Using bioacoustics for landscape-scale species conservation

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Habitat Loss
Climate Change
Invasive Species
Over-exploitation

The spotted owl as a model organism

=

*not to scale

Decades of research: natural history well-understood

Myriad threats: climate-driven change, habitat modification, invasive species, pollution, resource extraction

Noon and Franklin, 2002; Gutiérrez 2008; Tempel et al. 2014; Wiens et al. 2014; Jones et al. 2016; Jones et al. 2018


10-year fire interval
Small, low-intensity

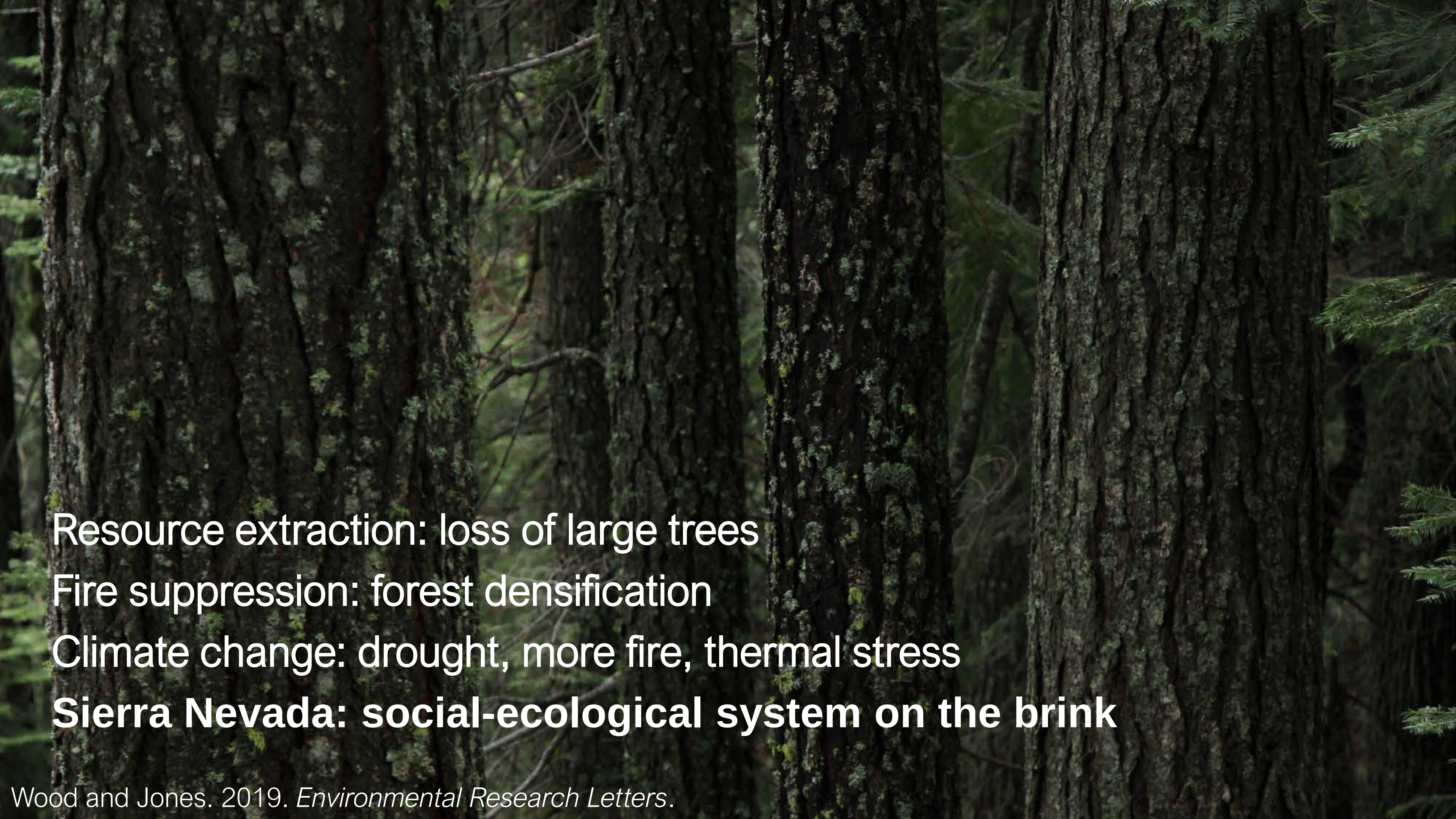
100 years of fire suppression:
extensive fuel accumulation

Large, high-intensity fires

Fuel reduction: homogenizes landscape

Matthew Henderson


Huge, old trees: nesting habitat, thermal refugia
Low-density stands



Resource extraction: loss of large trees

Fire suppression: forest densification

Climate change: drought, more fire, thermal stress

Sierra Nevada: social-ecological system on the brink

Wood and Jones. 2019. *Environmental Research Letters*.

1) Balancing species conservation – ecosystem restoration trade-offs

Between a rock and a hard place

- Large, severe fire is bad for spotted owls
- Fuel reduction treatments decrease habitat quality
  - Protections for owl territories may constrain restoration
- Can vacant territories be targeted for restoration treatments?
  - How long should we wait?



Owl territories as a metapopulation

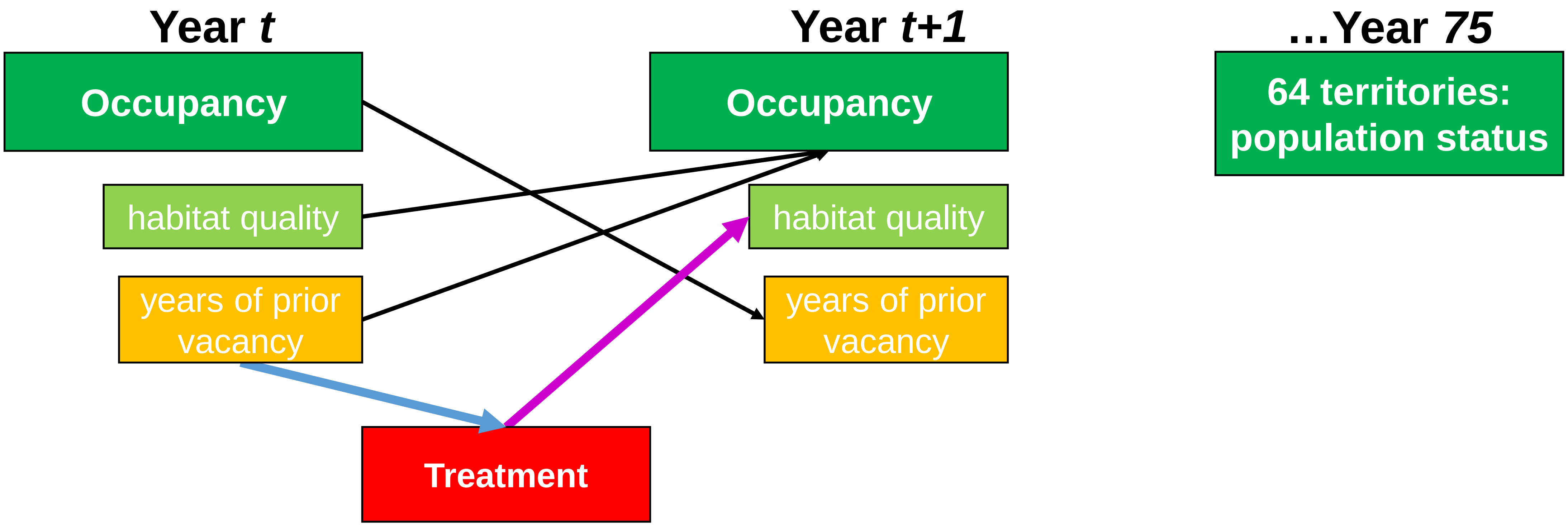
Owl territories function like patches in a metapopulation

- Vacant sites are still important

Conventional walk-in surveys

- 64 territories, >20 years

Stochastic Patch Occupancy Model



More habitat
- Increases colonization
- Decreases extinction

Longer vacancy
- Decreases colonization
- 1 yr: 0.34
- 10 yrs: 0.06

Vacancy threshold:
- 0 – 10 years

Treatment effect:
- none, low, high

Balancing trade-offs in space and time

Long-term benefits vs short-term costs

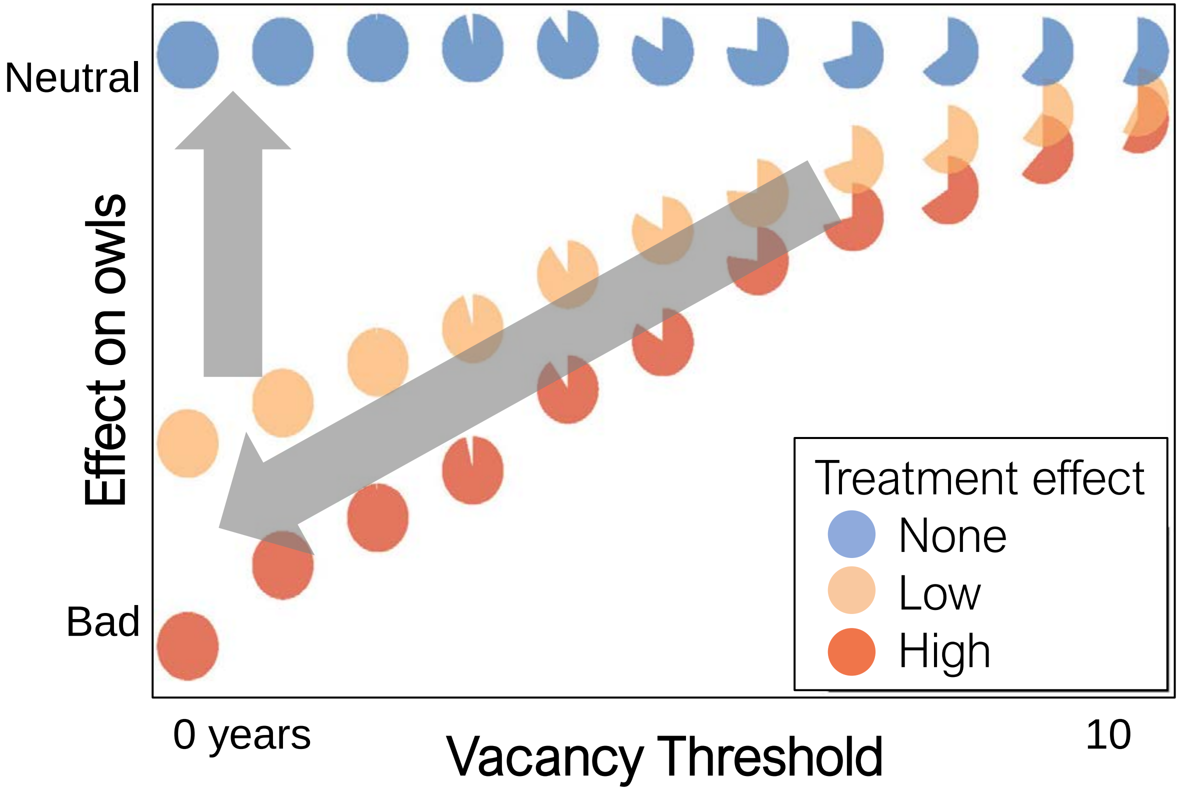
Spatial extent, intensity

Shorter vacancy threshold:

- Treatments more frequent, extensive
- Worse for owls

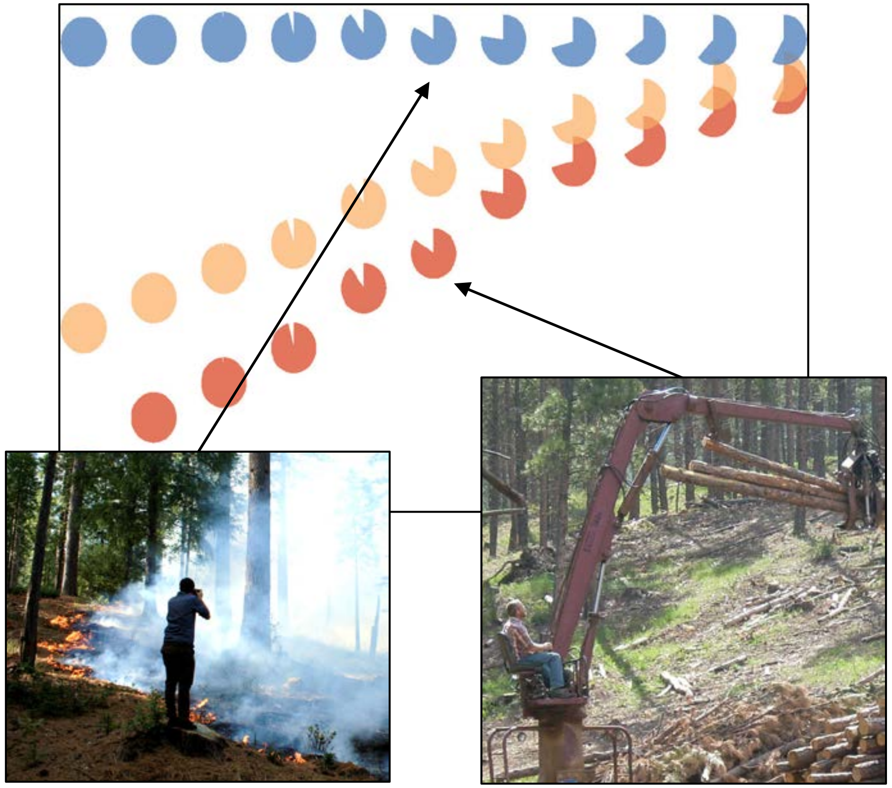
Lower impact: better for owls

- Mimic natural disturbance



Conclusion: informing mgmt. dilemmas

- Results bracket management options
  - Diminishing returns below 3 years of vacancy
- Restore natural disturbance regimes
- Restoration important, requires caution



Wood et al. 2018. *Biological Conservation*.

Developing a landscape-scale acoustic monitoring program

A new approach to owl monitoring

Mark-recapture: small sites (~300 km^2)

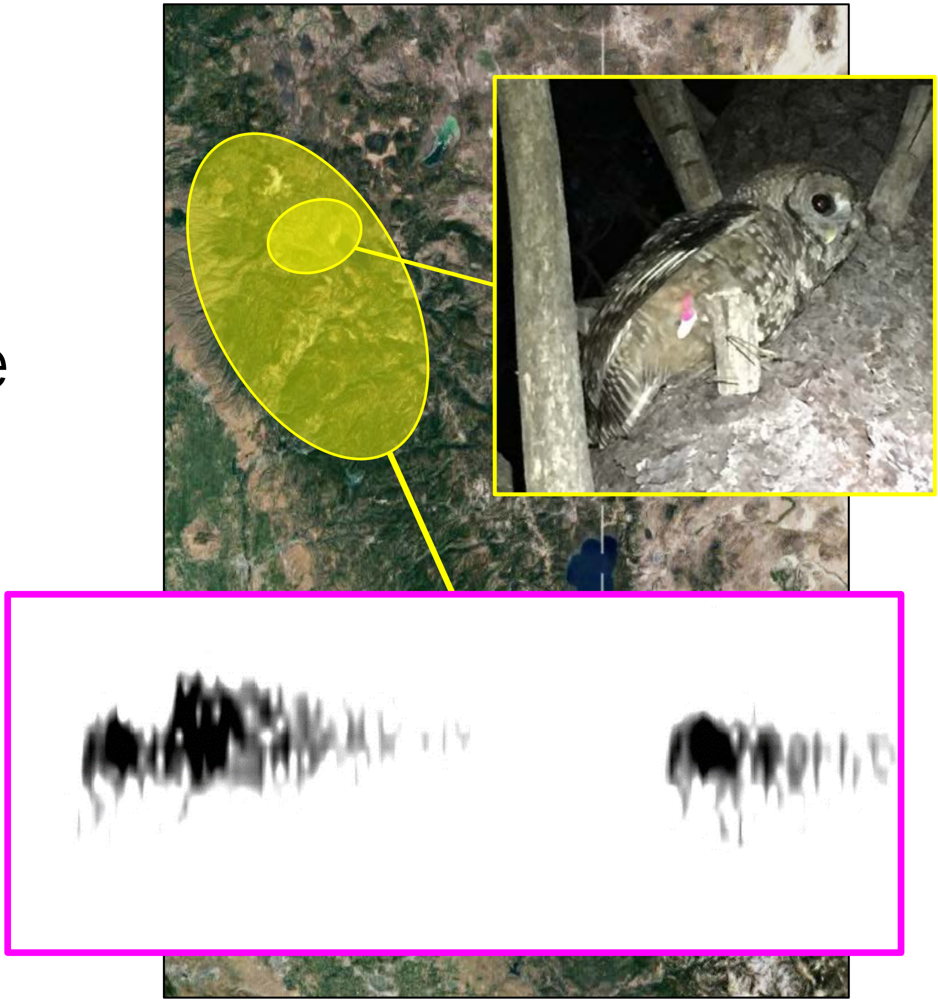
- Survival, reproduction
- Known nest/roost sites

Processes manifested across the landscape

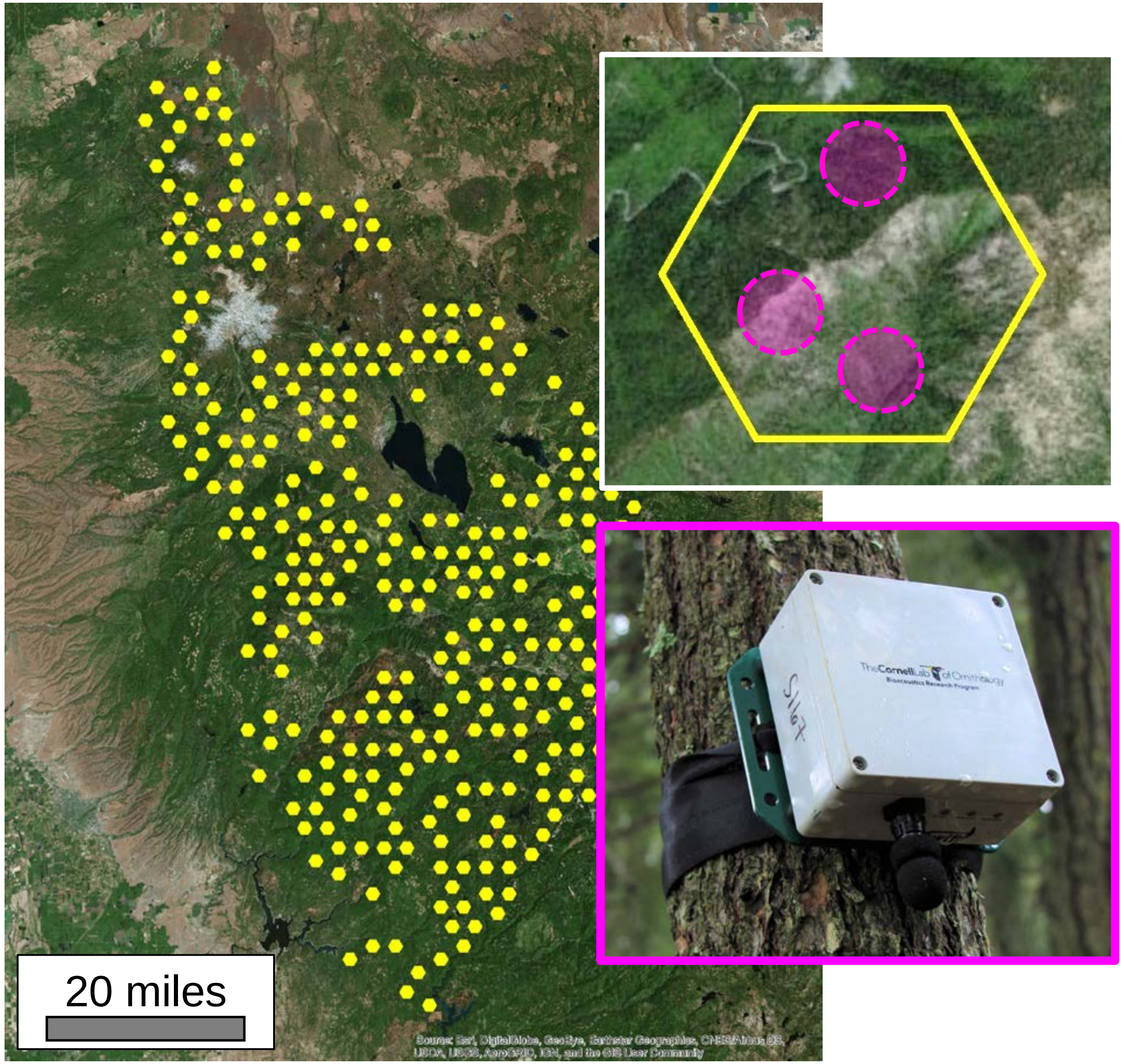
- Forest management
- Climate change
- Invasive species

Bioacoustics: large sites (~6,000 km^2)

- Do owls hoot in the forest?
- *Initially* yields less detail: occupied or not



Occupancy-based passive acoustic monitoring



Sites: 400 ha ≈ one owl territory

Survey: 2-3 units, 5-7 nights

Season: May – August

Data: 145,000 hours per year

Extracting target signals

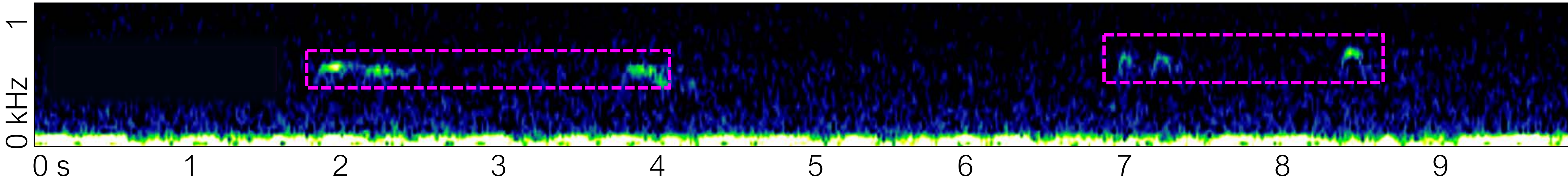
Sliding window template detector: scans data for user input

Test detectors against known data

- >550 spotted owl calls, >275 barred owl calls

Balance **precision** and **recall**

- Spotted owl: 94% of bouts
- Barred owl: 95% of bouts



Occupancy modeling

Detection/non-detection data: 101

"Non-detection": could be present but unobserved

Occupancy models

- Detection: probability of observing animal, given presence
- Occupancy: probability that animal is present

Estimating statistical power

Can we identify small population declines?

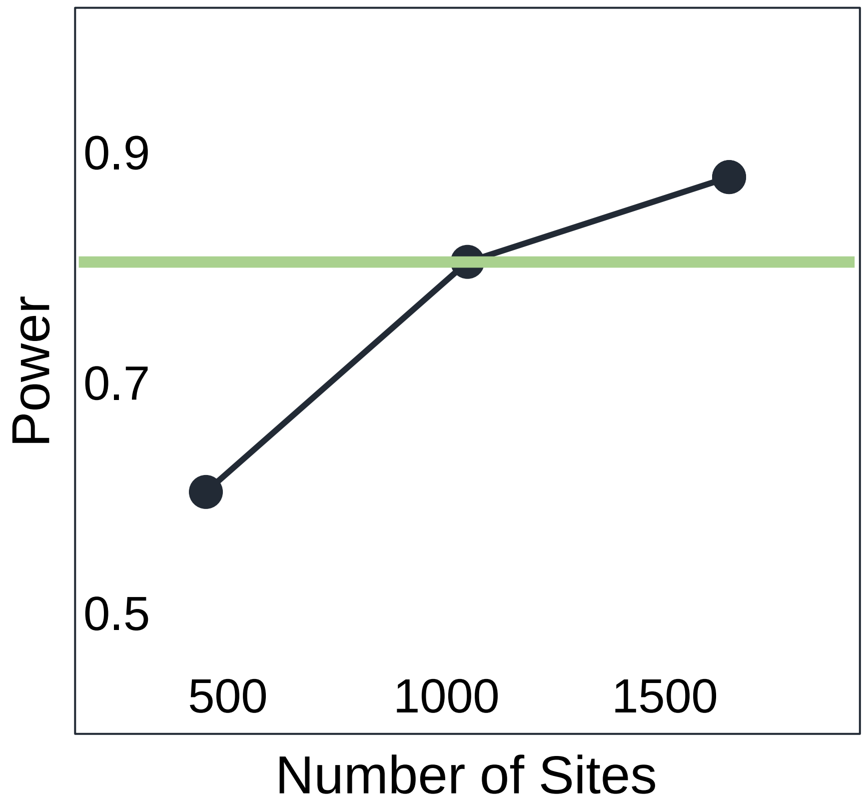
- Different survey designs
- Different species attributes

Simulate occupancy data, recreate inputs

- Viorel Popescu
- 80% accuracy is the standard

Acoustics: 82% power over 12 years

- Conventional: 20 years



Conclusion: effective at landscape-scales

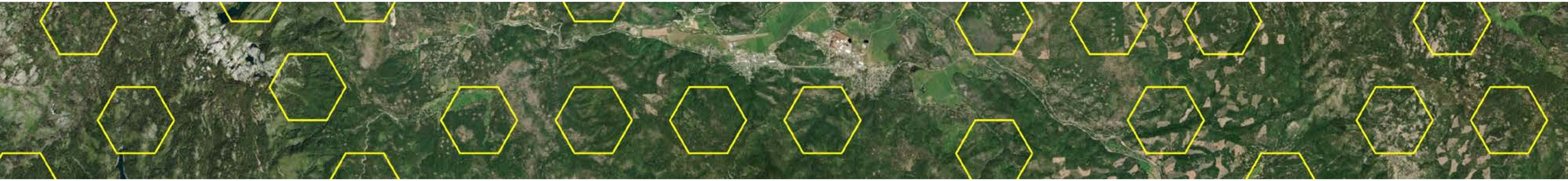
Effective at landscape scales

Semi-automated signal extraction

High statistical power to detect change

- Faster than conventional approaches

Flexible: one survey, many studies, species



Wood & Popescu et al. 2019. *Ecological Indicators.*

2) Early detection of a biological invasion provides novel conservation opportunities

Why does rapid detection matter?

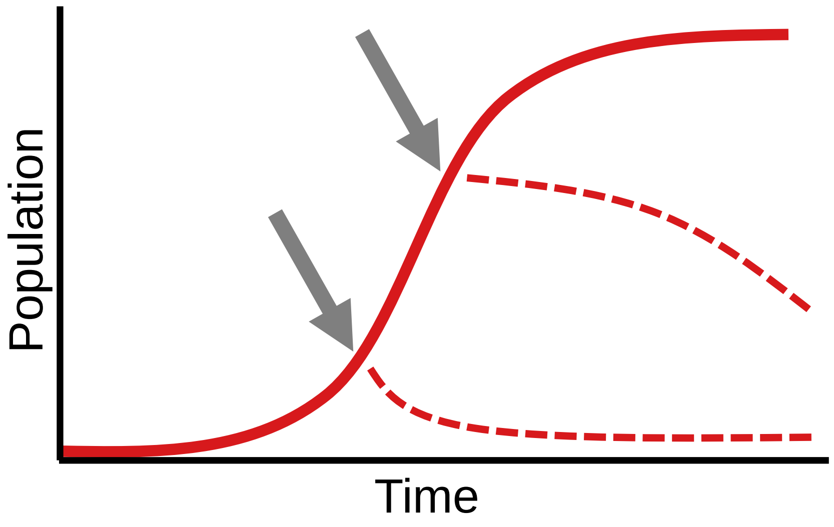
Invasive species display logistic growth

Early detection allows efficient, humane intervention

Barred owls expanded across N. America

- Existential threat to spotted owls

No systematic data in Sierra Nevada



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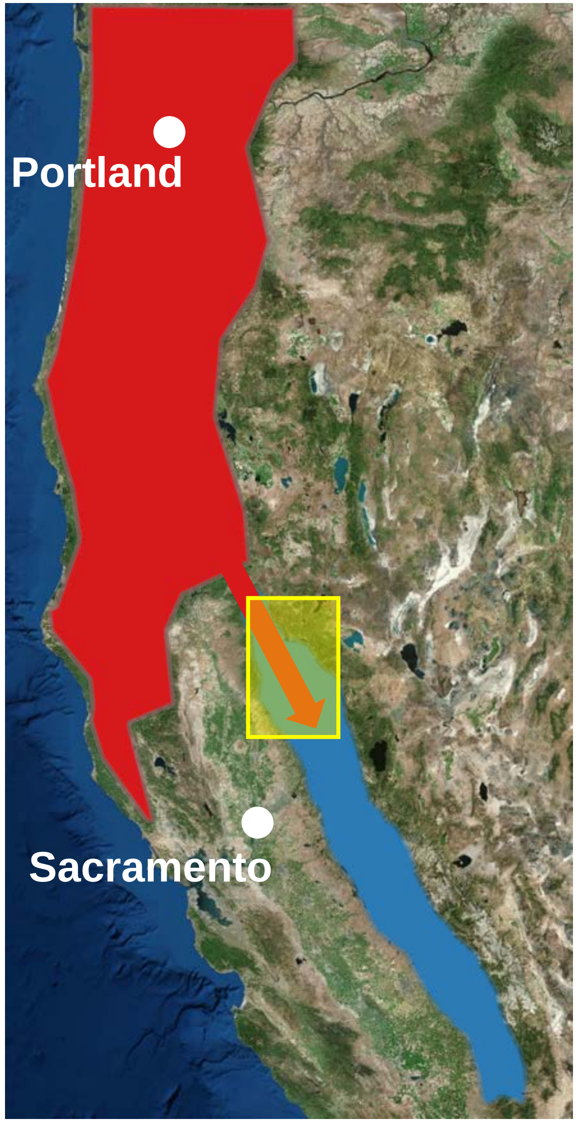
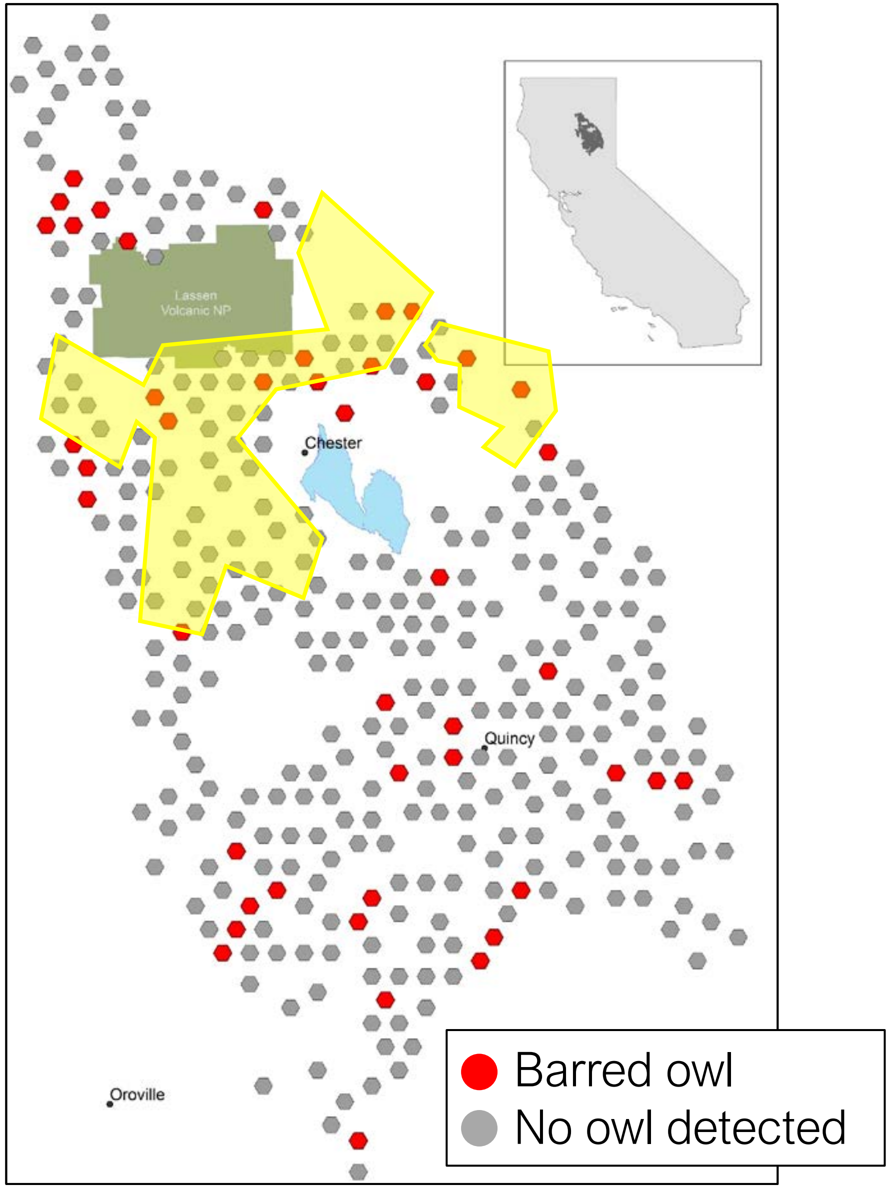
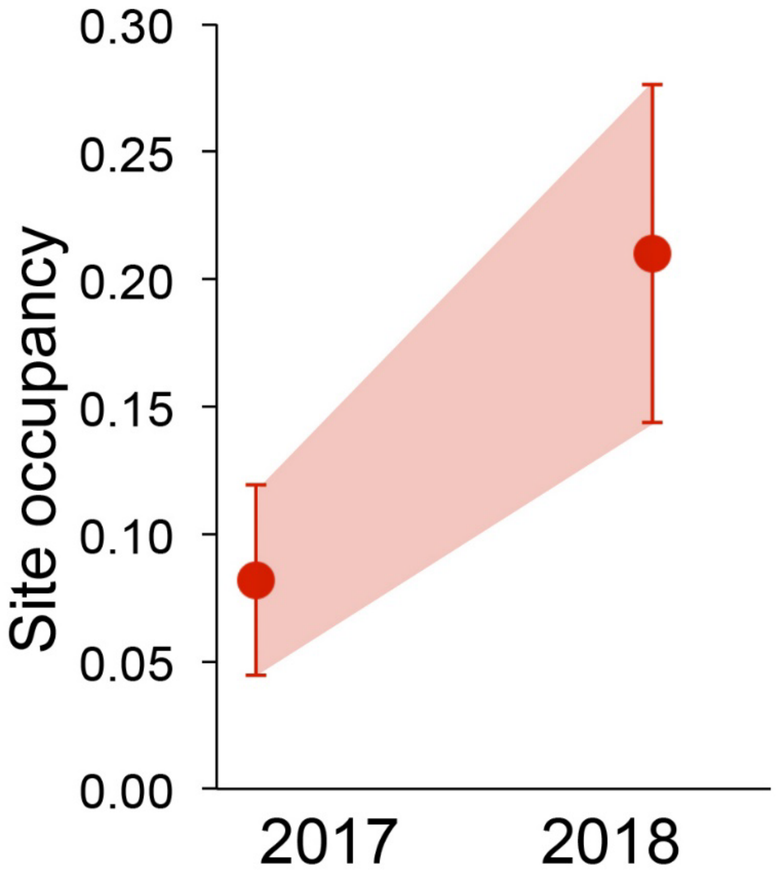


2.6-fold population increase in one year



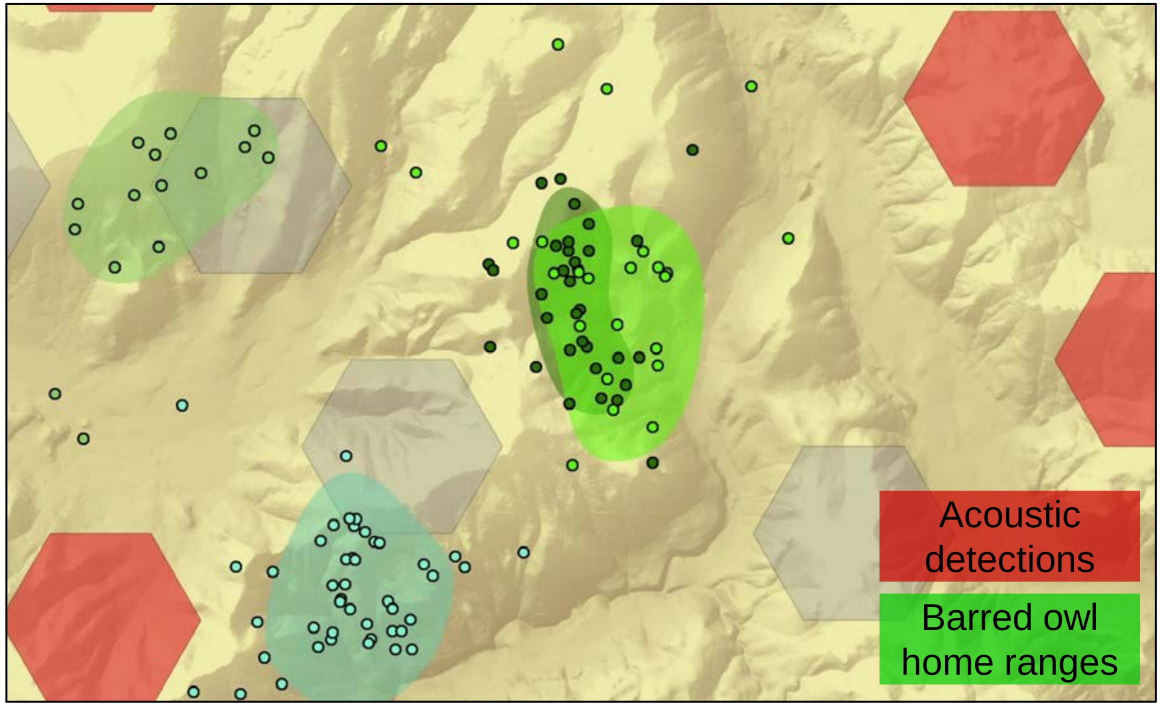


Testing model assumptions

GPS-tagged 10 barred owls, 13 months of data

Territory size ≈ grid cell size – not overestimating population

Stable territories across seasons, years – territorial



Conclusion: challenge and opportunity

Sierra Nevada barred owl population likely entering growth phase

Precautionary Principle: swift action likely necessary

- Spotted owls
- Cascading ecosystem effects

Landscape-scale multi-species monitoring

Wood et al. 2020. *The Condor: Ornithological Applications.*

3) Density dependence drives competition & hybridization at an invasion front

Predicting competition in a changing world

Changing geographic barriers facilitate range shifts

- Closely related species compete, hybridize

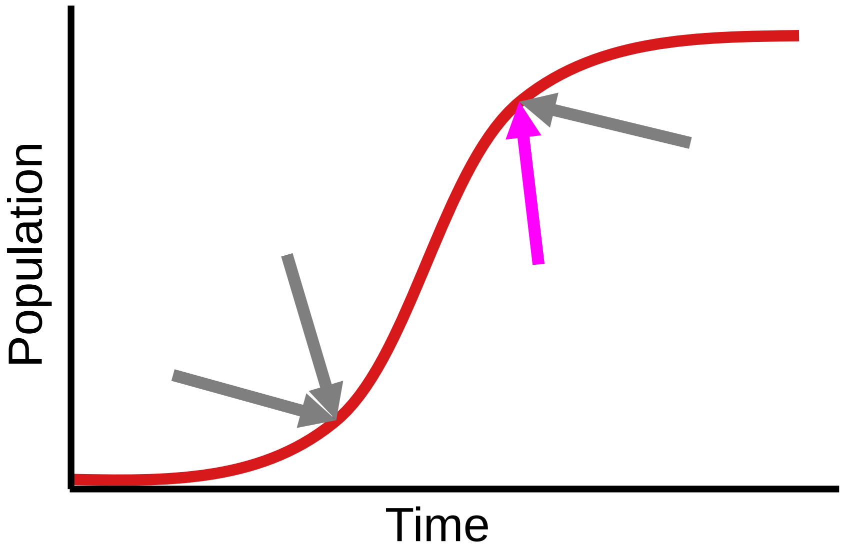
Data needed to justify action often lacking

Consistent results = density-independent

- Divergence, lack thereof
- Fundamental niche

Different results = density-dependent

- Empty niche space
- Alleé effects



A natural experiment

Barred owl invasion as a natural experiment

- High-density dynamics studied in PNW
- Low-density dynamics studied here

Niche overlap (competition)

- i. Landscape-scale habitat selection
- ii. Foraging habitat selection
- iii. Diet

Hybridization

- iv. Hybridization

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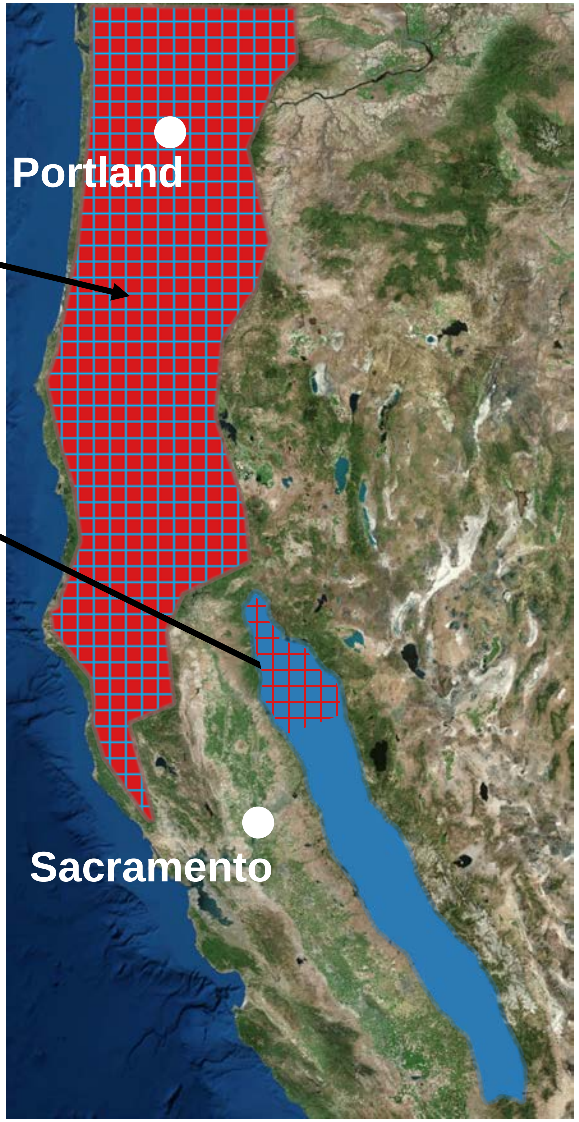
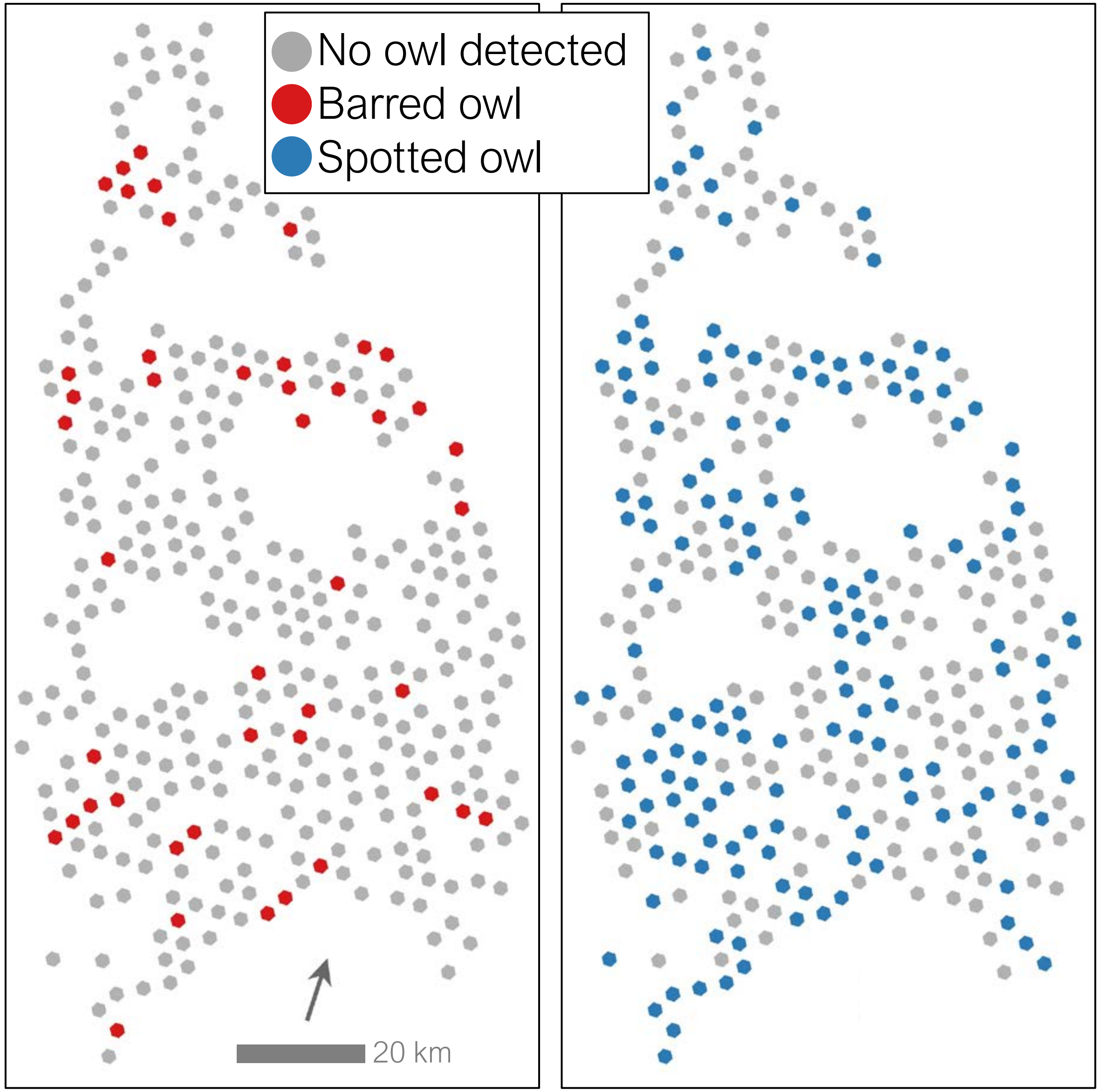


i) Landscape-scale habitat selection



Multi-scale dynamic occupancy models

Both: avoid open forest

Barred owl

- Colonization: (-) open forest
- Fine: (+) old forest, (-) slope

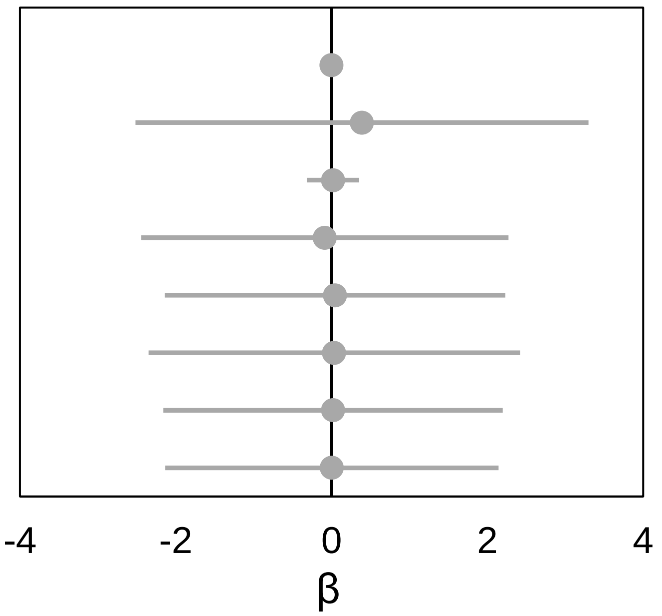
Spotted owl

- Low turnover on steep slopes
- Fine: (-) medium forest

Moderate overlap

ii) Foraging habitat selection

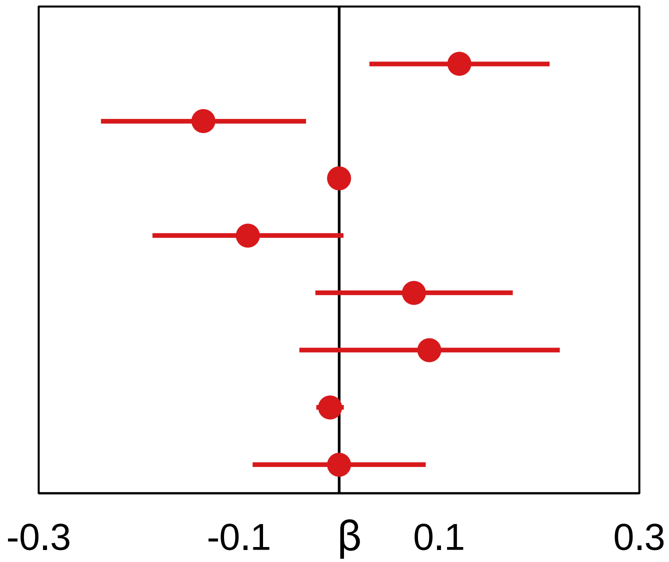
Logistic regression: spotted vs barred



Parameter	ΔAIC*c*
Null	**0.00**
Med. Hardwood	1.98
Slope	2.01
Open Forest	2.01
Young Forest	2.01
Mt. Riparian Forest	2.01
Old Forest	2.01
Medium Forest	2.02

Complete overlap

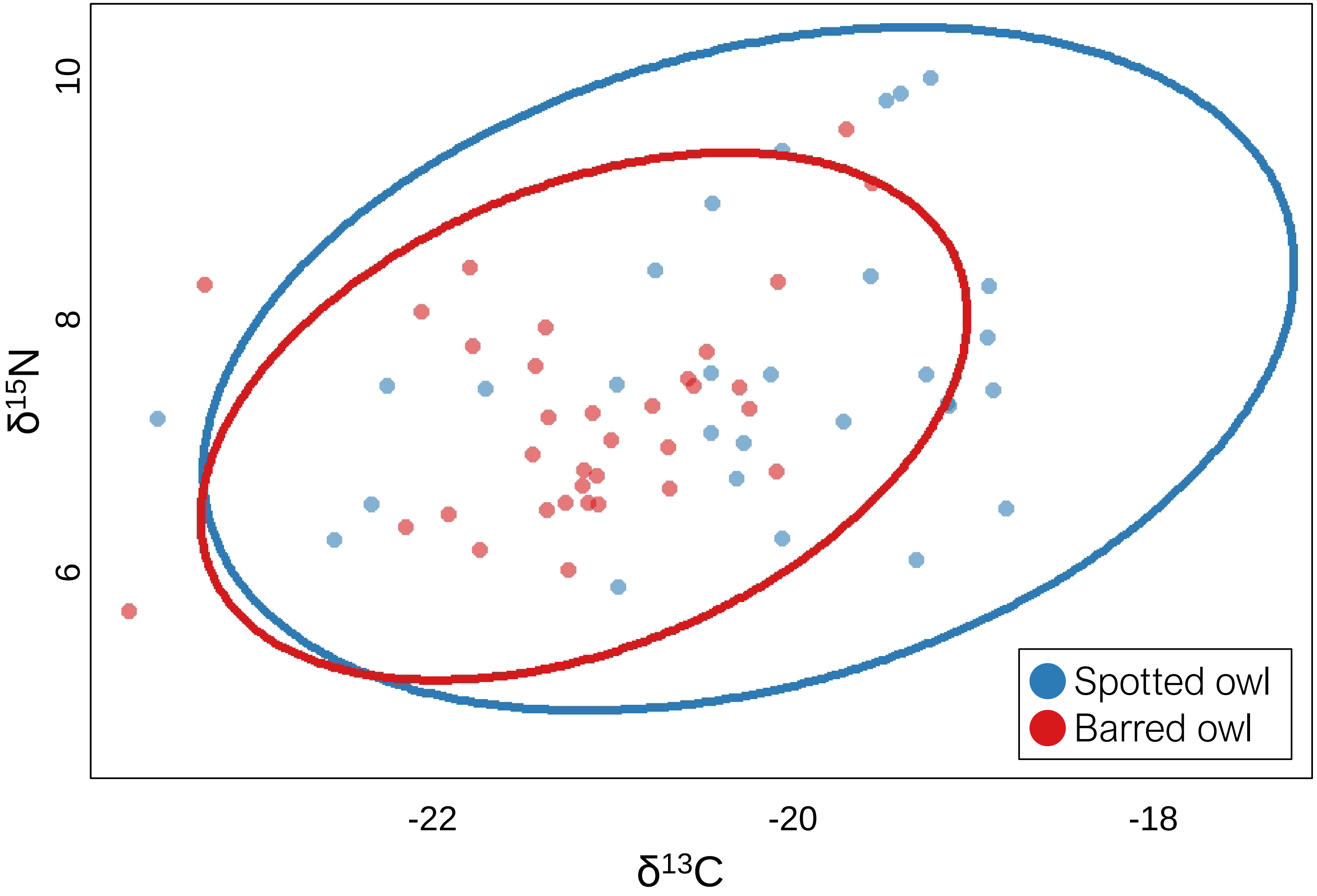
Resource Selection Functions



barred owls

Parameter	ΔAIC*c*
Young Forest	**0.00**
Old Forest	**0.03**
Null	**1.70**
Medium Forest	1.82
Open Forest	2.52
Med. Hardwood	2.55
Slope	2.85
Mt. Riparian Forest	3.71

iii) Isotopic niche space



Analyze feather samples

Standard Ellipse Area

99% overlap

iv) Hybridization

Spotted owl walk-in surveys, barred owl removals

Assess parentage by plumage, vocal characteristics

Hybrids: 36% of barred population, ~7% of spotted population

Hybridization common at low densities

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Density dependent dynamics

	Low density (this study)	**High density** (lit. review)
i) Landscape-scale habitat	Moderate overlap	High overlap
ii) Foraging habitat	Equivalent	Equivalent
iii) Diet	Overlapping	Overlapping
iv) Hybridization	Common	Uncommon

Density-dependent: landscape-scale habitat selection, hybridization

Density-independent: foraging habitat selection, diet

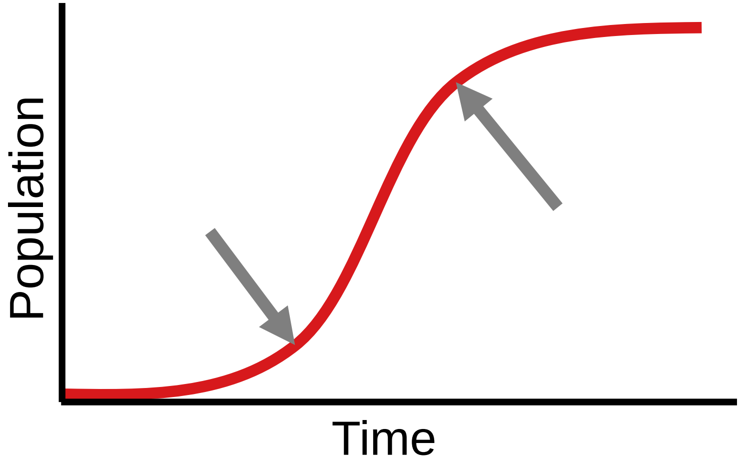
Conclusion: density dependent dynamics

Higher-order selection density-independent

Sister taxa and evolutionary divergence

- Fundamental niche
- Reproductive biology

Changing barriers, impending interactions



Wood et al. In Prep.

4) Improving inference in acoustic monitoring programs

Moving beyond occupancy

Mitigating information loss in occupancy studies

Detections vs. signals

i. Determining pair status

ii. Call rate as a behavioral metric

iii. Differentiating individuals

i) Determining pair status

Single State: all owls

p: 0.43

p_{Female}: 0.20

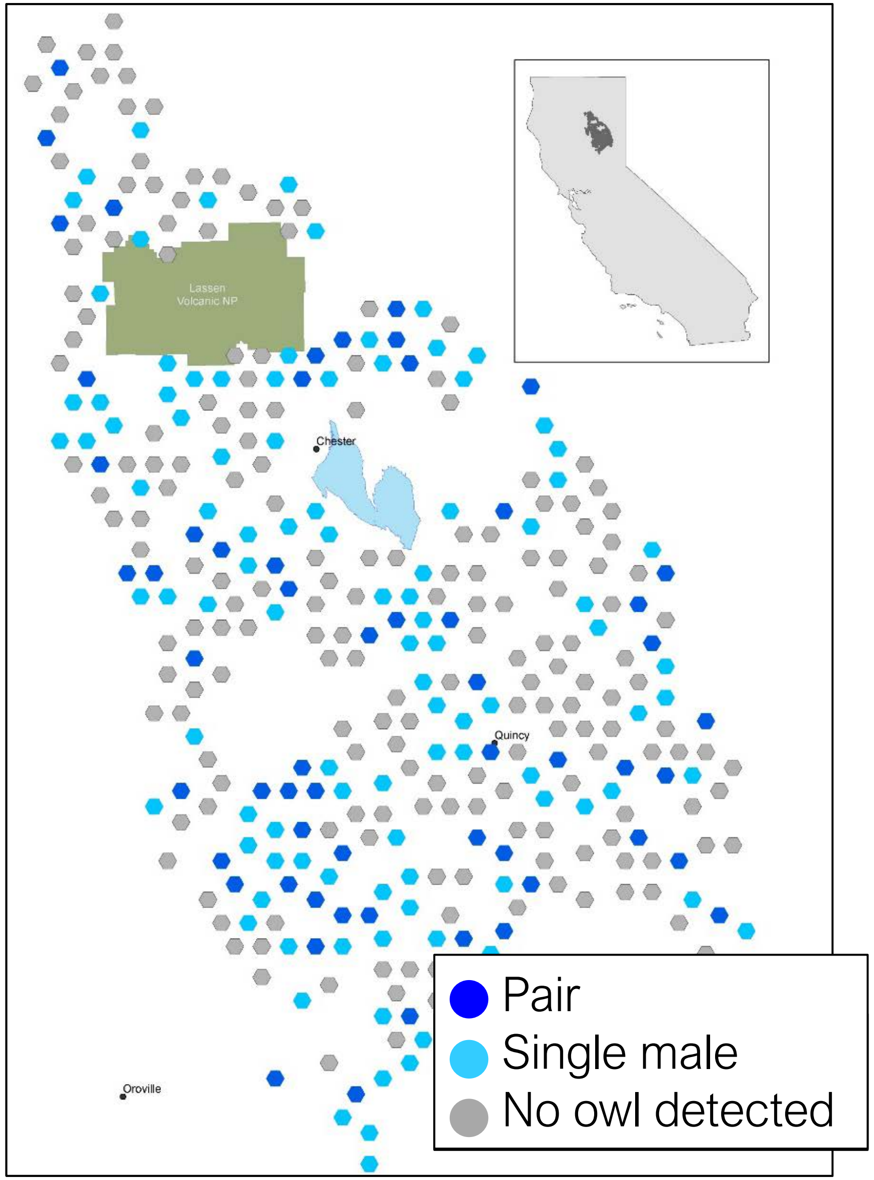
ψ: (-) open forest

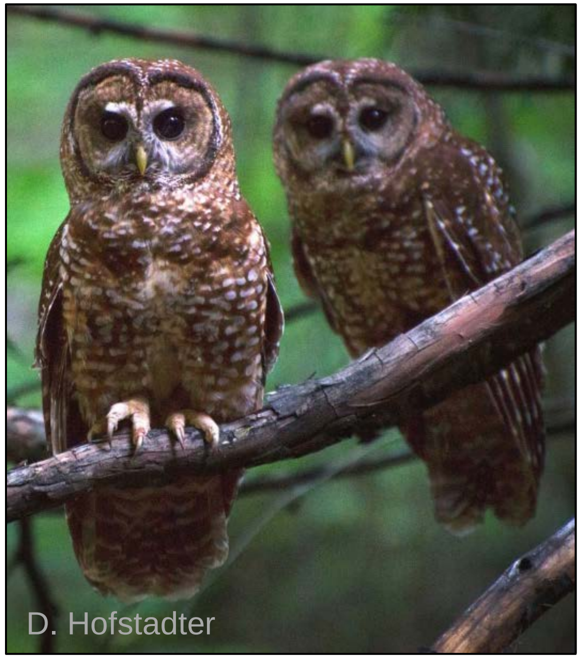
Multi-state: single, pair

p_{Pair}: 0.18

ψ_{Any}: (+) old forest

ψ_{Pair}: (+) mt. riparian





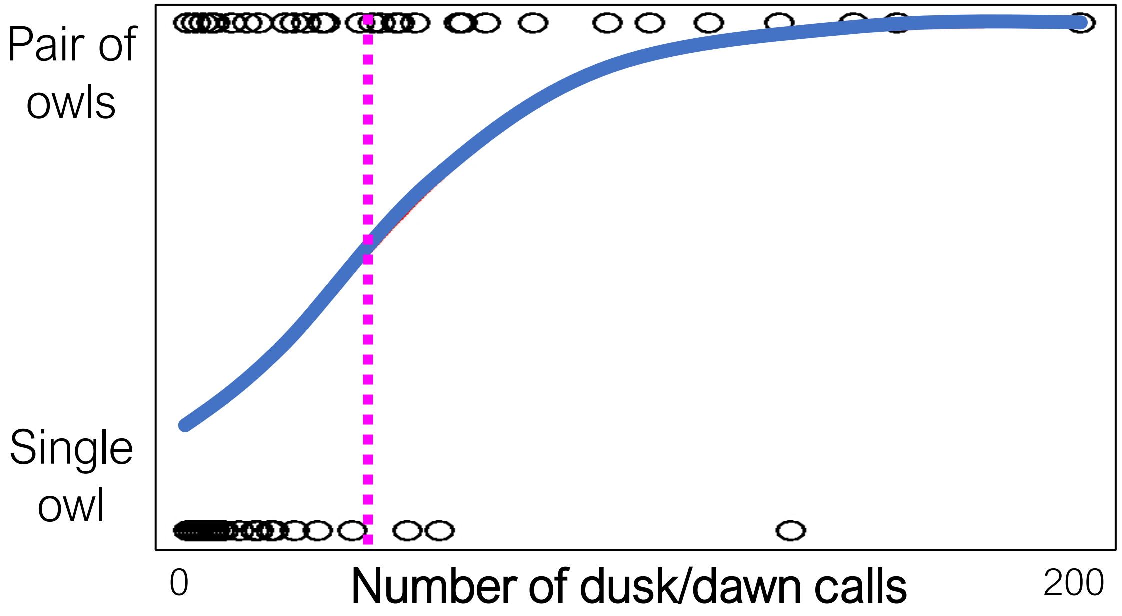
ii) Evaluating behavior

Variation in call rate offers behavioral insights

Overall: reduced in putative foraging habitat

Night: *increased* if barred owls present

Dusk/dawn: increased at sites with pairs



iii. Differentiating individuals

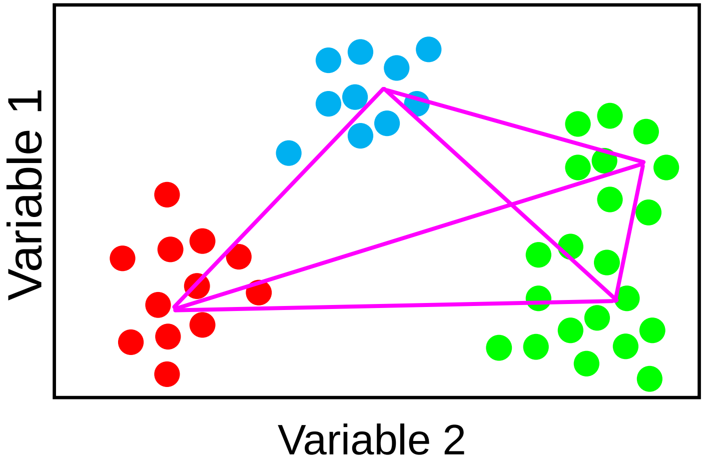
Within years: avoid double-counting mobile birds

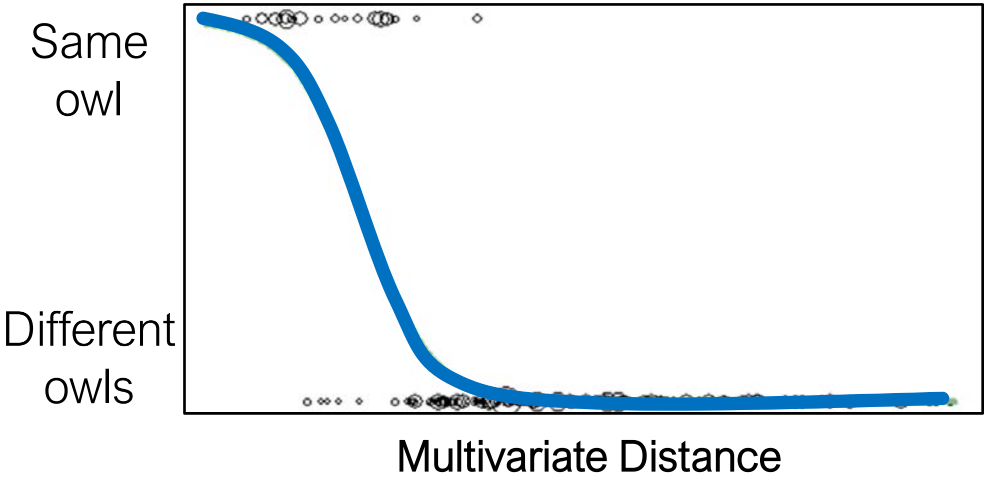
Between years: estimate site turnover

>1,000 calls

Can differentiate birds with 93% accuracy

First step towards acoustic mark-recapture monitoring





Conclusion: detailed inferences possible

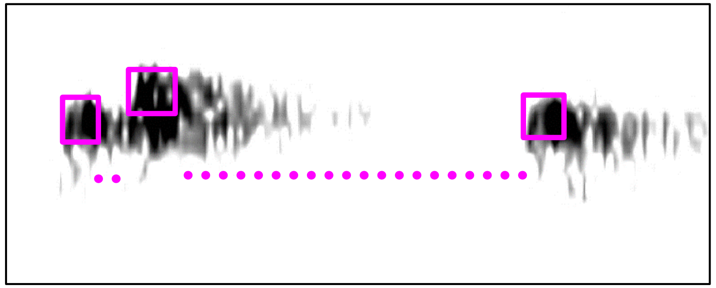
i. Determine pair status

ii. Observe complex behavior

iii. Accurately differentiate individuals

Improve inference by treating sounds as signals

Applicable to many vocally active species



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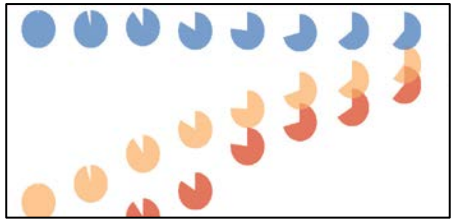
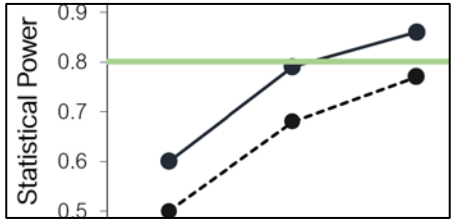
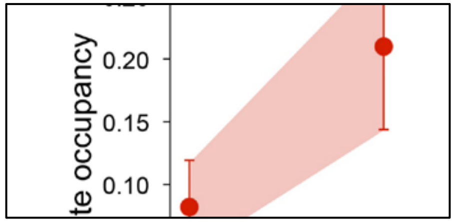
Wood et al. 2020. *Conservation Biology*.; Wood et al. 2019. *Western Birds*.



1. Balancing species conservation – ecosystem restoration tradeoffs



- Statistically powerful landscape-scale acoustic monitoring



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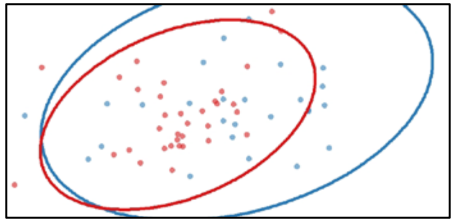

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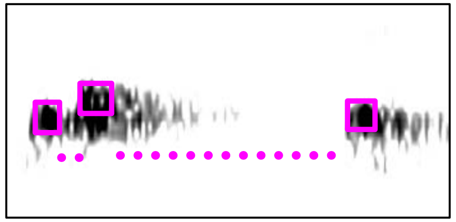

4. Improving inference in acoustic monitoring programs

Statistical Power
0.9
0.8
0.7
0.6
0.5
te occupancy
0.20
0.15
0.10

Acknowledgments

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