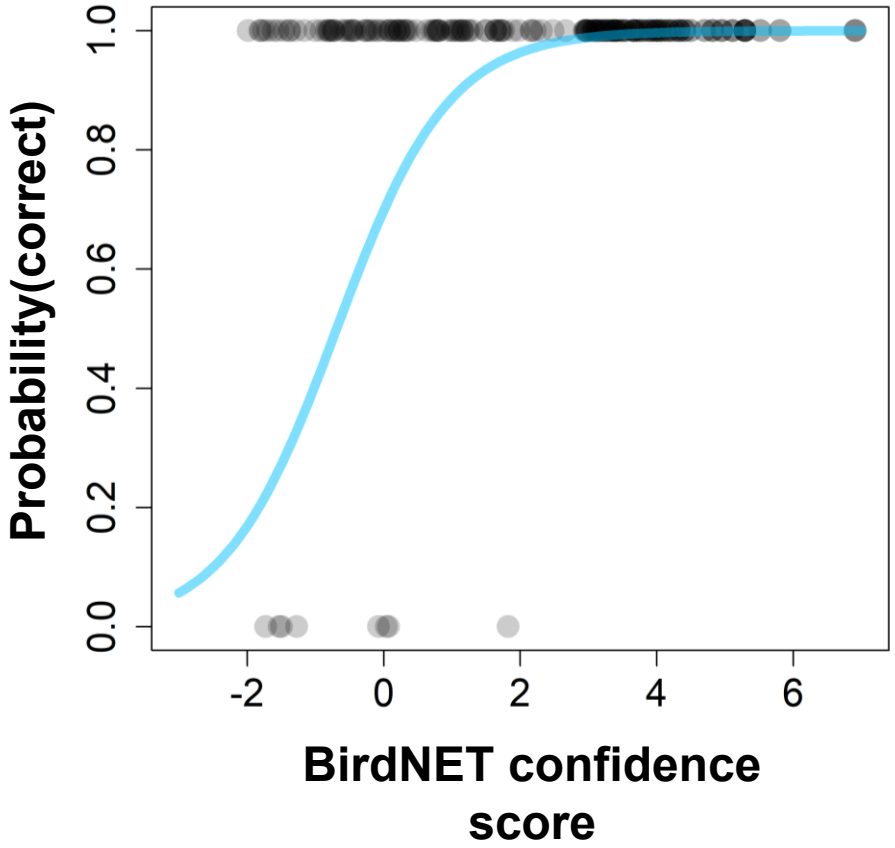
Automated Processing

- Manually validate a random subset of BirdNET detections



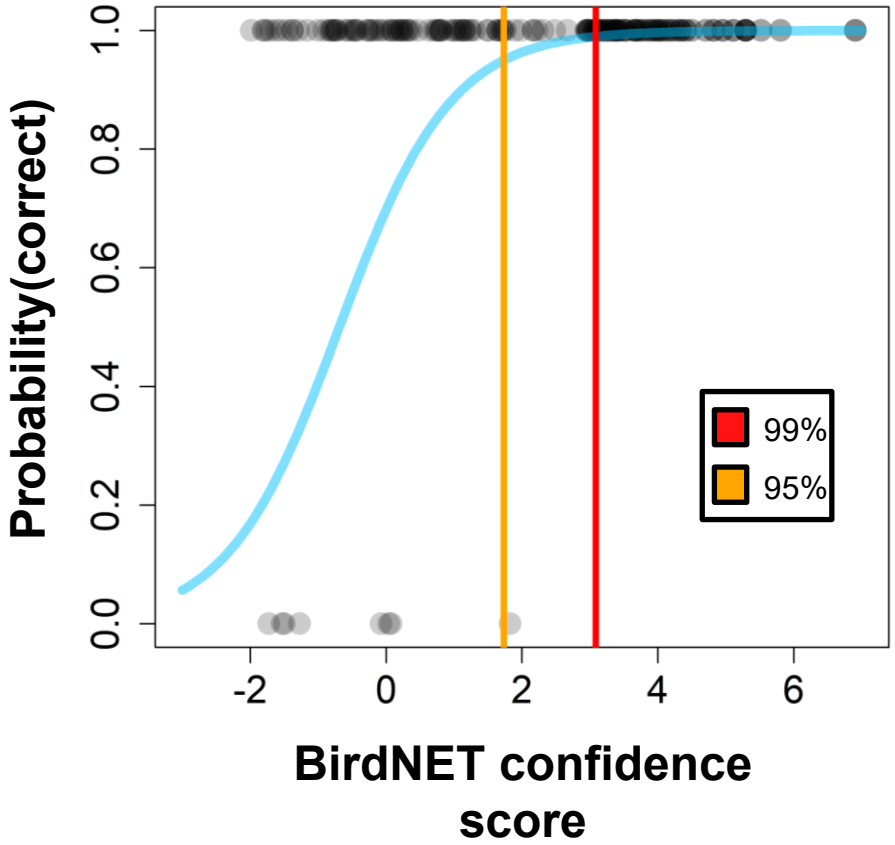
Automated Processing

- Manually validate a random subset of BirdNET detections
- Use logistic regression to associate a BirdNET confidence score with an actual probability of being correct

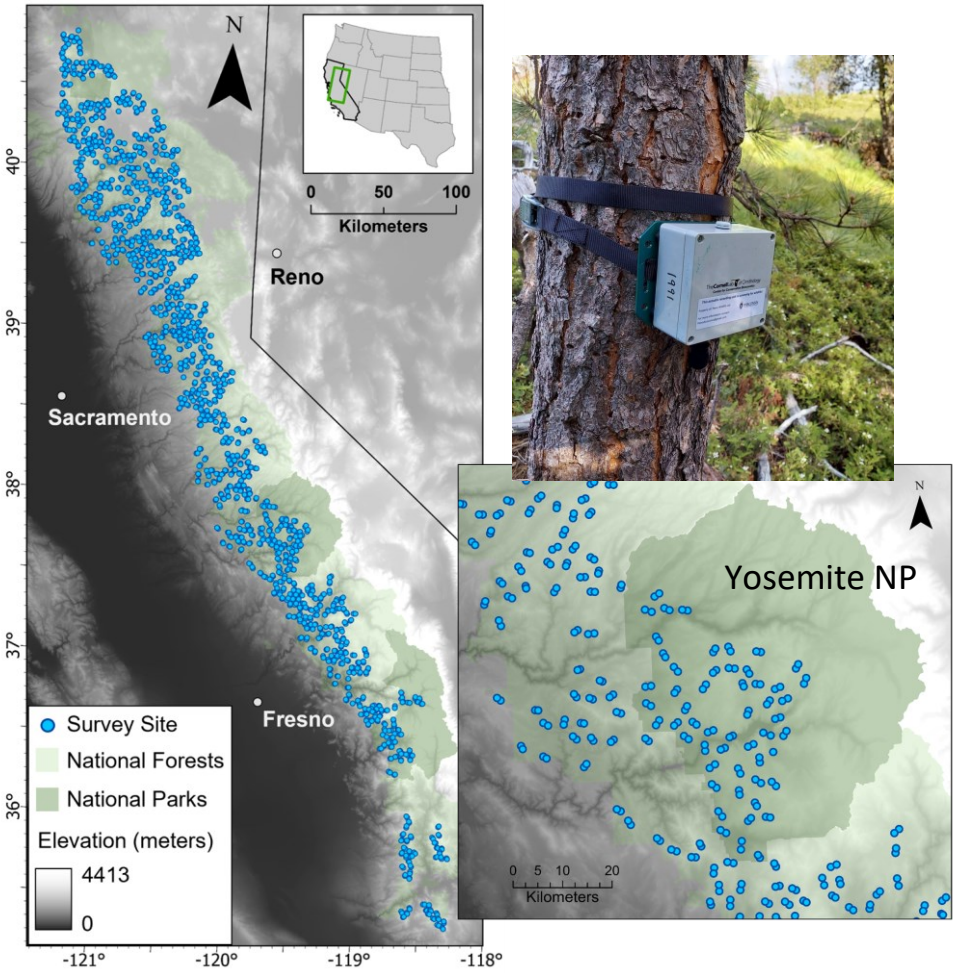


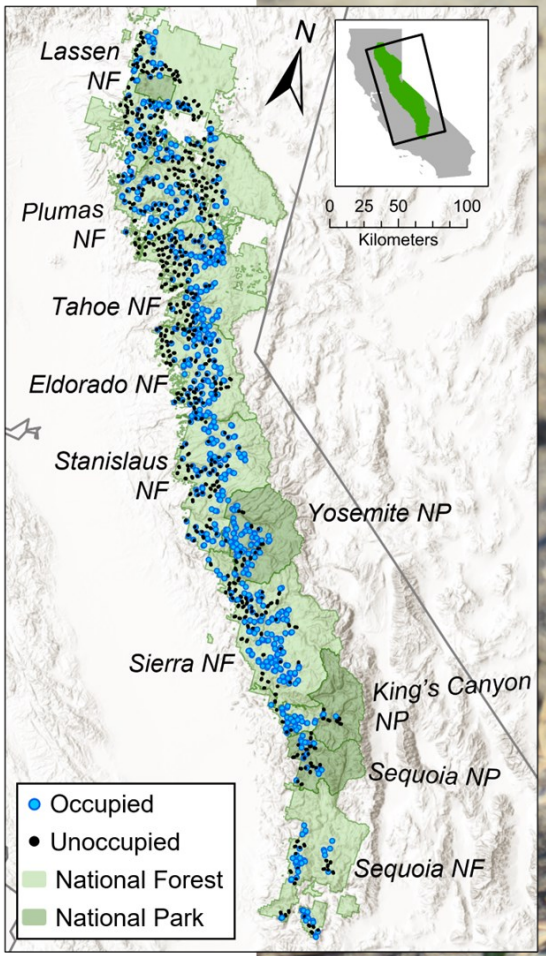
Automated Processing

- Manually validate a random subset of BirdNET detections
- Use logistic regression to associate a BirdNET confidence score with an actual probability of being correct
- Choose a threshold that fits with the goal of the study and modeling methods



Landscape-scale passive acoustic monitoring enables new insights about acoustically-active species across the entire Sierra Nevada



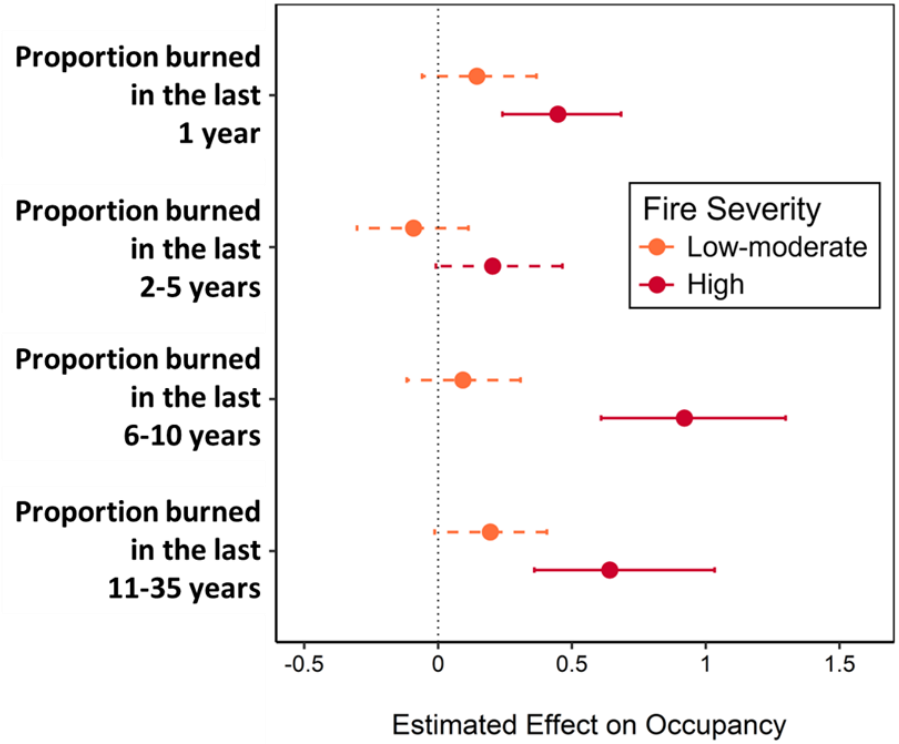


We examined mountain quail habitat and fire associations across 1,636 sites using acoustic data

- 227,972 hours of audio
- 678,104 total detections

Estimated mean occupancy 54% (48%-61%)

Mountain Quail occupancy is positively correlated with high-severity fire, especially 6-10 years post-fire



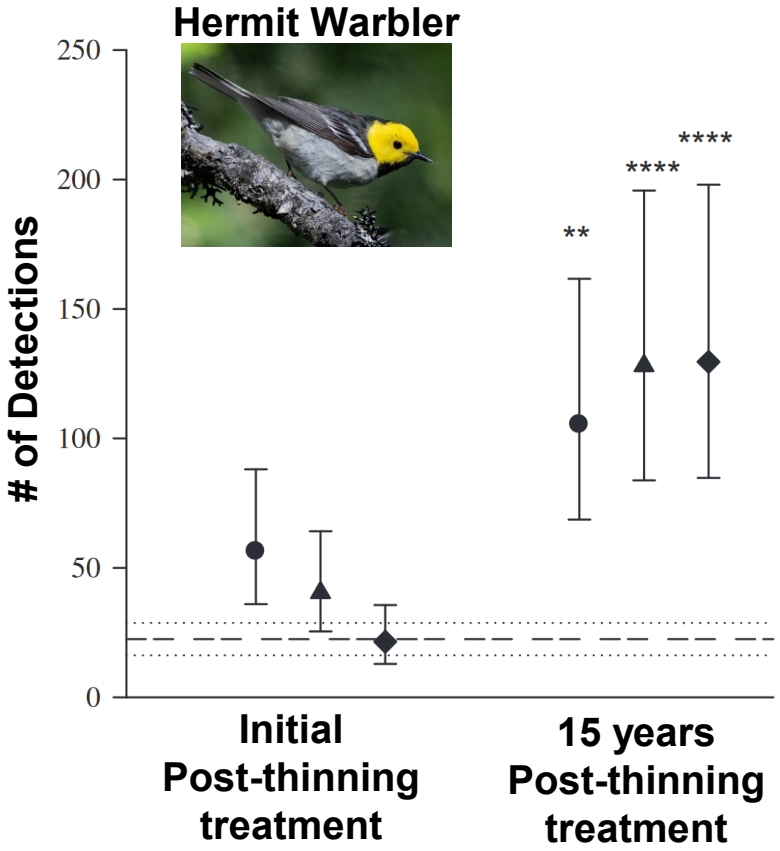
California's Sierra Nevada

- Altered forest structure interacts with climate to create more frequent, large, and homogenously severe fires

- Megafires reduce forest resilience
  - Limit ability of forests to regenerate
  - Large-scale ecosystem shift?

- Forest restoration activities have trade-offs

Restoration treatments are a balancing act



Figures adapted from Jones et al. (2021) *Front Ecol Environ* (left), Cahall et al. (2013), *Forest Ecol Manag* (right)

Management Indicator Species

Shrubland

Riparian

Oak/
Hardwood

Early-Mid
Seral Conifer

Green Forest
Snags

Burned Forest
Snags

Late Seral, Open-
canopy Conifer

Late Seral,
Closed-canopy
Conifer

Management Indicator Species (and friends)

Shrubland

Riparian

Oak/
Hardwood

Early-Mid
Seral Conifer

Green Forest
Snags

Burned Forest
Snags

Late Seral, Open-
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Late Seral,
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Goals

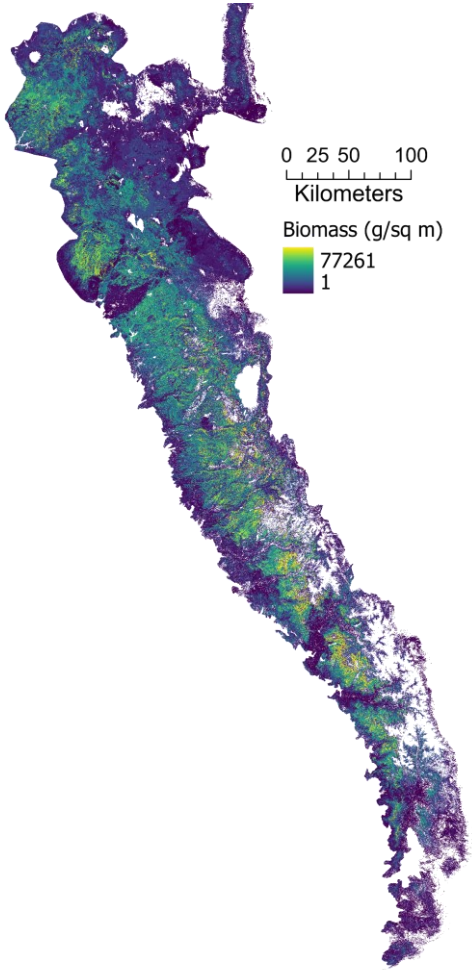
Create systematic Sierra-wide models of indicator species distributions in the context of habitat characteristics and fire history

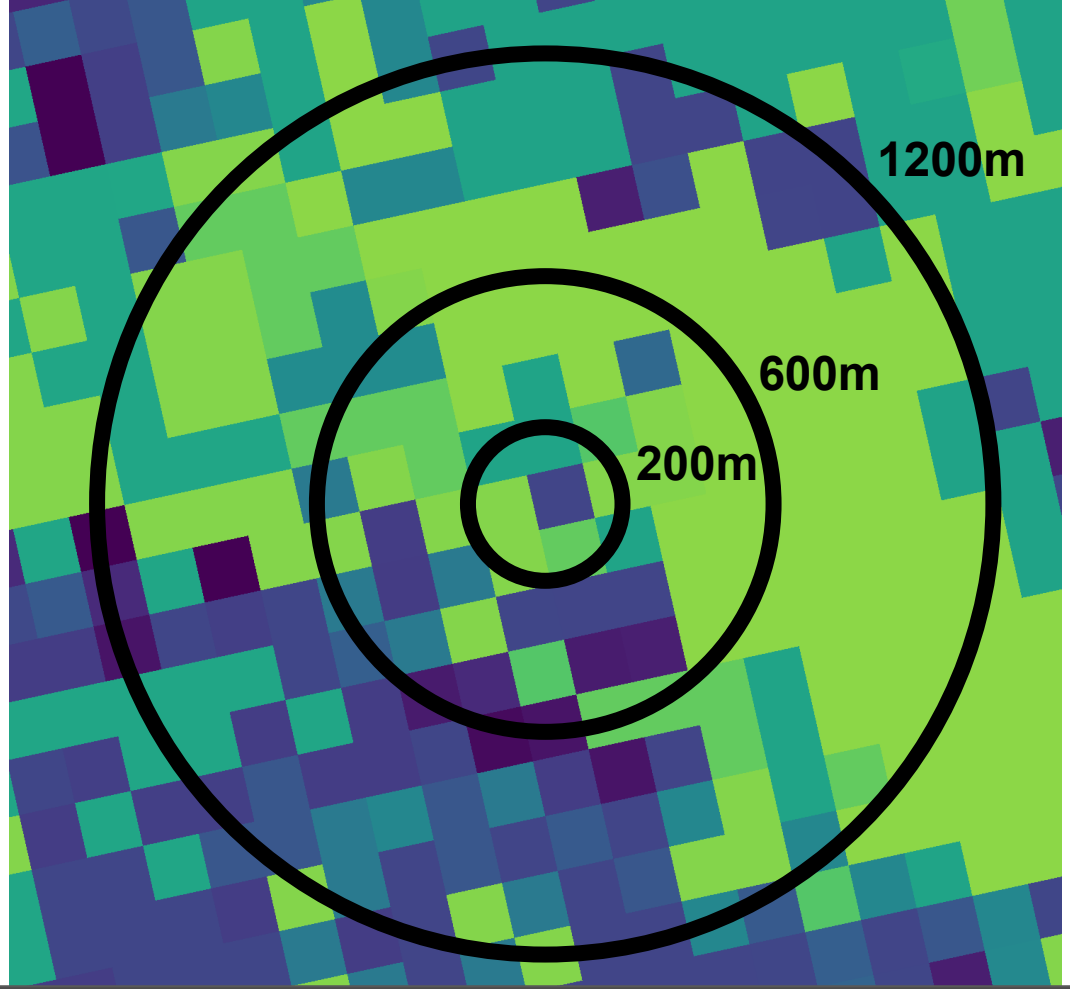
Enhance understanding of short-term and long-term tradeoffs associated with forest restoration treatments

Modeling

- Bayesian occupancy modeling
  - Accounts for imperfect detection

- Fuels, forest structure metrics, fire history, + elevation to predict distributions
  - Biomass, canopy cover, canopy height, trees per acre, basal area per acre
  - Forest cover type
  - Fire – severity and time-since-fire





Three spatial scales

200m buffer
(12.5 ha)

600m buffer
(113 ha)

1200m buffer
(452 ha)

Naïve occupancy of indicator species

4,570 detections
4%

1,803 detections
5%

354,573 detections
15%

5,983 detections
17%

678,104 detections
44%

736,813 detections
58%

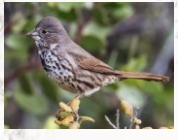
970,409 detections
59%

225,396 detections
88%

5,431 detections
5%

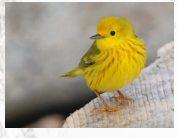
19,715 detections
22%

Fox Sparrow



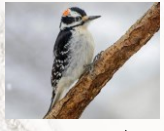
Shrubland

Yellow Warbler



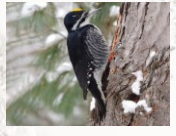
Riparian

Hairy WP

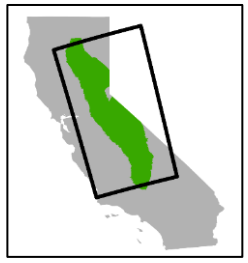


Green Forest Snags

Black-backed WP



Burned Forest Snags

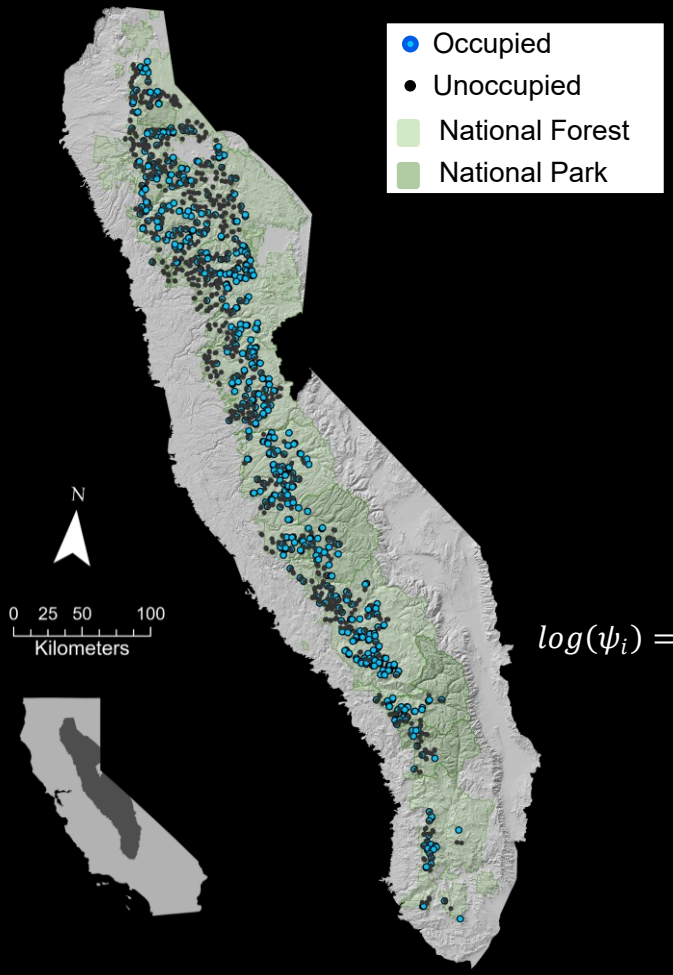


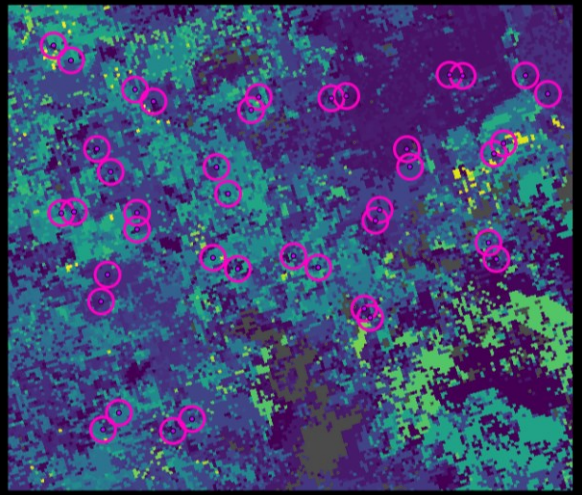
N

0 25 50 100

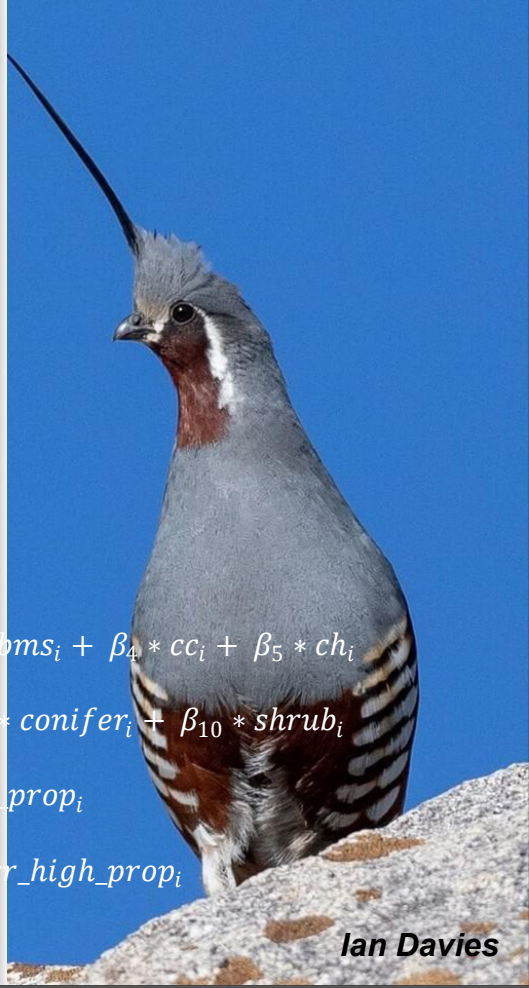
Kilometers

- Occupied
- Unoccupied
- National Forest
- National Park

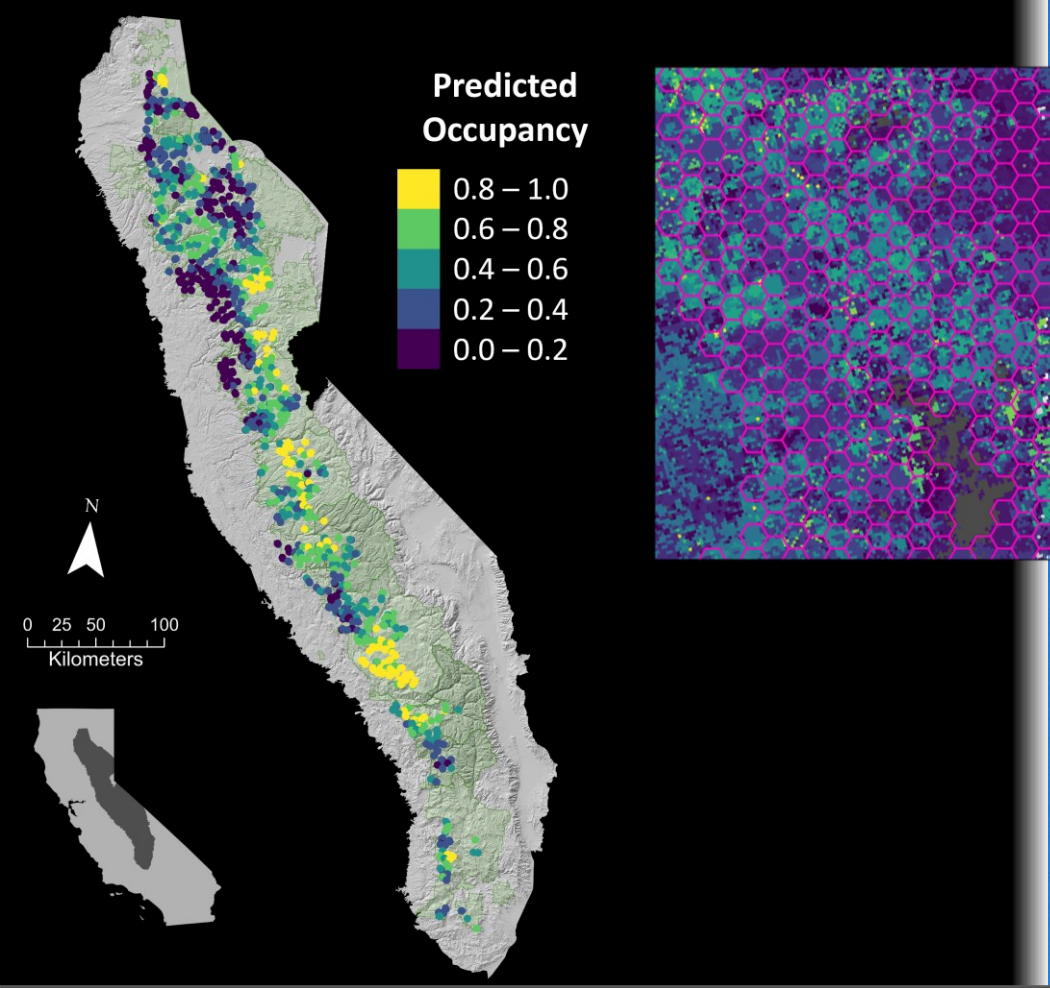


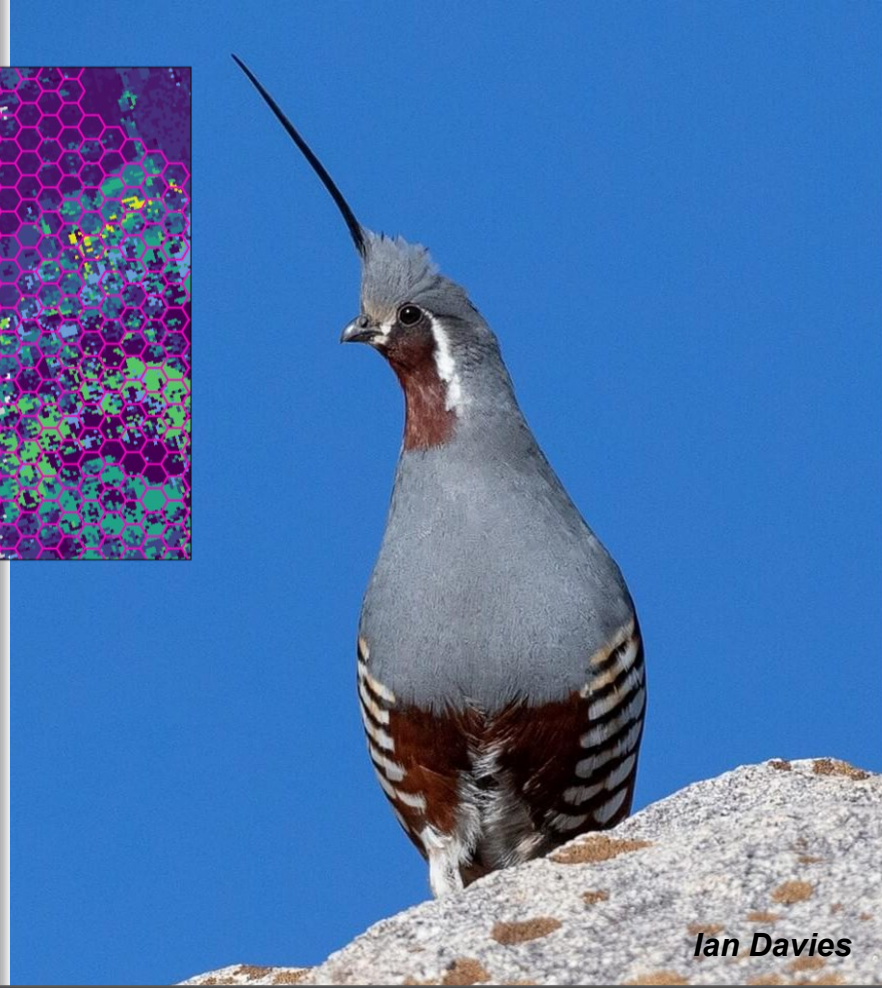


$$log(\psi_i) = \beta_0 + \beta_1 * elev.resid_i + \beta_2 * elev.resid_i^2 + \beta_3 * bms_i + \beta_4 * cc_i + \beta_5 * ch_i$$
$$+ \beta_6 * bapa_i + \beta_7 * tpa_i + \beta_8 * mixed_i + \beta_9 * conifer_i + \beta_{10} * shrub_i$$
$$+ \beta_{11} * bapa * tpa_i + \beta_{12} * fire5yr\_lowmod\_prop_i$$
$$+ \beta_{13} * fire5yr\_high\_prop_i + \beta_{14} * fire6\_10yr\_high\_prop_i$$



Ian Davies


Predicted Occupancy
0.8 – 1.0
0.6 – 0.8
0.4 – 0.6
0.2 – 0.4
0.0 – 0.2
N
0 25 50 100
Kilometers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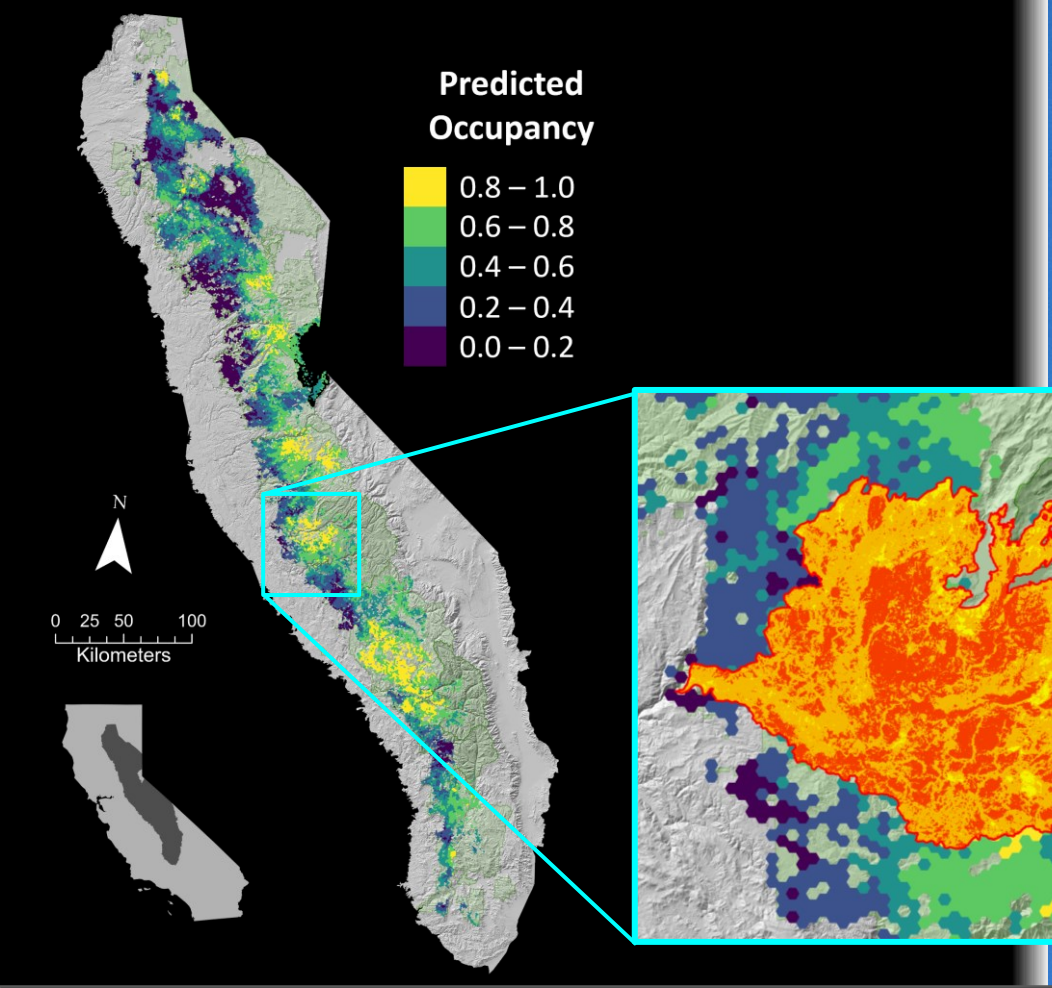
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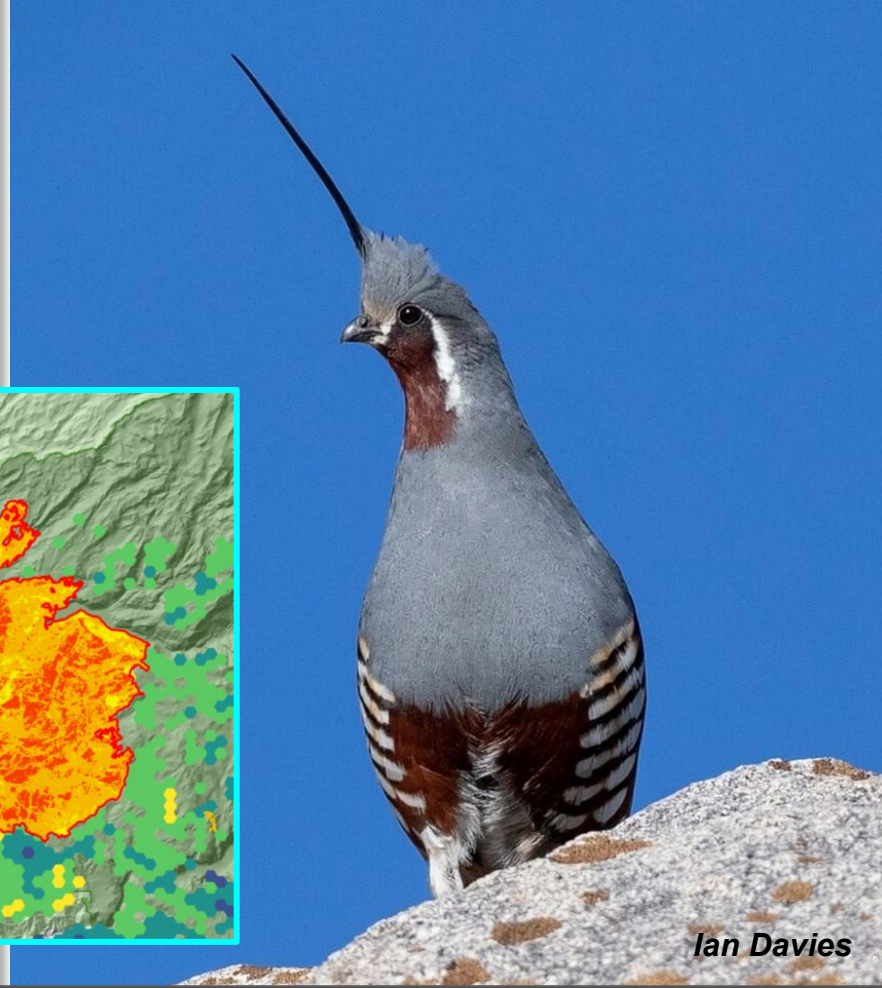
0 25 50 100
Kilometers



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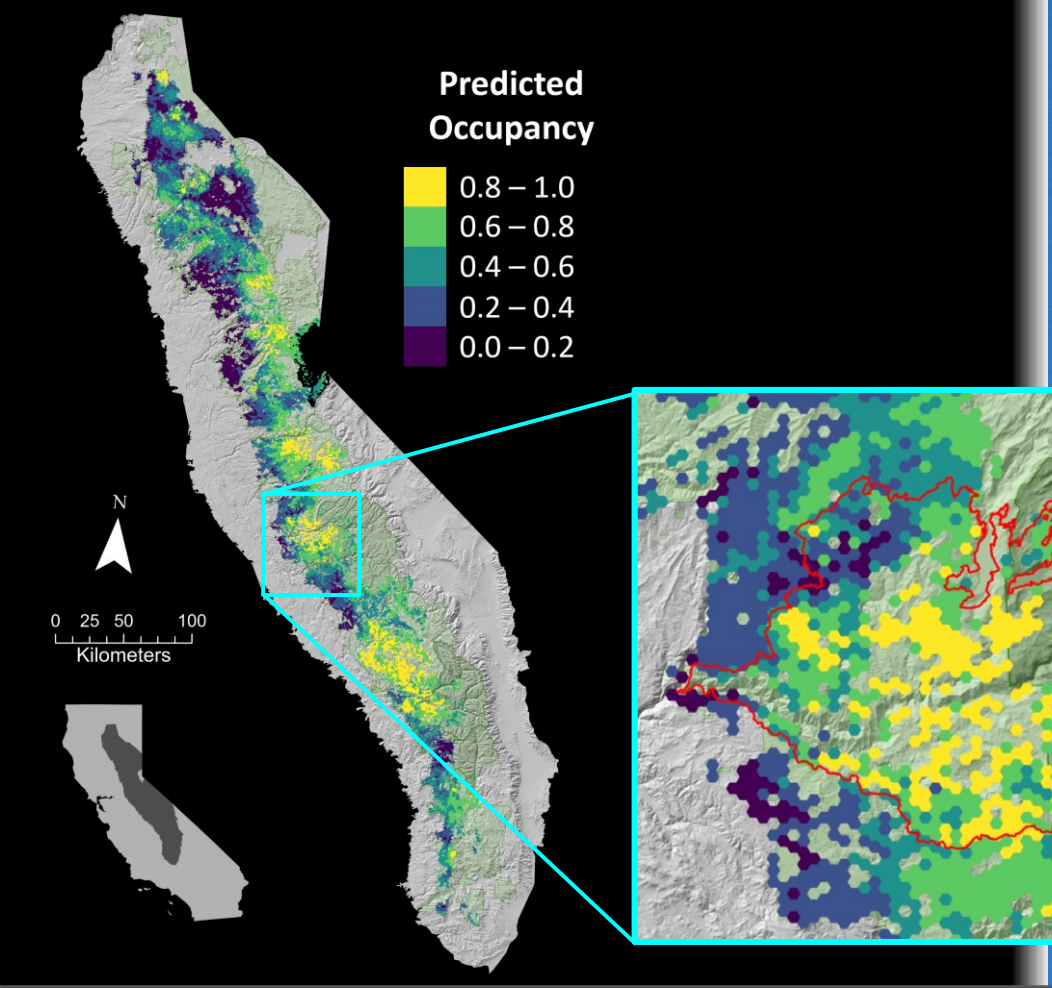
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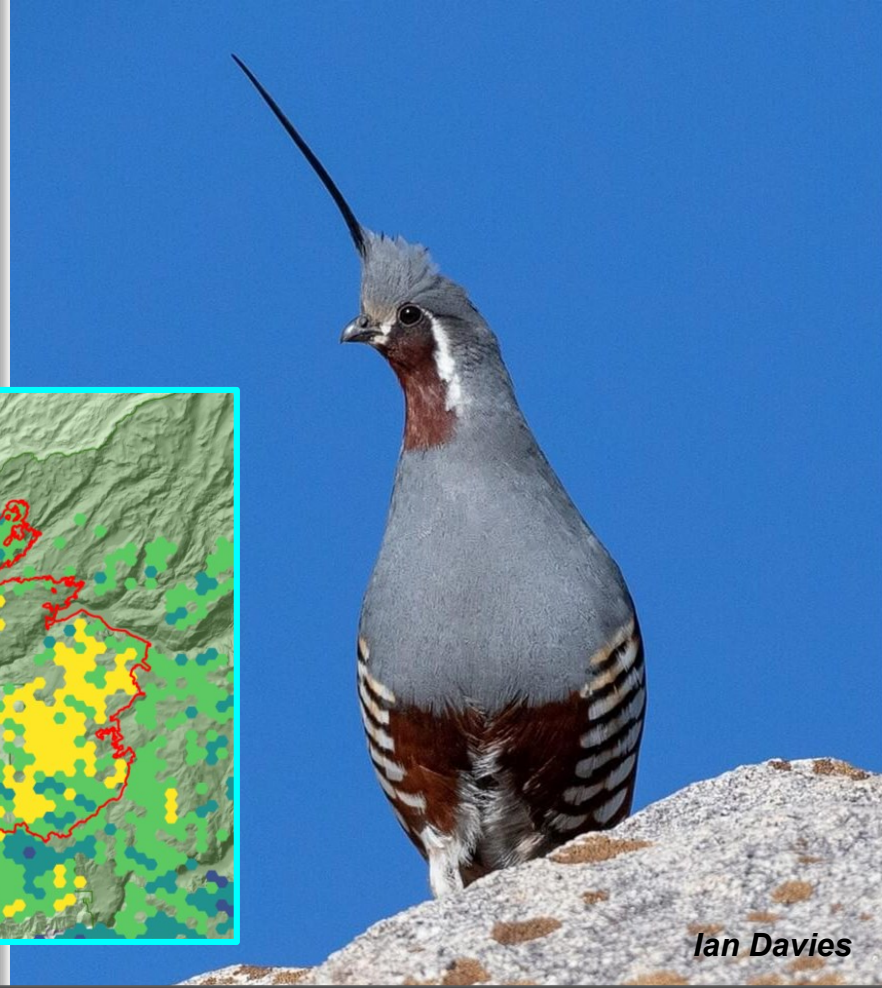
0 25 50 100
Kilometers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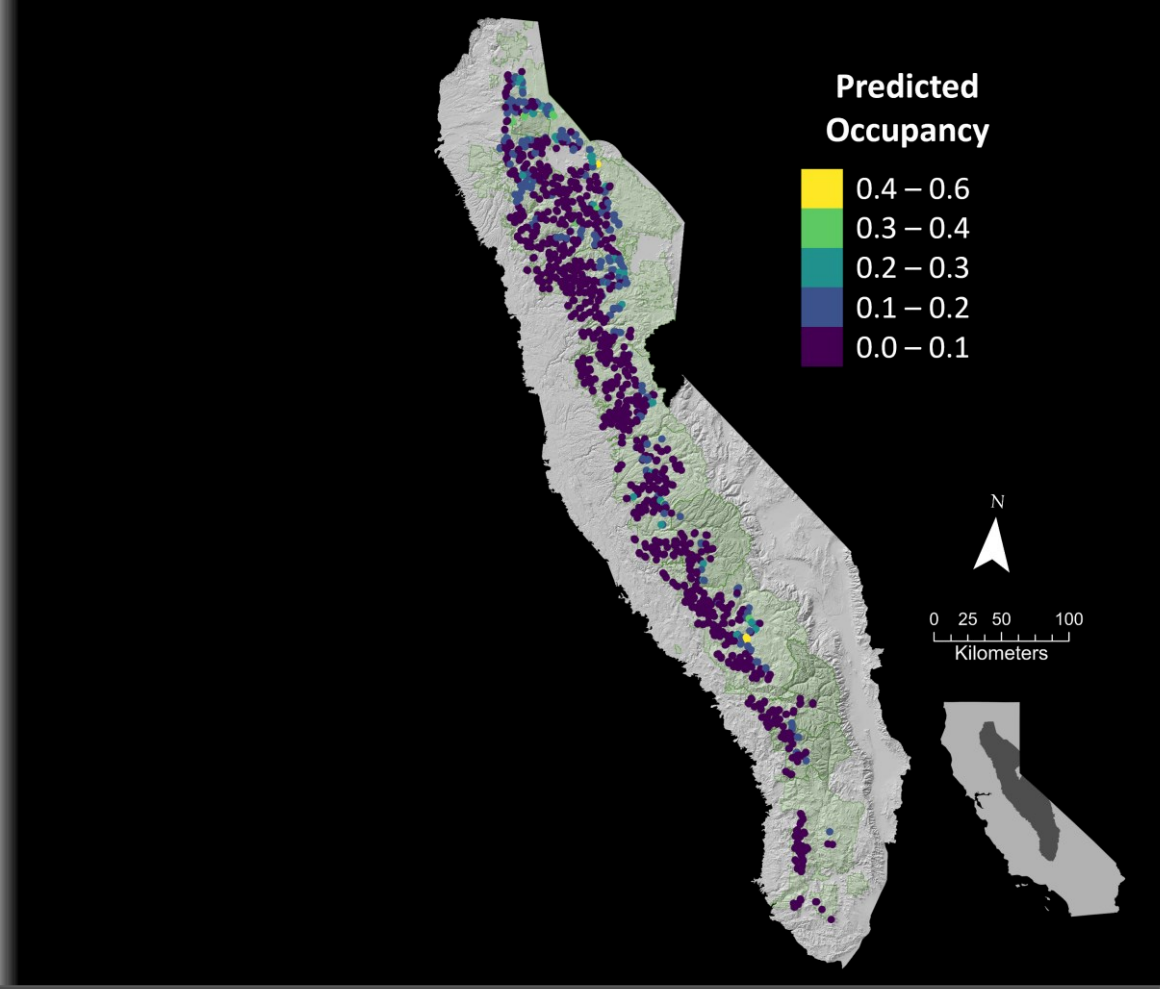
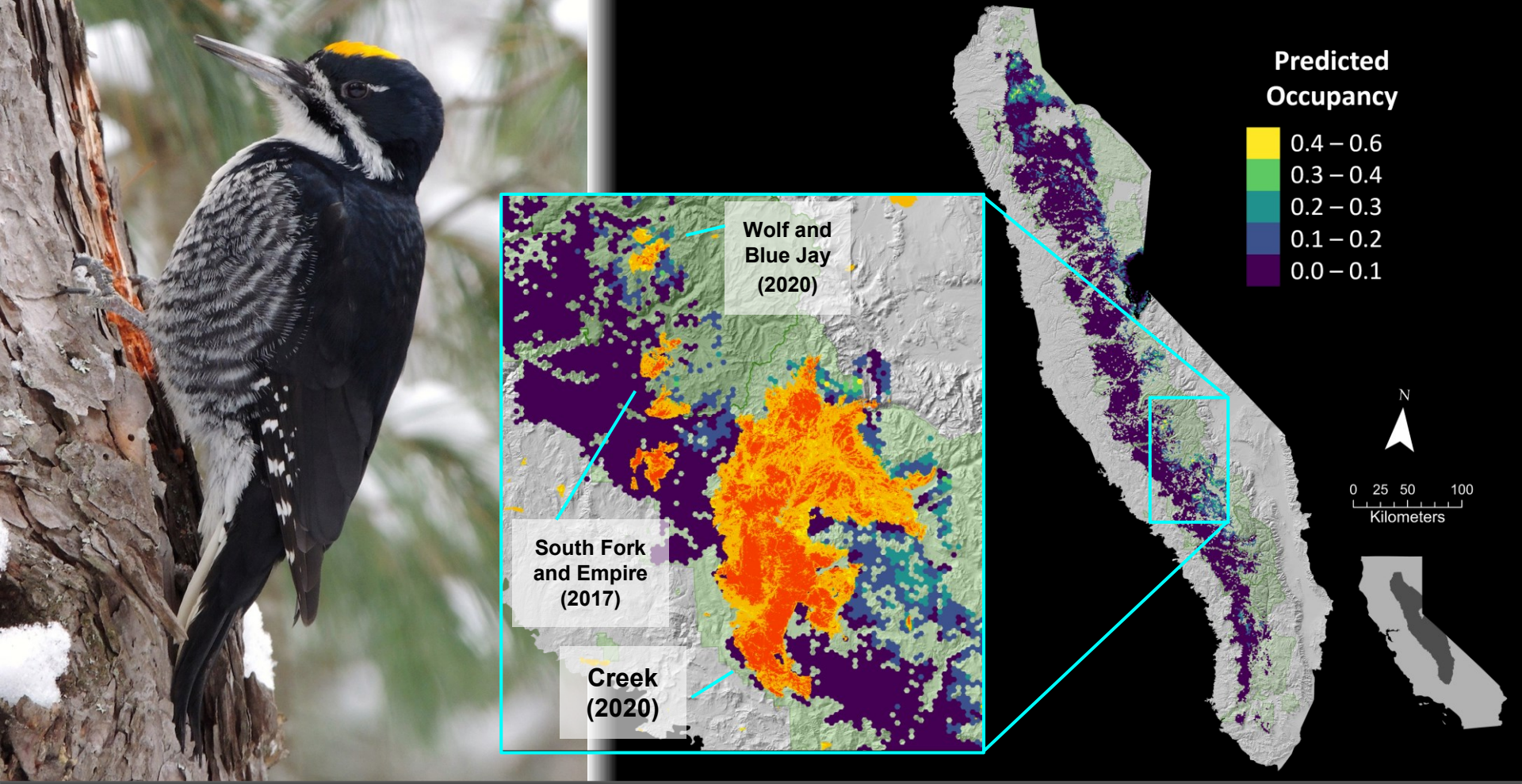
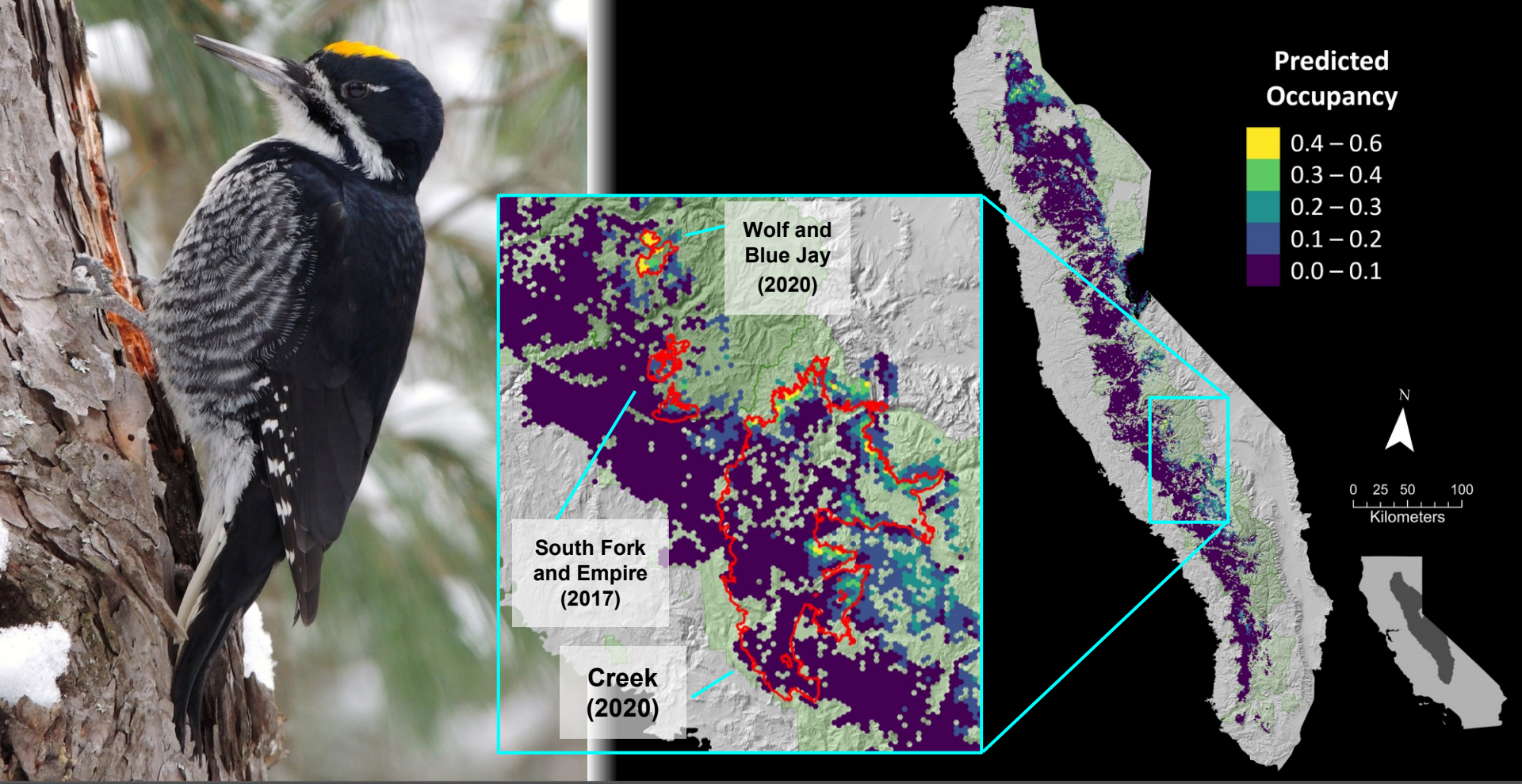

Predicted Occupancy
0.4 – 0.6
0.3 – 0.4
0.2 – 0.3
0.1 – 0.2
0.0 – 0.1
N
0 25 50 100
Kilometers


Predicted Occupancy
0.4 – 0.6
0.3 – 0.4
0.2 – 0.3
0.1 – 0.2
0.0 – 0.1
Wolf and Blue Jay (2020)
South Fork and Empire (2017)
Creek (2020)
N
0 25 50 100
Kilometers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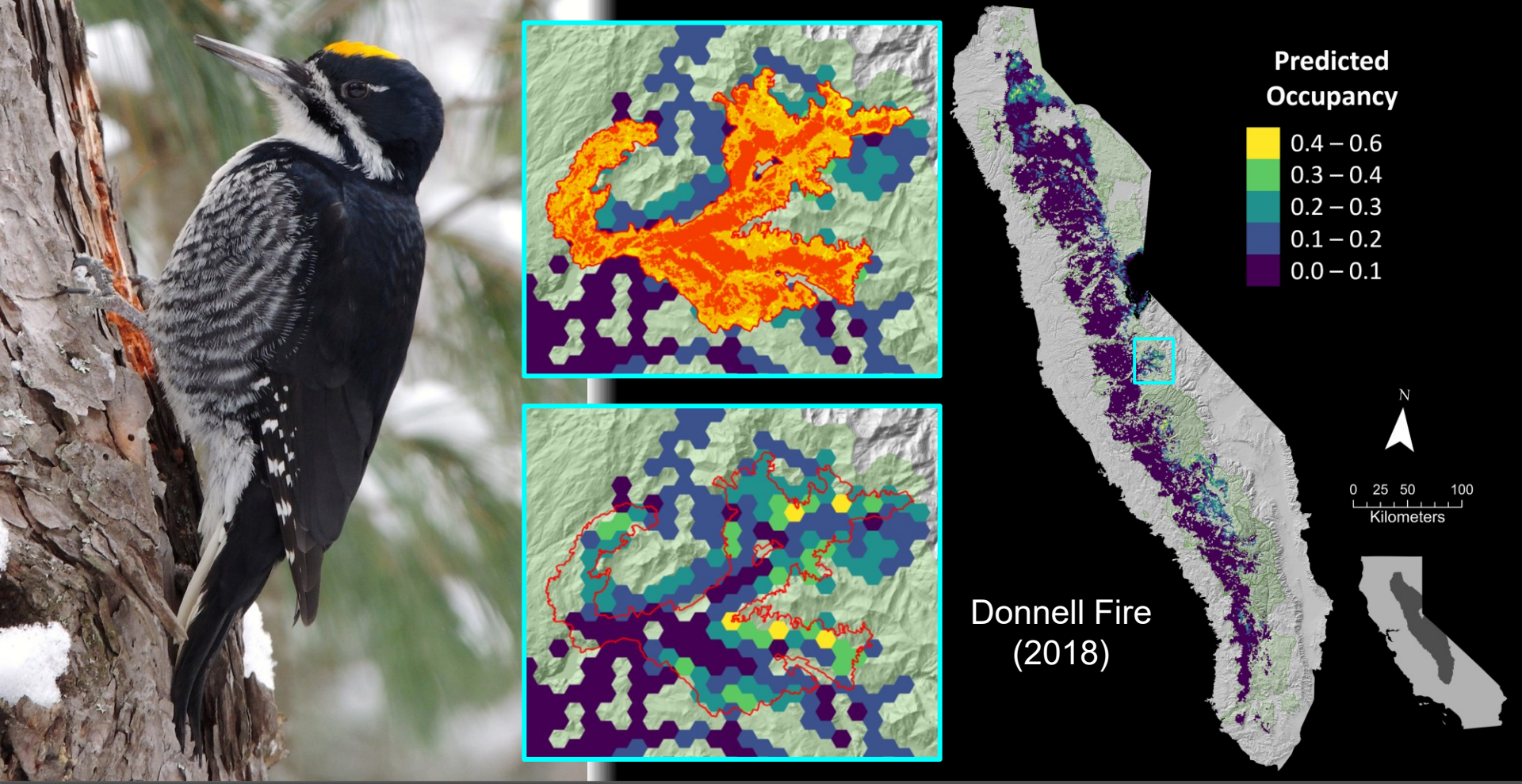
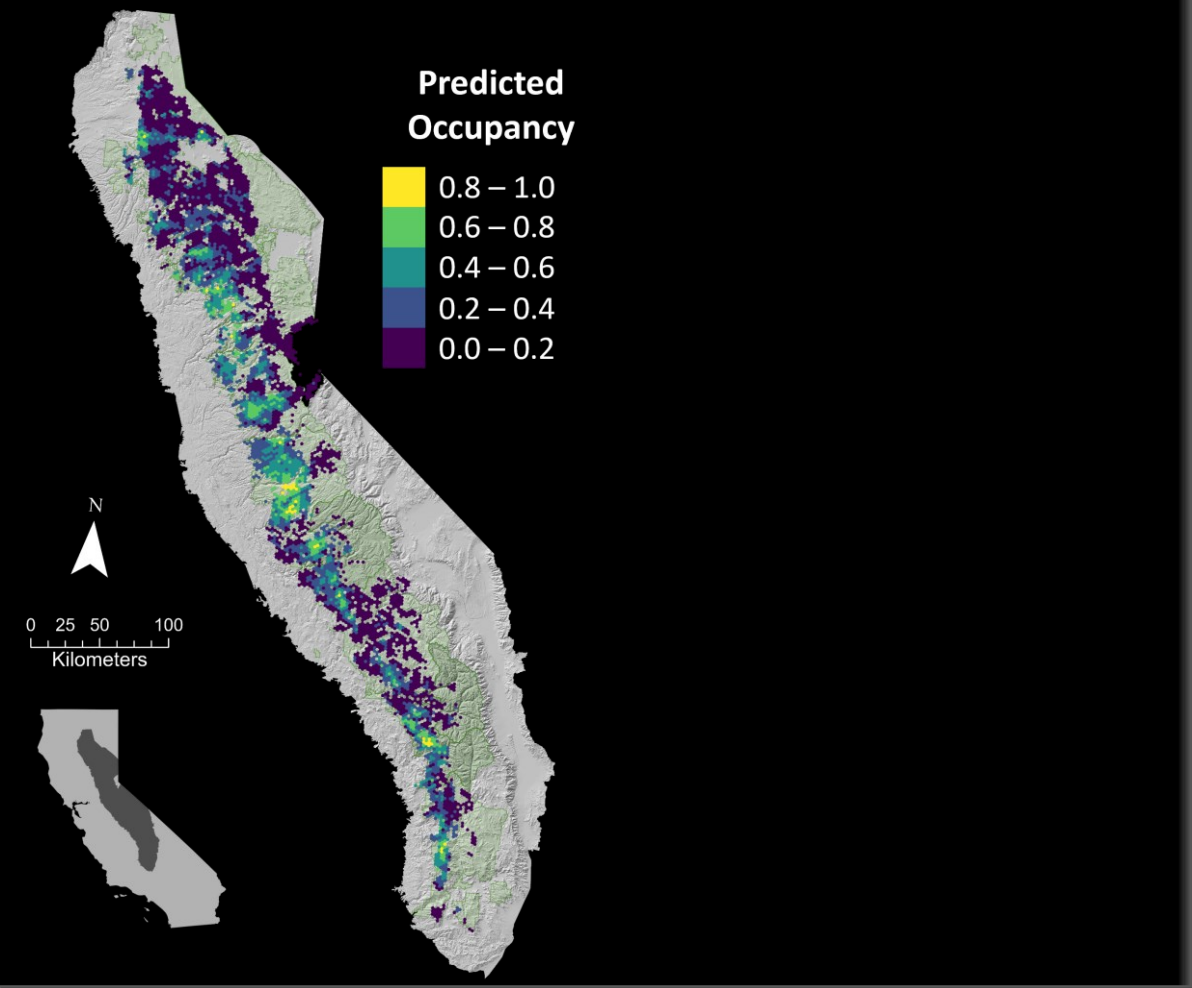

Predicted Occupancy
0.4 – 0.6
0.3 – 0.4
0.2 – 0.3
0.1 – 0.2
0.0 – 0.1
N
0 25 50 100
Kilometers
Donnell Fire (2018)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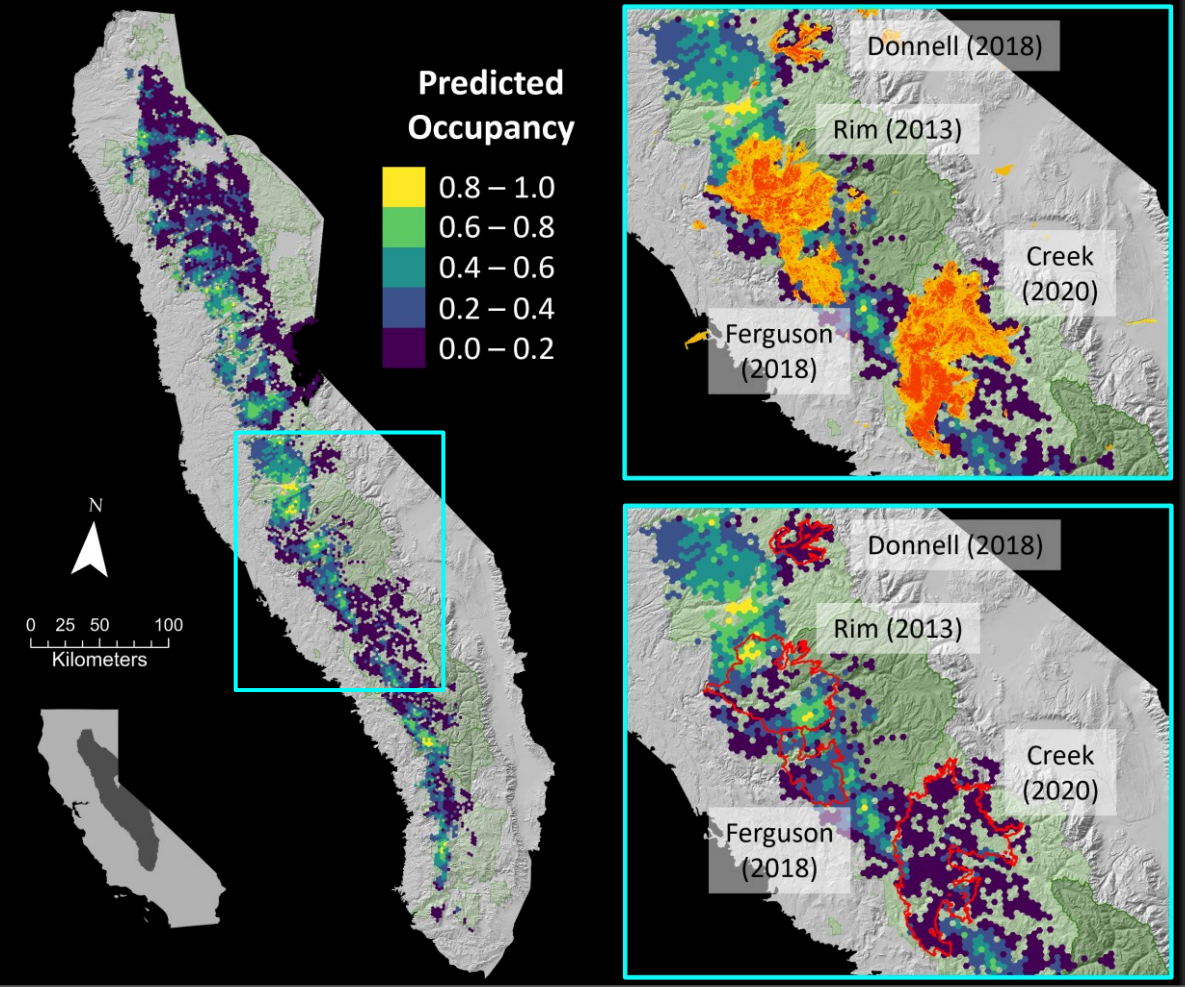
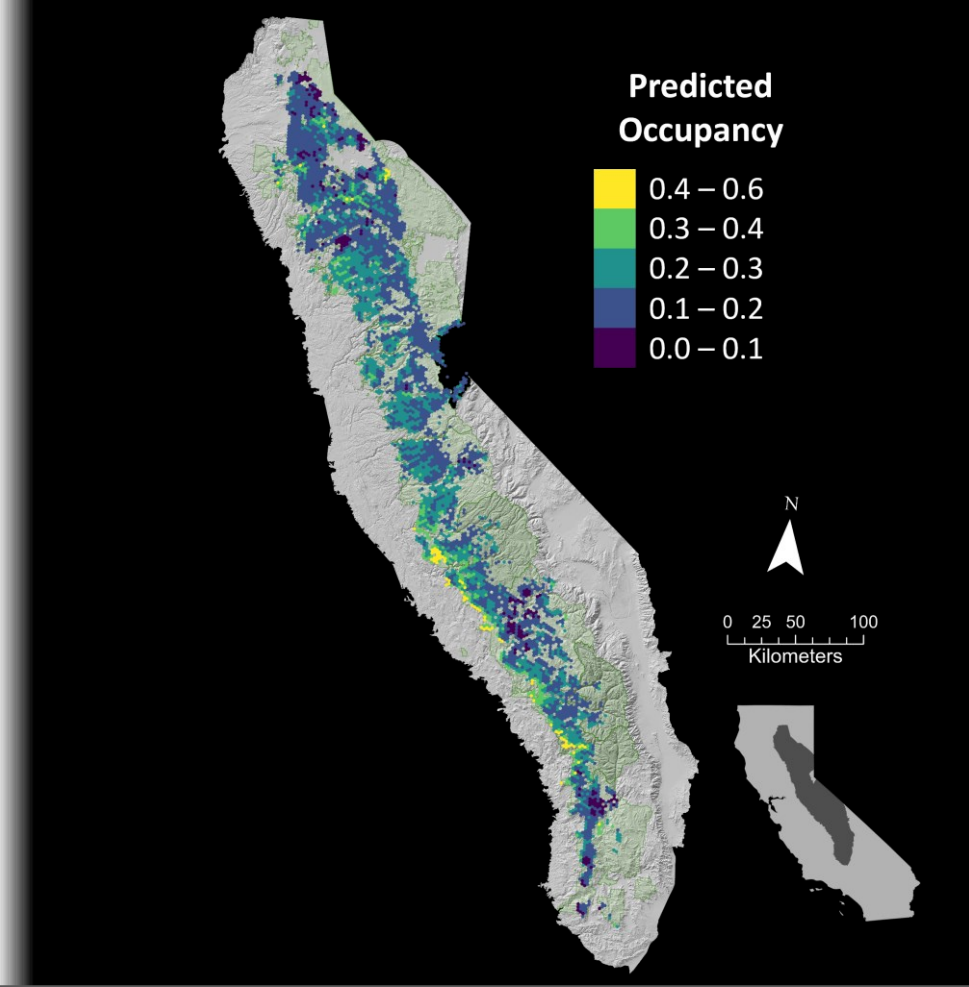
Kilometers

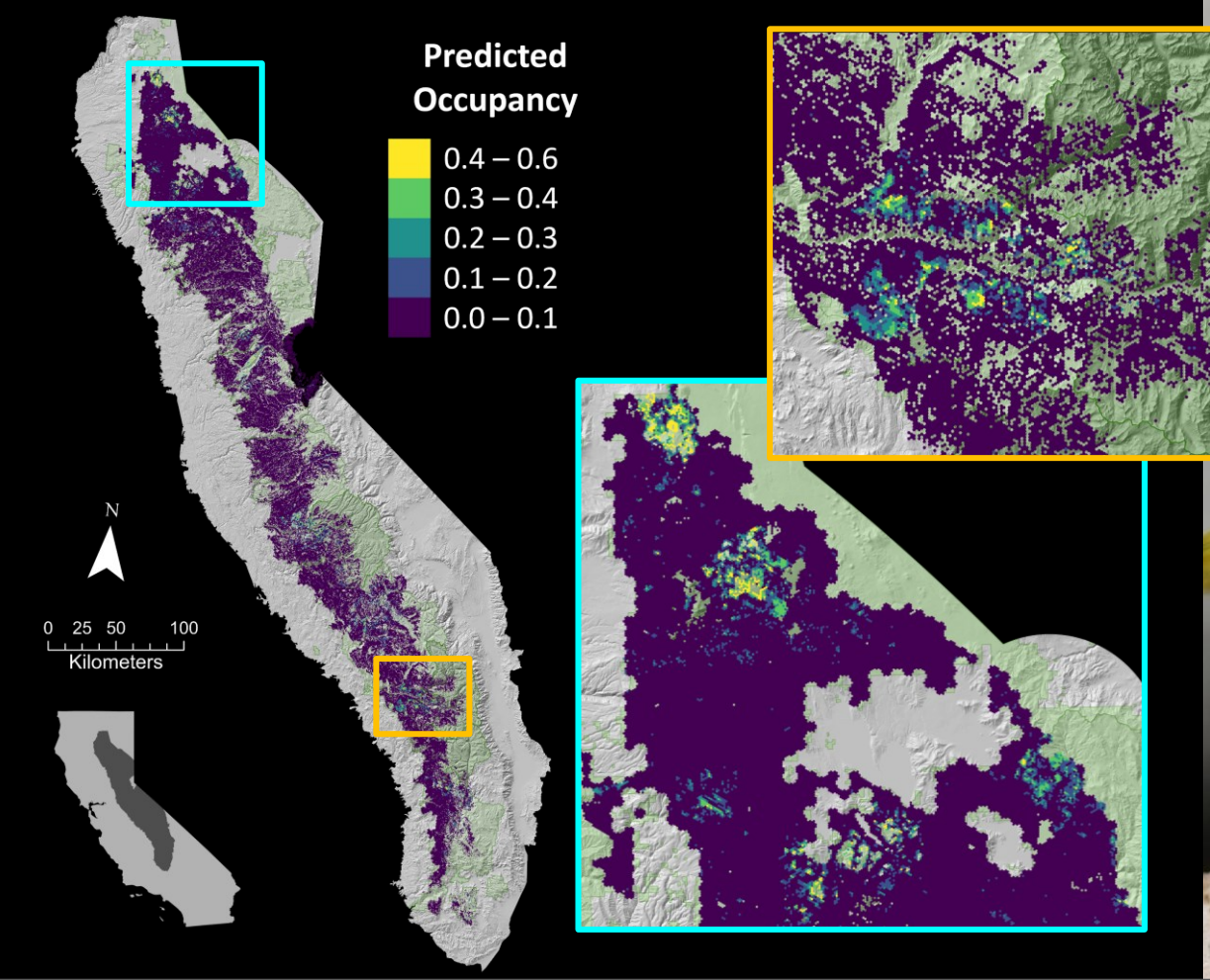

Danny Hofstadter



Danny Hofstadter

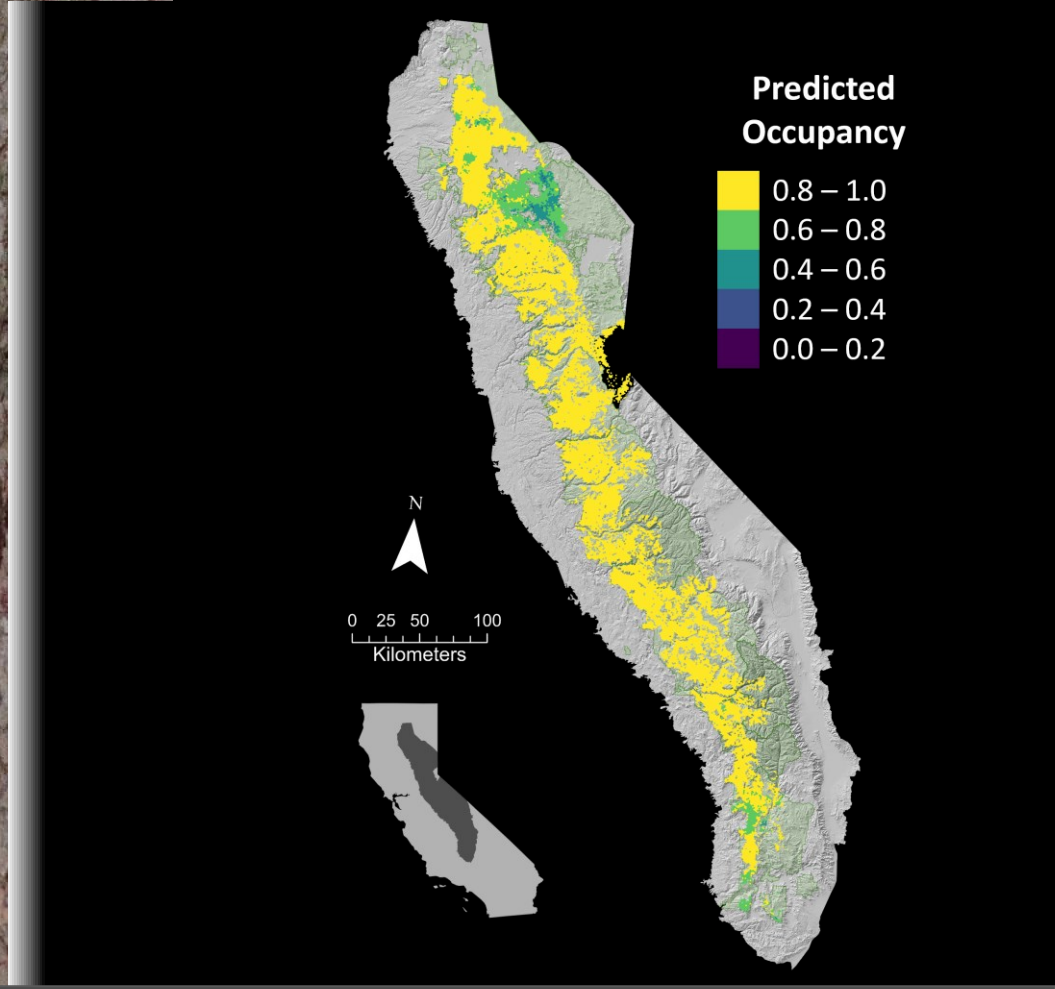
Lev Frid

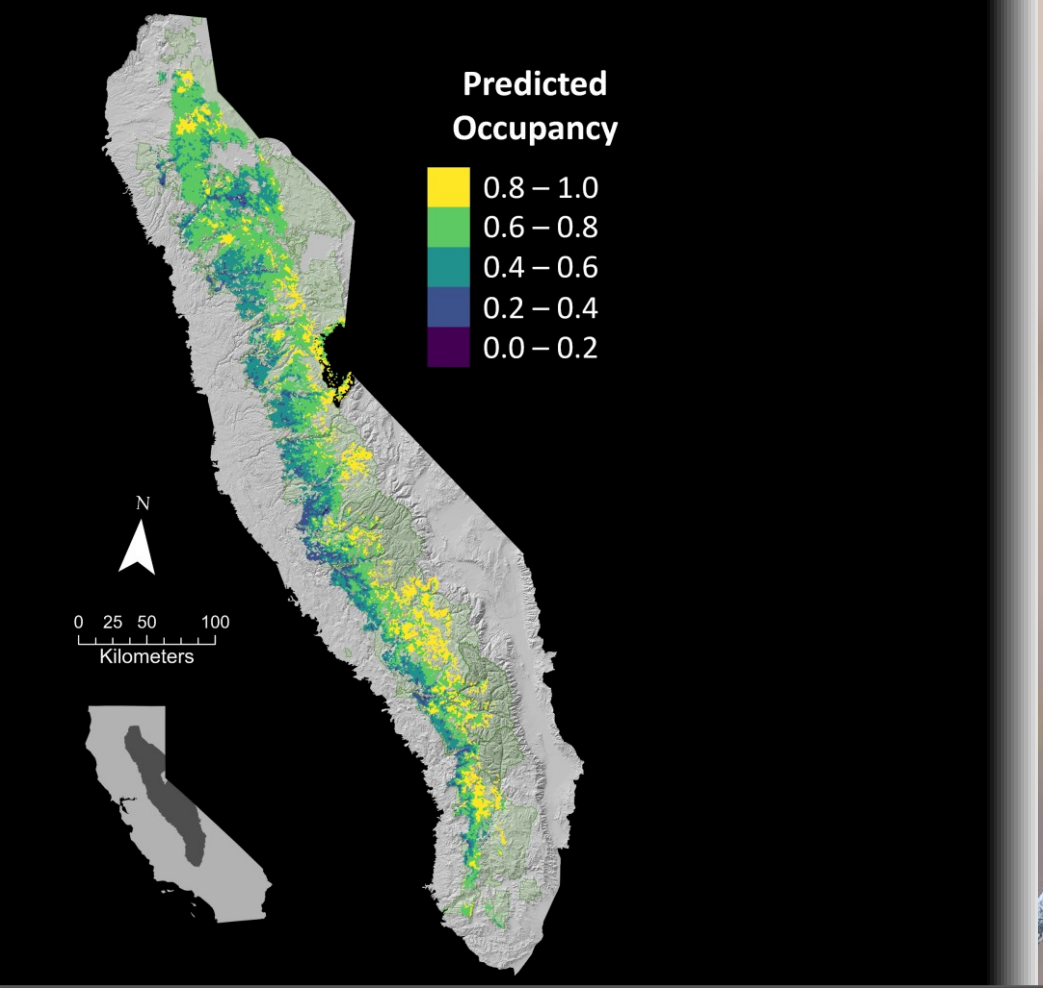

Predicted Occupancy
0.4 – 0.6
0.3 – 0.4
0.2 – 0.3
0.1 – 0.2
0.0 – 0.1
N
0 25 50 100
Kilometers



Keenan Yakola

Dominique Genna

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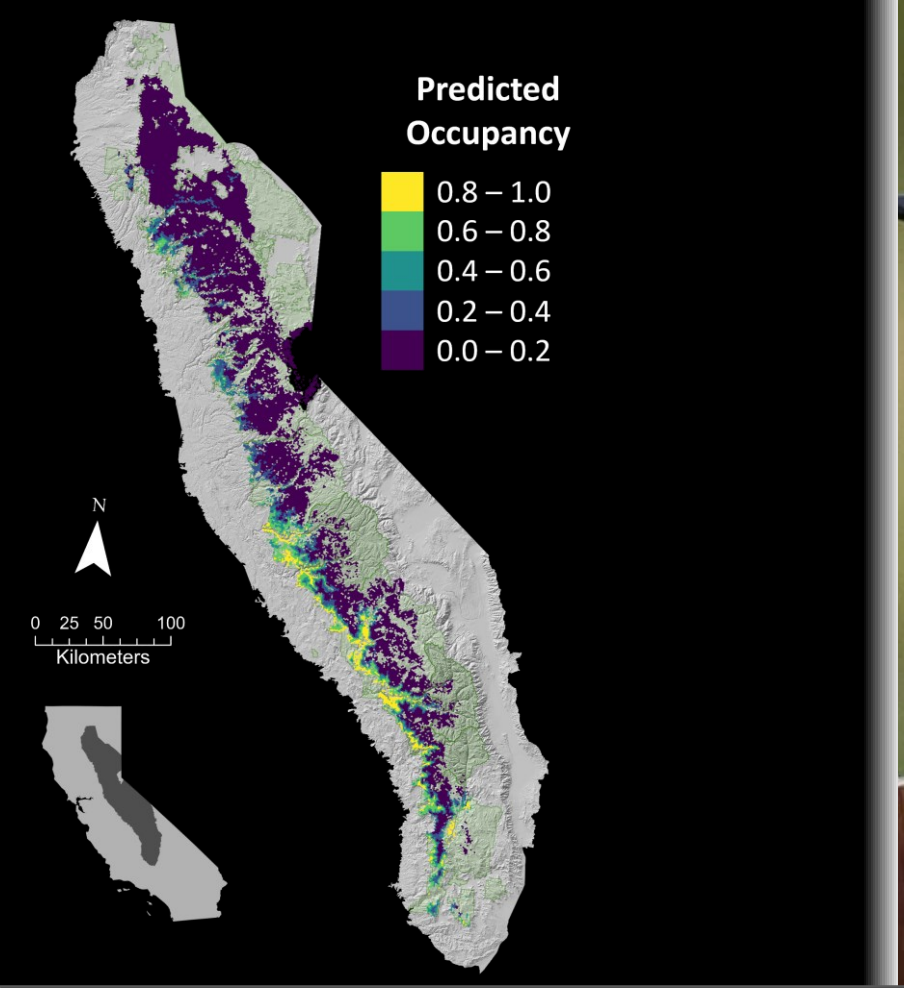
0.2 – 0.4
0.0 – 0.2
N
0 25 50 100
Kilometers


Steve Wickliffe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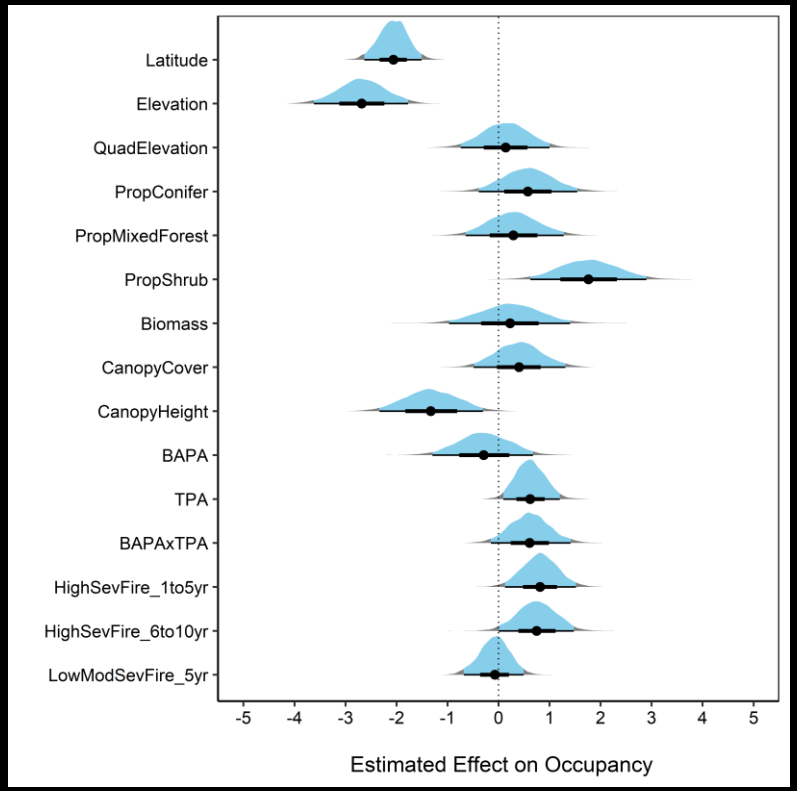
N
0 25 50 100
Kilometers


Kyle Blaney


Latitude
Elevation
QuadElevation
PropConifer
PropMixedForest
PropShrub
Biomass
CanopyCover
CanopyHeight
BAPA
TPA
BAPAxTPA
HighSevFire_1to5yr
HighSevFire_6to10yr
LowModSevFire_5yr
-5
-4
-3
-2
-1
0
1
2
3
4
5
Estimated Effect on Occupancy

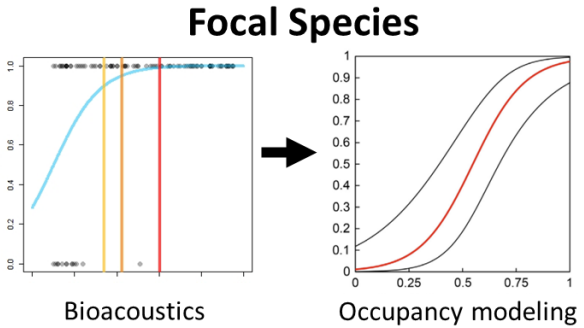

Kyle Blaney

Goals

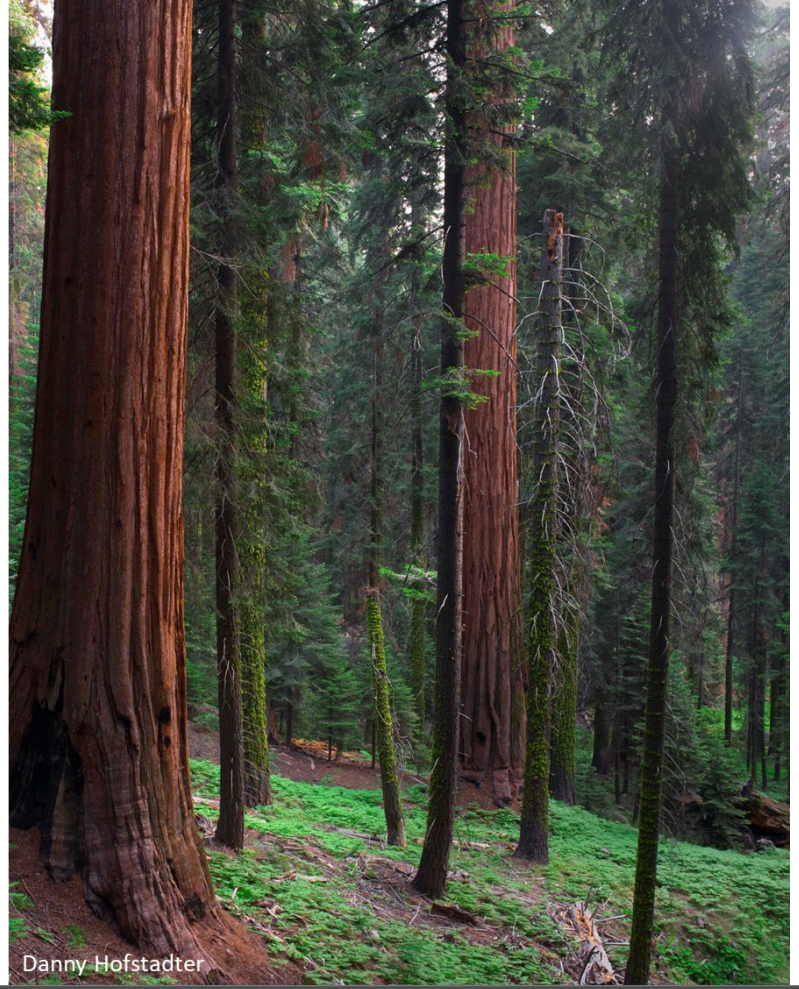
Create systematic Sierra-wide models of indicator species distributions in the context of habitat characteristics and fire history

Enhance understanding of short-term and long-term tradeoffs associated with forest restoration treatments

Where we're headed…




Ervins Strauhmanis


Danny Hofstadter

Passive acoustic monitoring and advances in AI for automatic signal classification enable local and landscape-scale insights about common and rare species alike

Insights from this program can be used to directly inform forest, wildlife, and habitat management

Close collaboration with partners in management agencies is imperative

Thank you!

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Danny Hofstadter