Modeling the Effects of DNR Forest Management Alternatives on Marbled Murrelets in Washington:
A Population Viability Analysis Approach

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Population Viability Analysis (PVA)

What is a PVA?

There is no standard definition, most scientists favor a definition that explicitly requires a mathematical model.

"We define PVA as an analysis that uses data in an analytical or simulation model to calculate the risk of extinction or a closely related measure of population viability…" (Ralls et al. 2002)

Why use a PVA?

To ***help*** make management ***decisions*** about species of conservation concern.

Common PVA Applications

- Assessing extinction risk for a population or species
- Determine "MVP" needed to achieve the desired level of protection
- Informing population recovery - is the species still imperiled?
- Identifying key life stages or threats that should be managed (sensitivity analyses)
- Evaluating risks or benefits associated with different management options


cc: Bill and Dot Bell


cc: Sheila Whitmore

PVAs: Panacea or Wishful Thinking?

Panacea?

"Population Viability Analyses represent the flagship technology of the field of Conservation Biology….

Michael Soule (2002)

Wishful Thinking?

Challenges to Strong Inference from PVAs

- Insufficient data to "parameterize" model
- Little information on species-environment relationships
- Little ability to test model-based predictions of risk

Reality

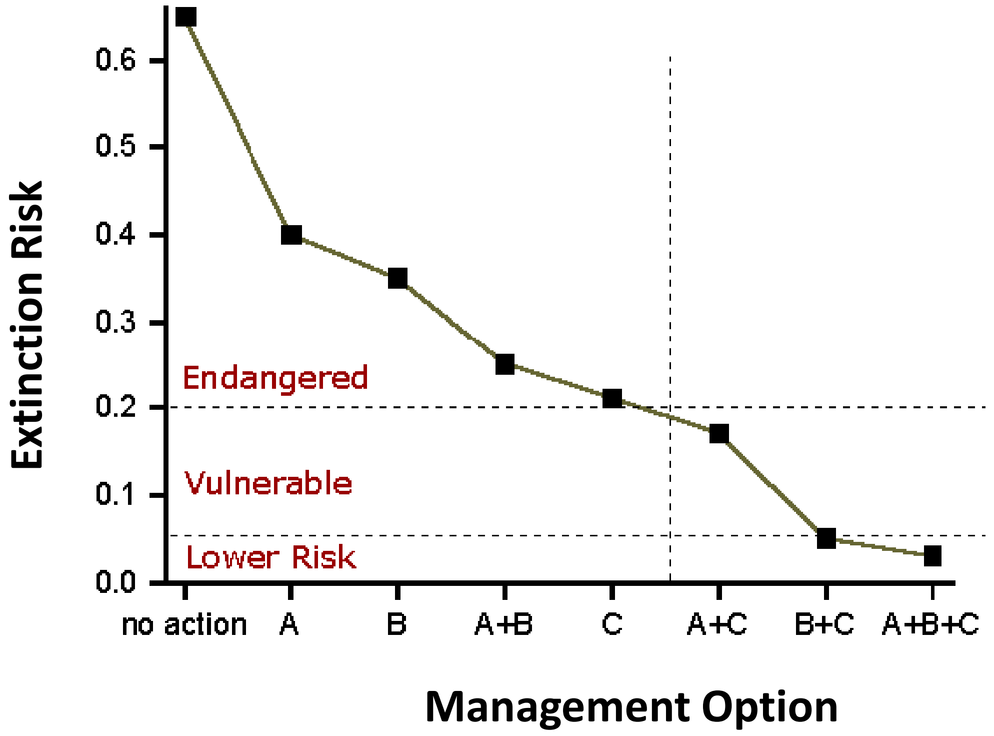
"All models are wrong, but some are useful…"

Box and Draper (1987)

Absolute vs Relative Risk

- ***Absolute*** projections of extinction risk are generally considered unreliable
- Assessment of risk should instead be made on a ***relative*** basis (e.g. among management alternatives)

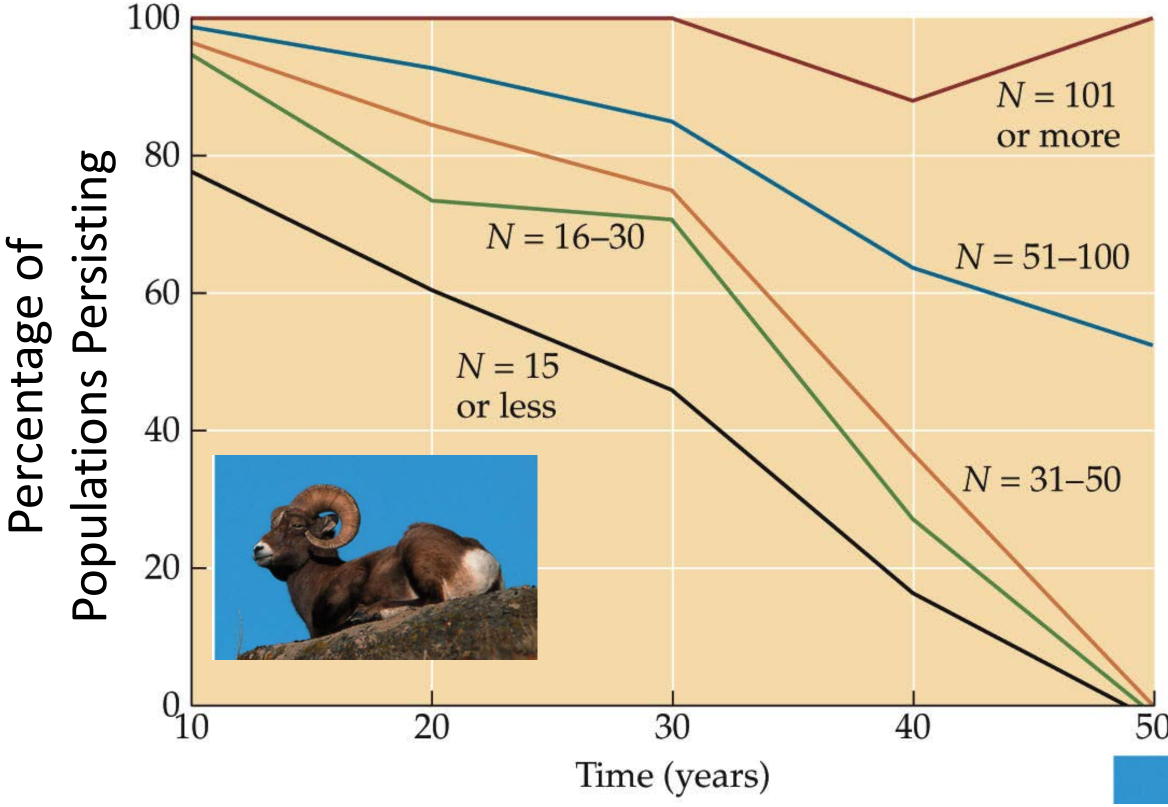
For example, Akçakaya and Atwood (1997. Cons. Bio) ranked management options for California Gnatcatchers based on relative risk of extinction



Biology of Small Populations

- Small populations are more likely to go extinct than large populations

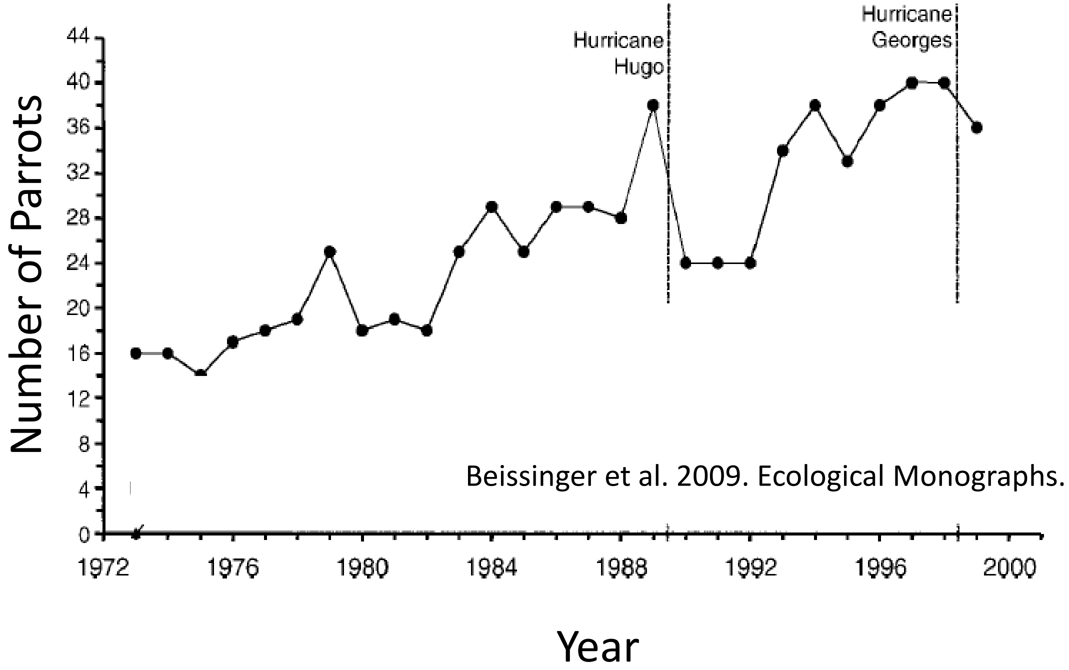
Image Credit: http://www.randykinnick.com/wp-content/uploads/2011/09/Lost-Springs-Population.jpg



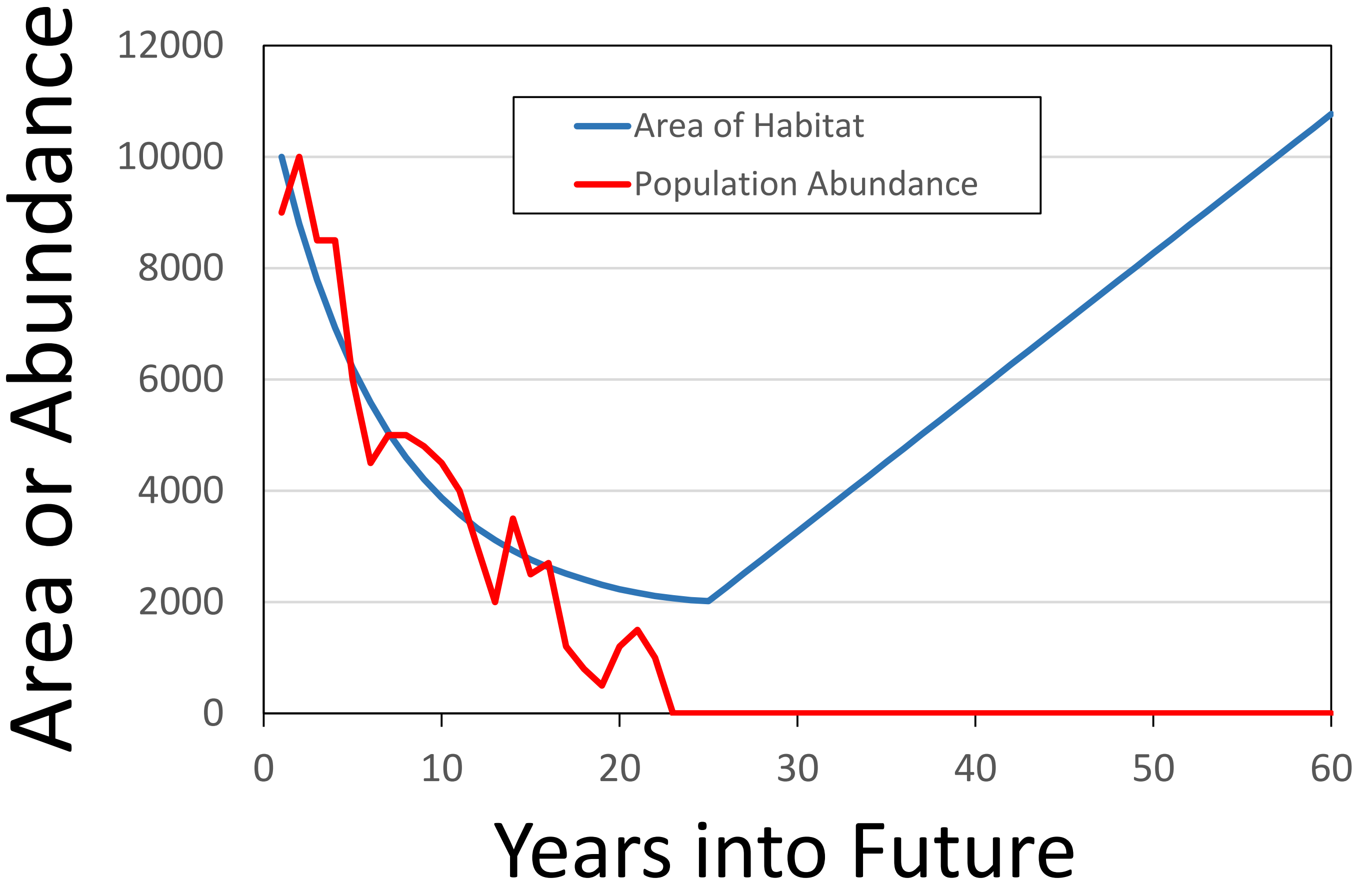
Richard Primack (2010) Essentials of Conservation Biology, 5th edition

Small Populations affected by both Deterministic and Stochastic Factors

- **Deterministic factors**: factors that change population size in a relatively predictable manner such as habitat loss.
- **Stochastic factors**: factors that result in less predictable changes in population size (e.g., genetics, "random" demography, weather, food supplies)

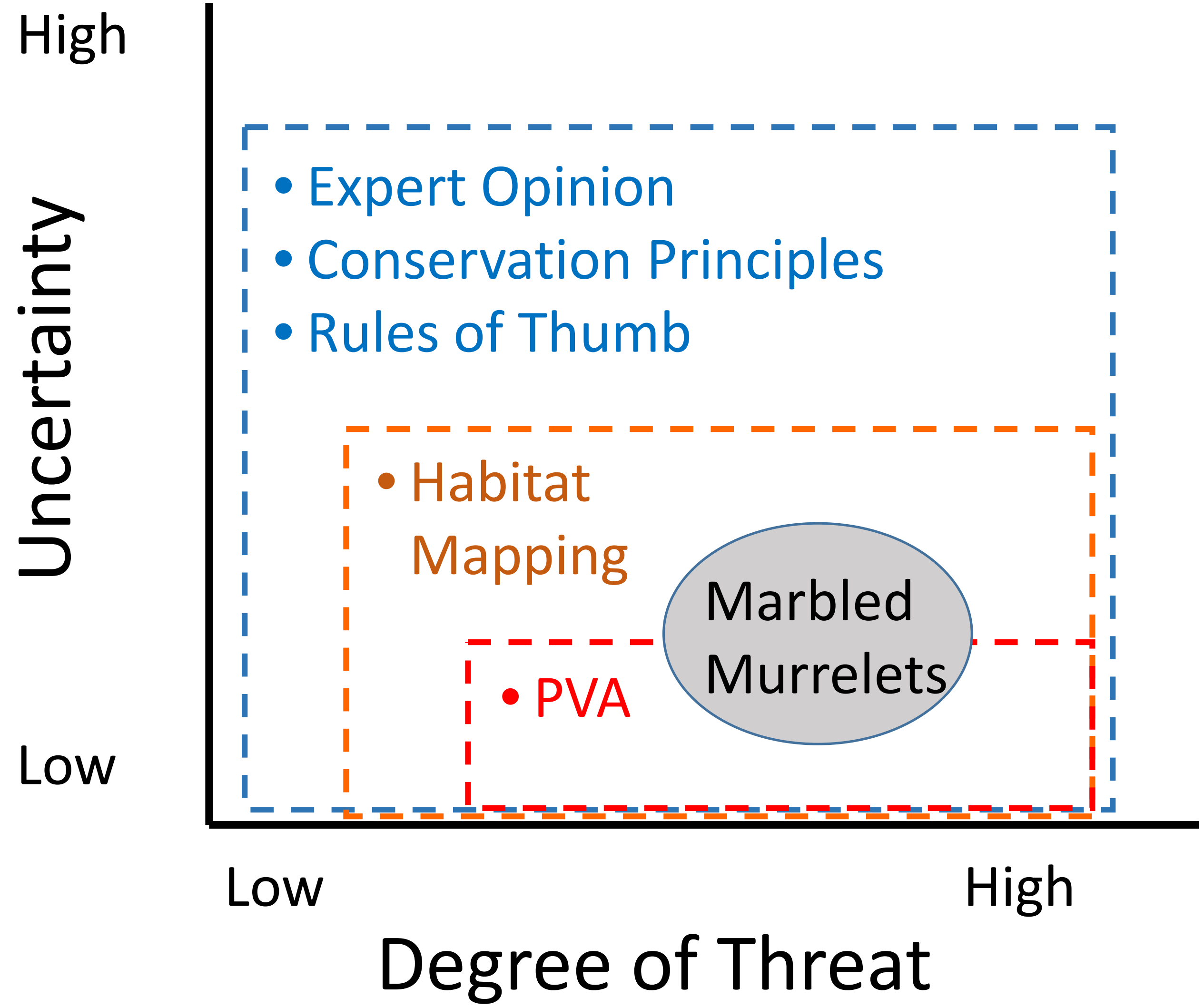


Deterministic and Stochastic Factors can Interact



- PVAs can measure risk during the "bottleneck" (small population) phase

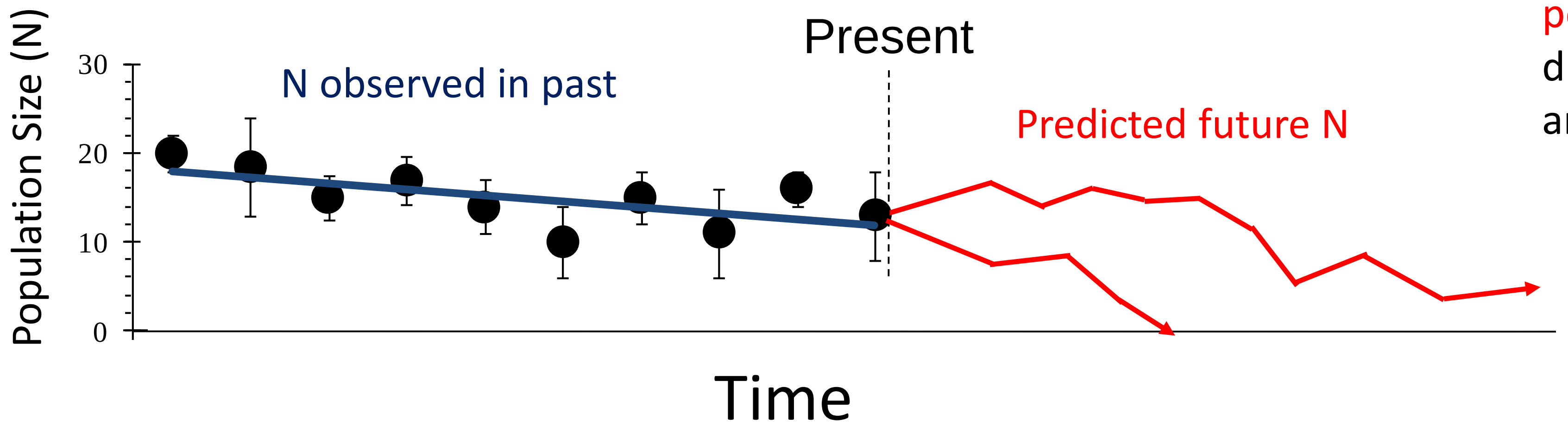
Uncertainty, Threat, and Assessment Method



Population Viability Analysis

<u>PV-*what?*</u>

- Simplest PVAs are based only on numbers of individuals in a population
- Need estimates of historic population growth rates, current population size, and effects of stochasticity
- Use mathematical model (equations) to “project” simulated populations in forward in time



<u>Risk Metrics</u>

Extinction probability: proportion of simulated populations where N becomes zero

Expected change in population size: average difference in beginning and ending N

Incorporating Environmental Effects with Model Parameters

Modified from: Dennis et al. (2000) Journal of Wildlife Management

Effect of rain on foxes

Effect of coyotes on foxes

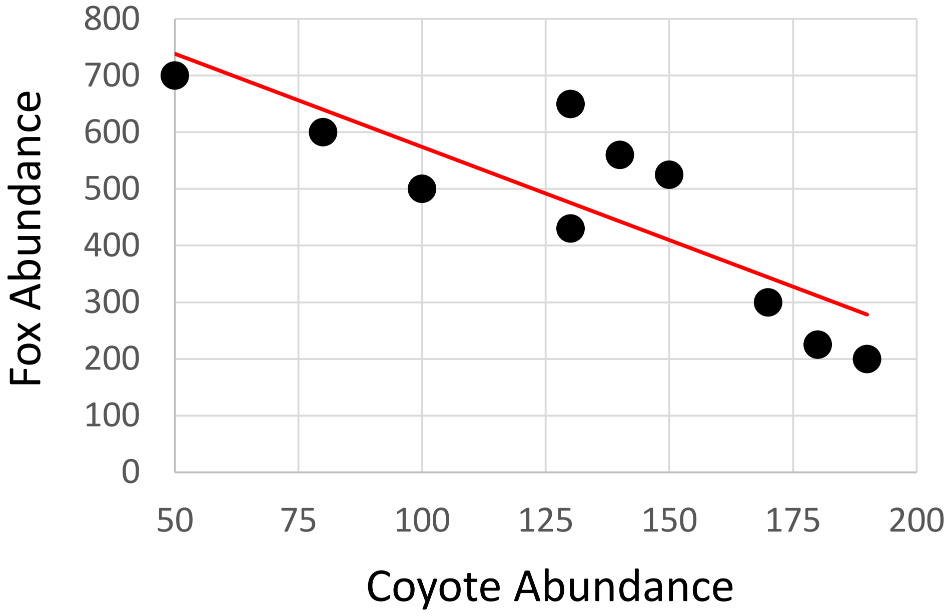
Change in fox abundance = x + x

Amount of rainfall

Coyote abundance

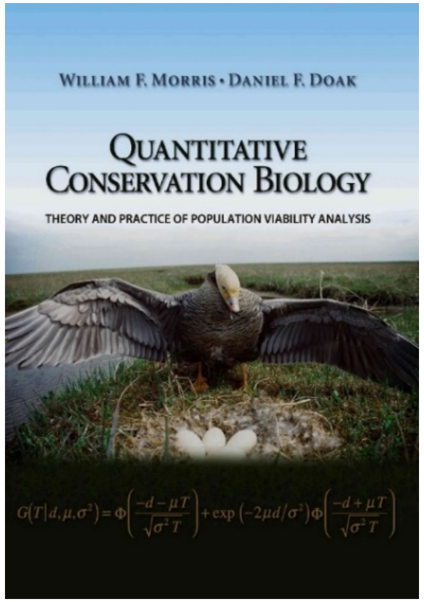
How Do We Estimate Model Parameters?

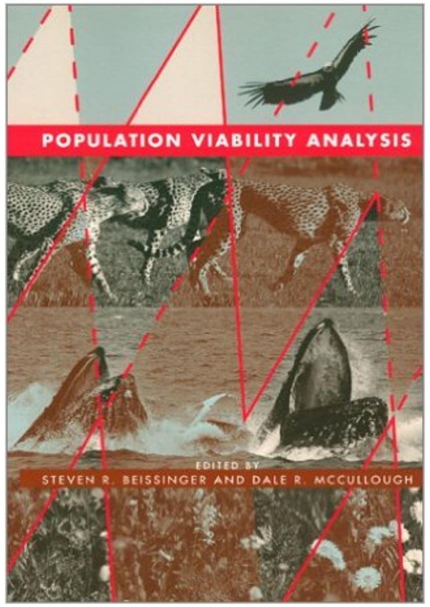
Preferably with data!

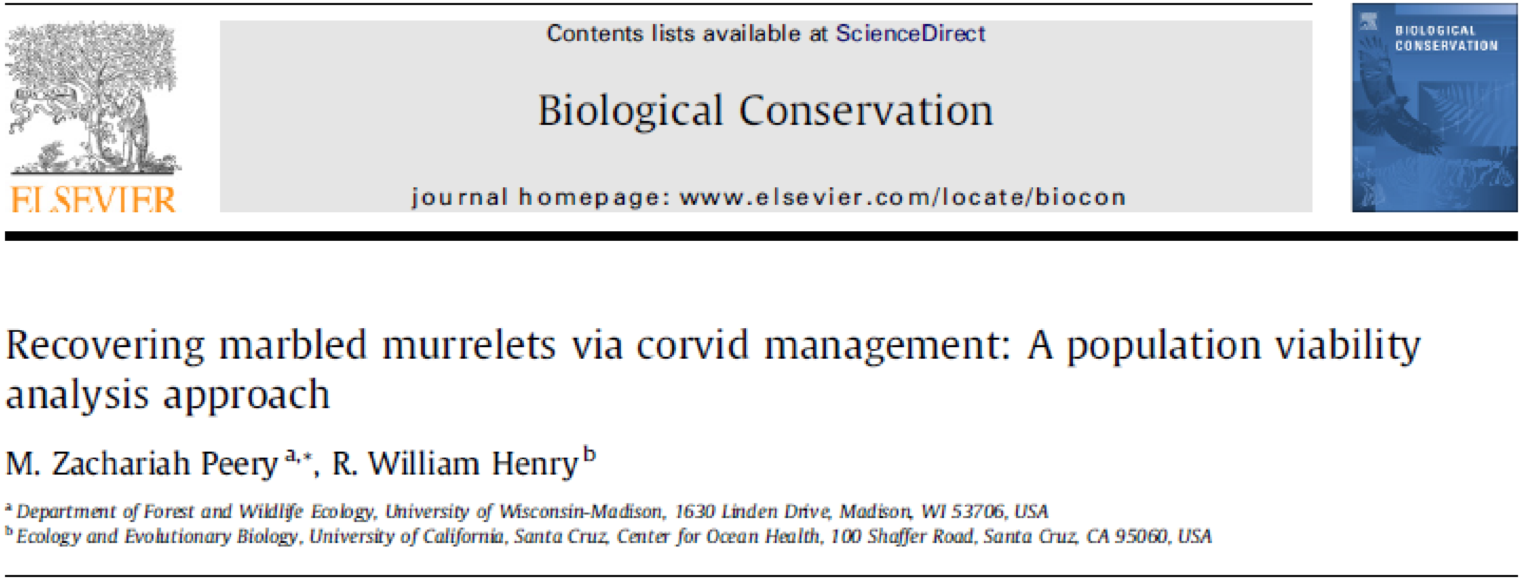


Applying PVA methods to Marbled Murrelets and Forest Management in Washington

- Developed a **demographic, metapopulation** PVA model that projects murrelet populations forward in time
- Estimates risk under various forest management alternatives.
- Basic model structure developed previously for a corvid-based murrelet PVA in California



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Recovering marbled murrelets via corvid management: A population viability analysis approach

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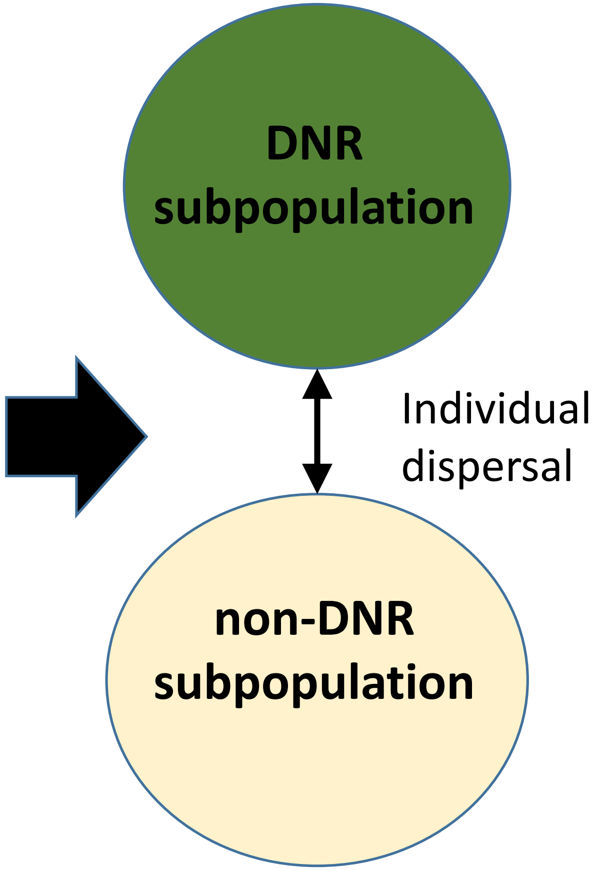
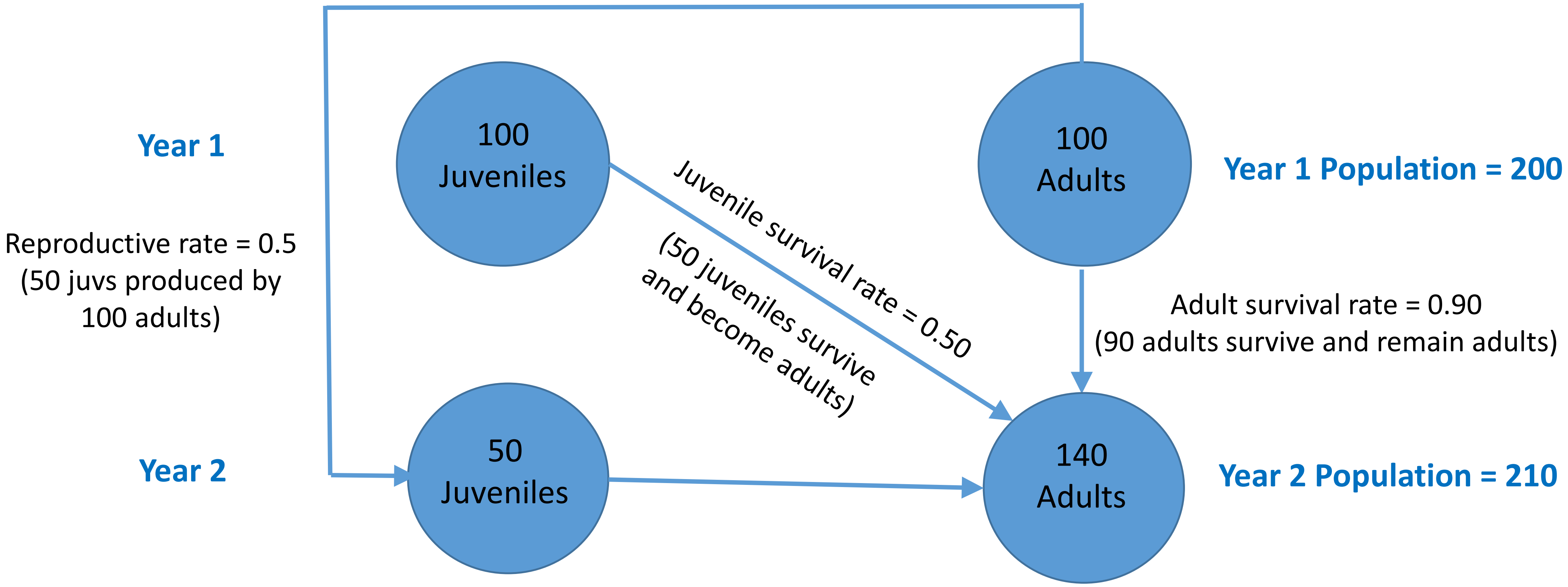
A “Meta-population” Model

- A **metapopulation** consists of a group of spatially separated subpopulations “linked” by the dispersal of individuals.
- Dispersal of individuals influences local population dynamics
- The murrelet PVA model assumes two simplified populations (DNR and non-DNR)

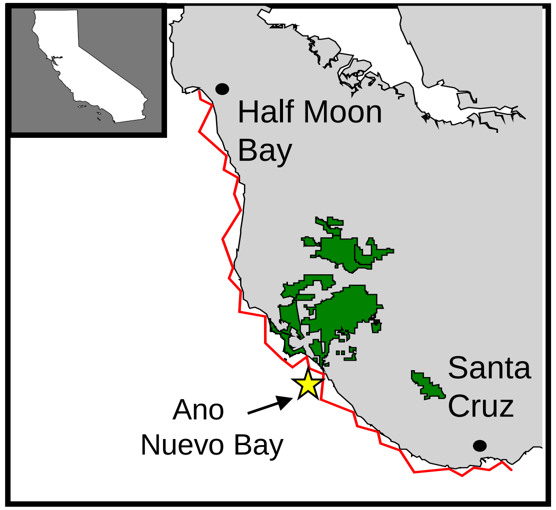


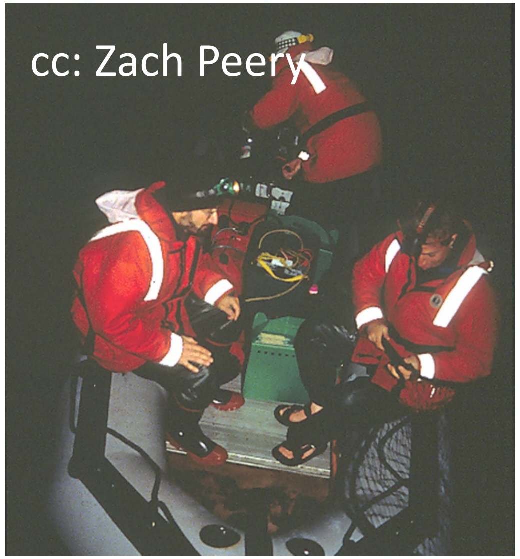
A “Demographic” PVA Model

- The model projects the WA murrelet population forward in time based on demographic rates - **reproductive** and **survival rates -** within subpopulations
- Quiz: how do we incorporate stochasticity?



Estimating Survival Rates





- Non-juvenile survival rates estimated based on a mark-recapture study of murrelets in California (Peery et al. 2006)
- Estimates ranged from *ca.* 0.87 to 0.90
- Juvenile survival rates assumed to be 70% of non-juvenile survival rates (Beissinger 2005)

Reproductive Rule Sets:
Linking the Analytical and PVA Models

- **Habitat quality** (6 *Pstages*) affects **max nesting density**
  - Platform density, canopy layers, stand origin, forest type

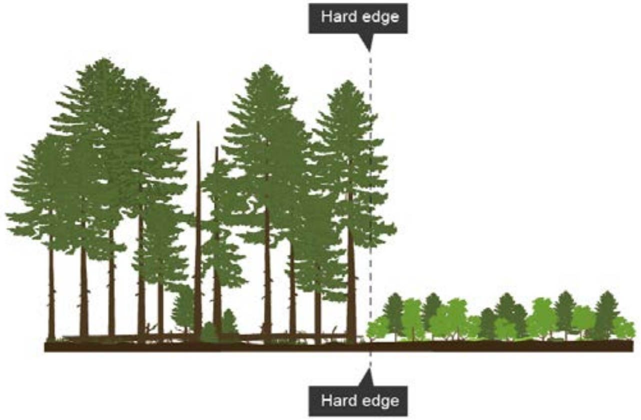
Pstage: 0 | 0.25 | 0.36 | 0.47 | 0.62 and 0.89 | 1

Increasing Max Nesting Density

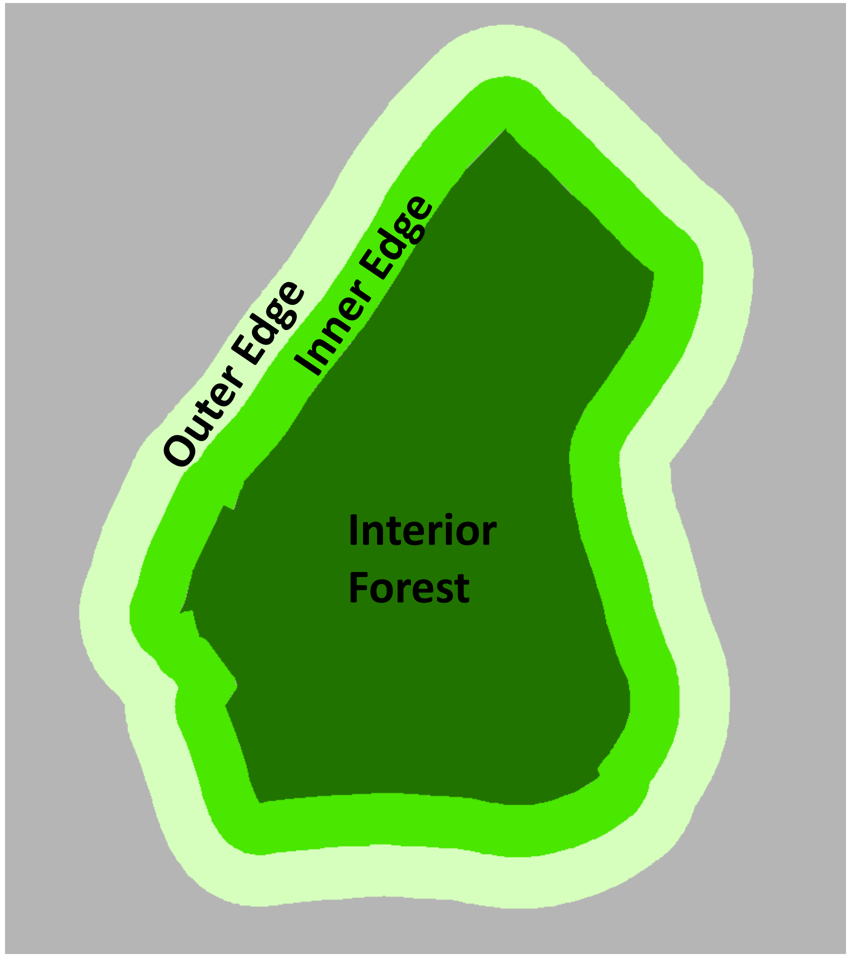
For example, max nesting density in pstage 1 is 4x greater than in pstage 0.25

Reproductive Rule Sets:
Linking the Analytical and PVA Models

- Edge conditions affect **max nesting density**

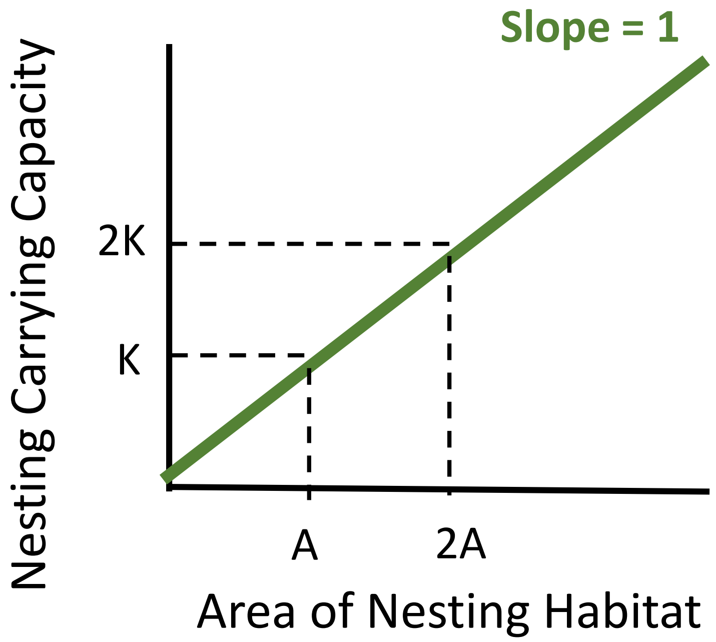


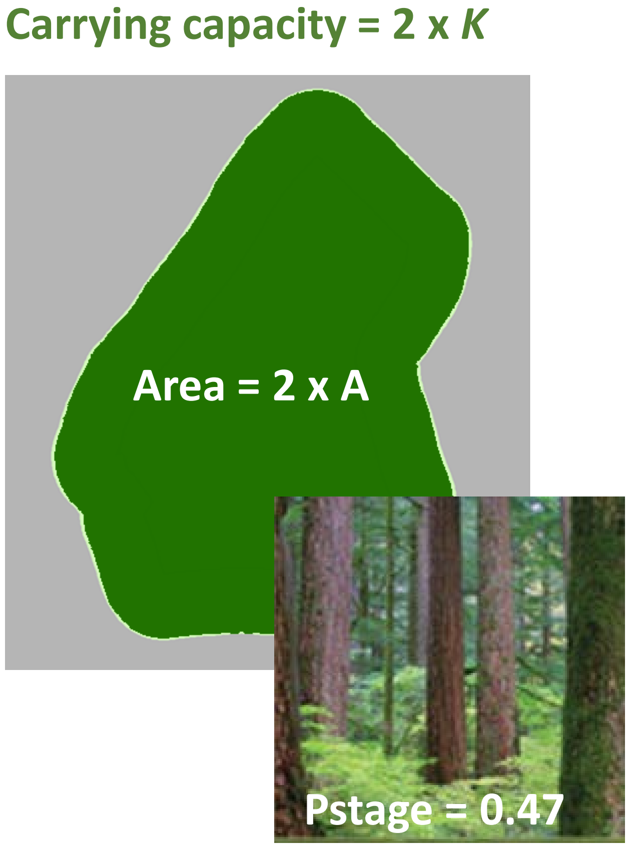
	Max Nest Density
IF	D
IE	Soft: 0.80 x D Hard: 0.625 x D
OE	Soft: 0.60 x D Hard: 0.25 x D



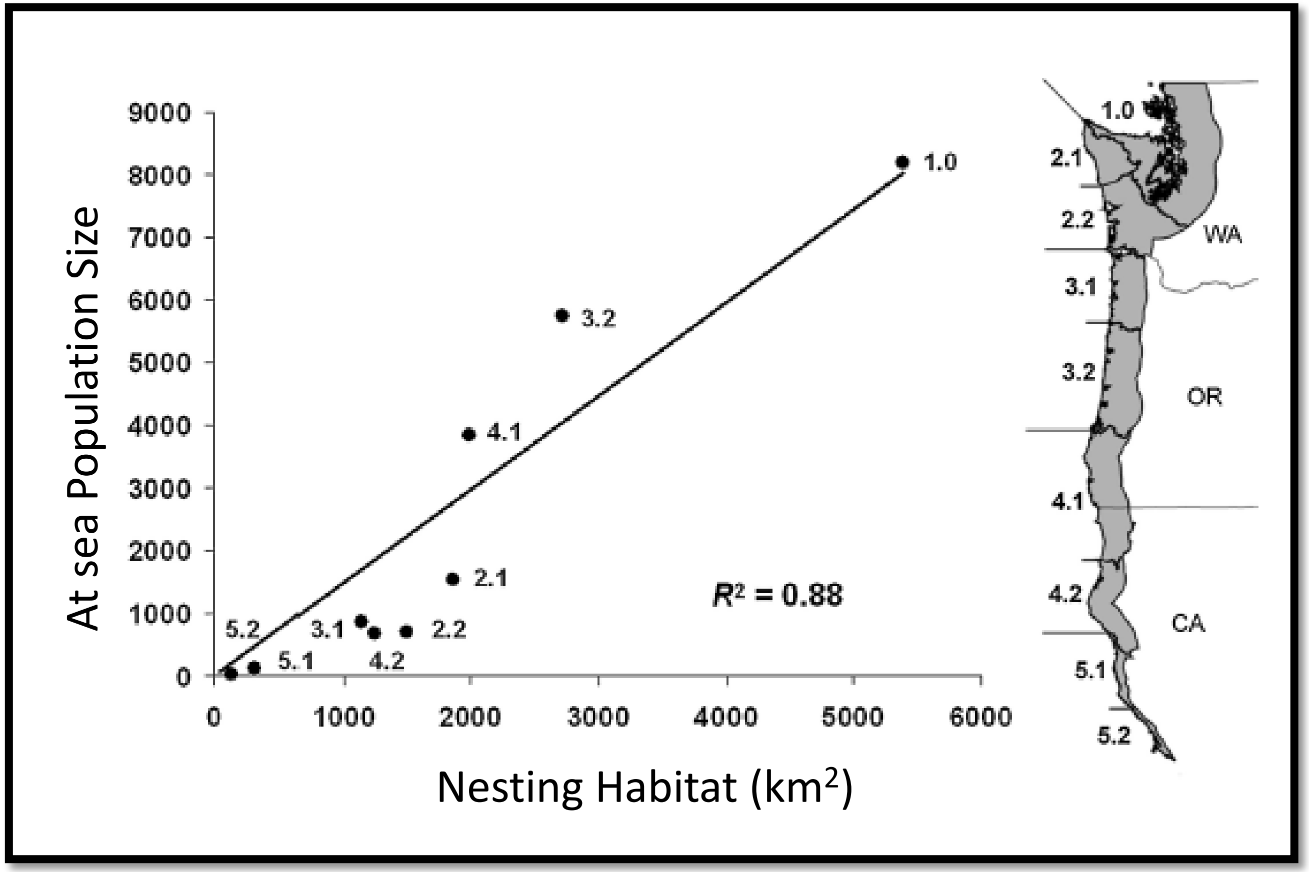
Reproductive Rule Sets:
Linking the Analytical and PVA Models

- Nesting habitat area affects **nesting carrying capacity** in a 1 to 1 manner
- **Nesting carrying capacity = nesting habitat area x max nesting density** (Pstage and edge)



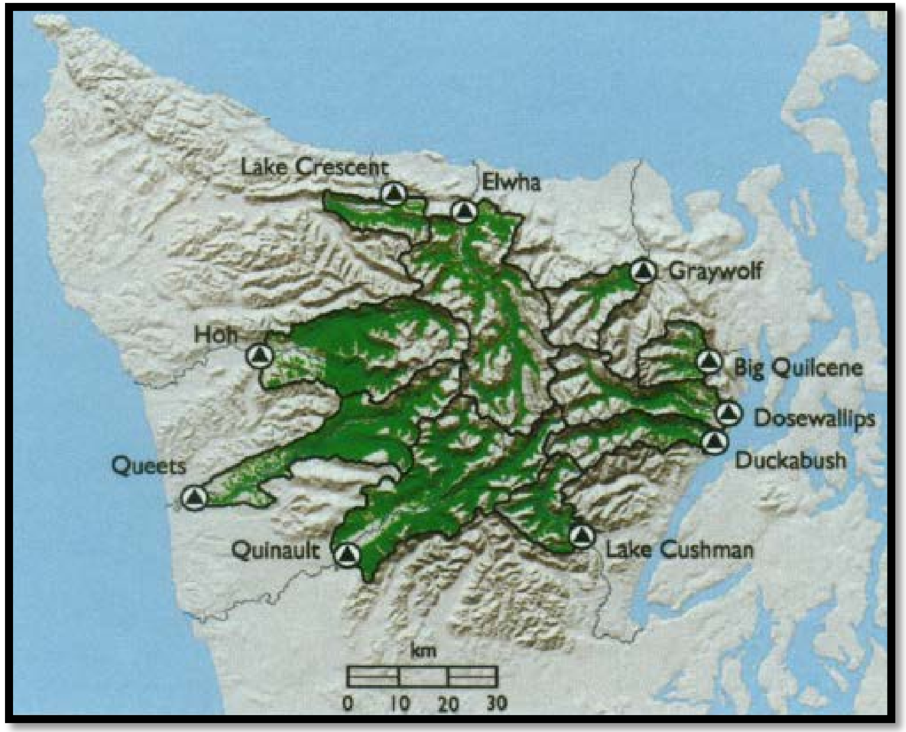


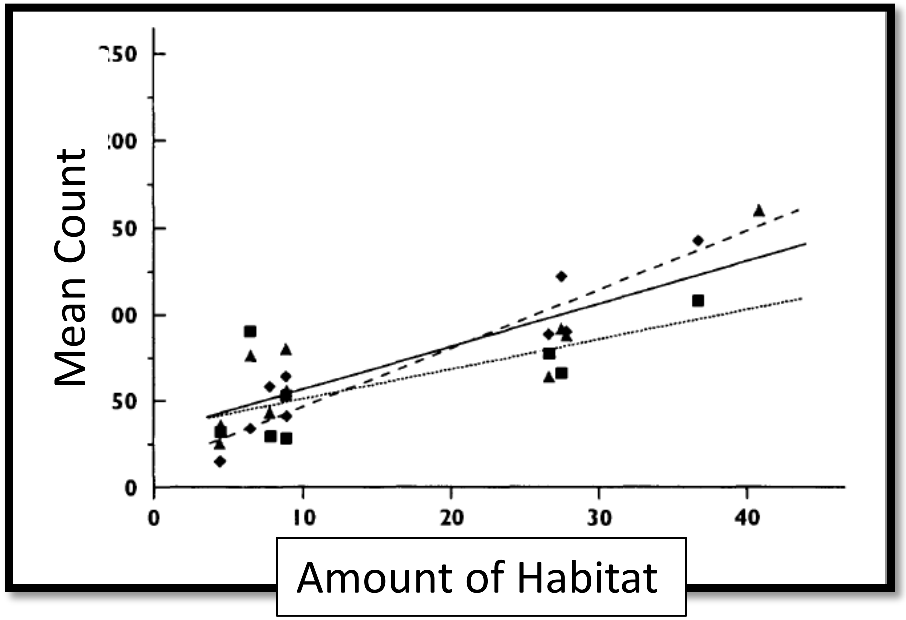
Relationship between Murrelets Numbers and Nesting Habitat



Raphael (2006). Conservation Biology.

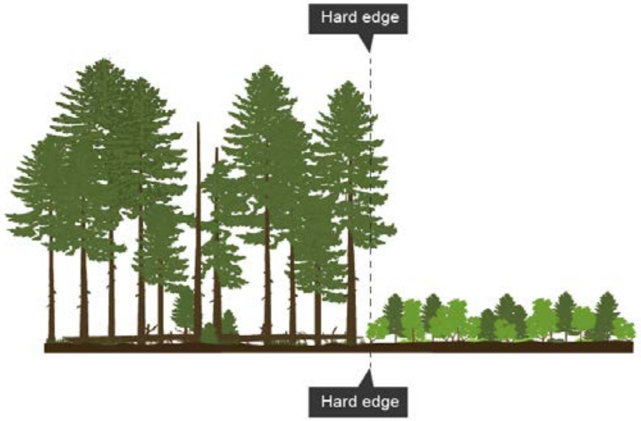
Raphael et al. (2002). Condor.



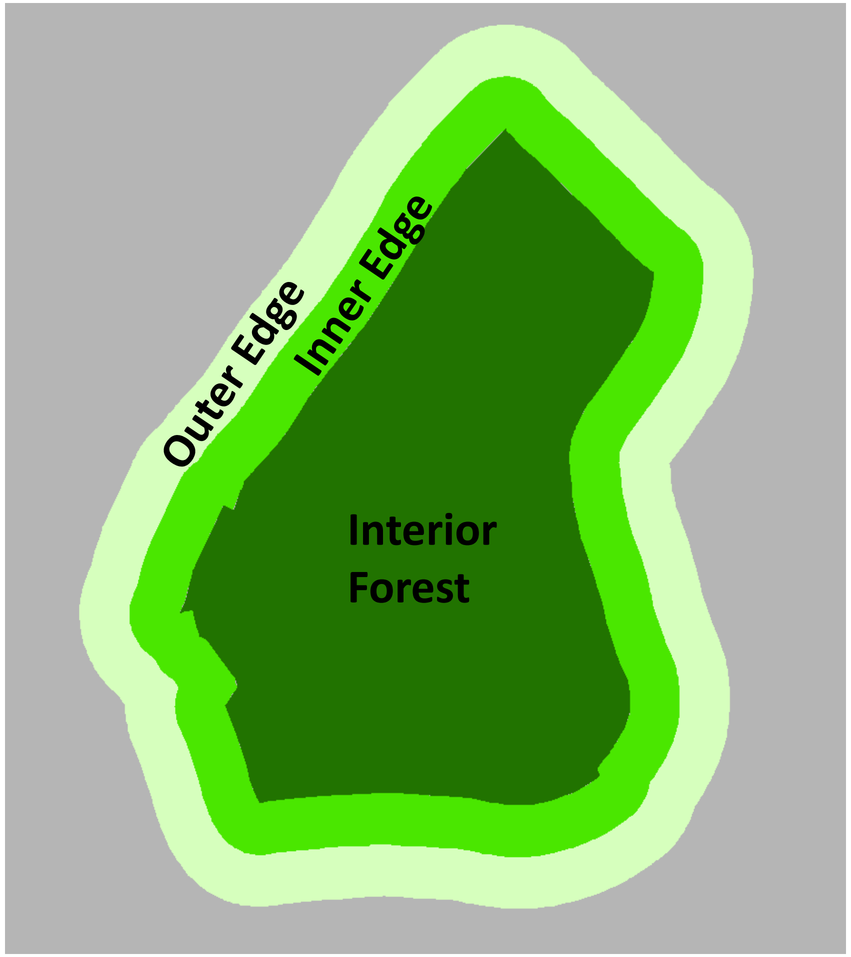


Reproductive Rule Sets: Linking the Analytical and PVA Models

- Edge conditions also affect ***nest success***

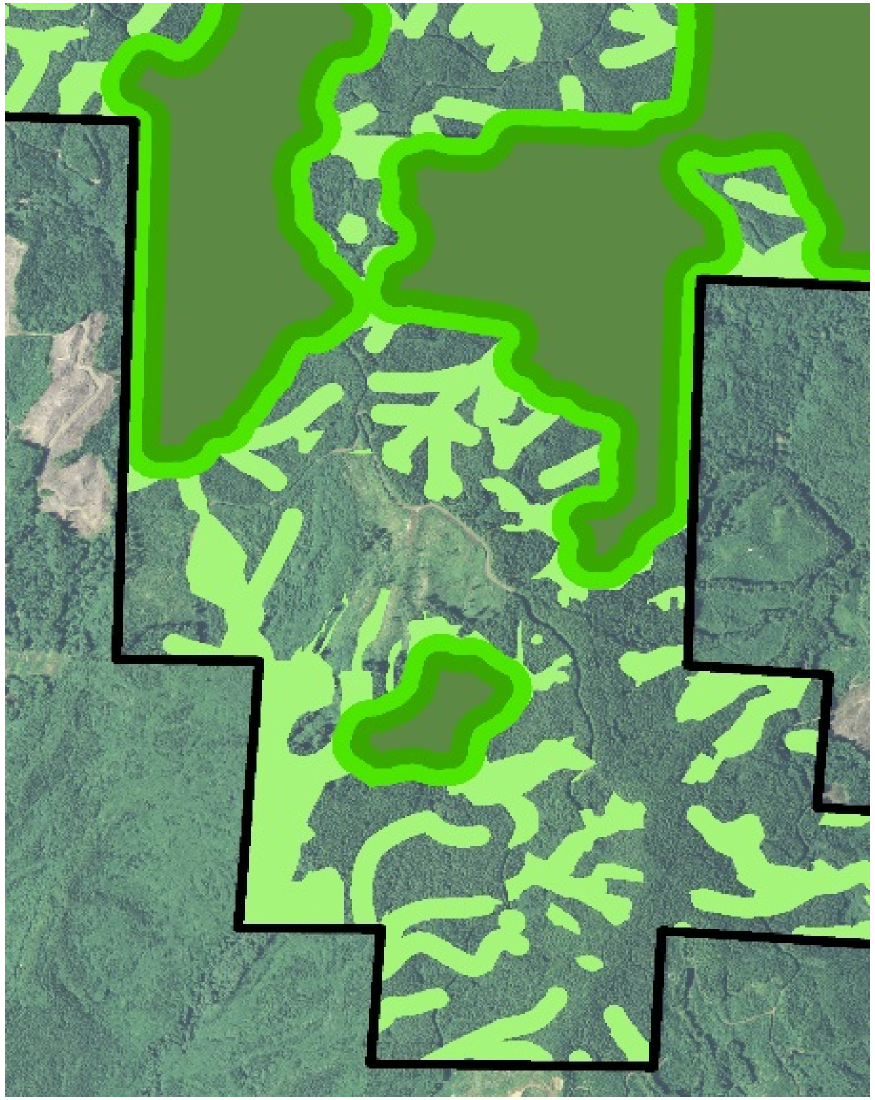


	Nest Success
OE	0.380
IE	0.465
IF	0.550



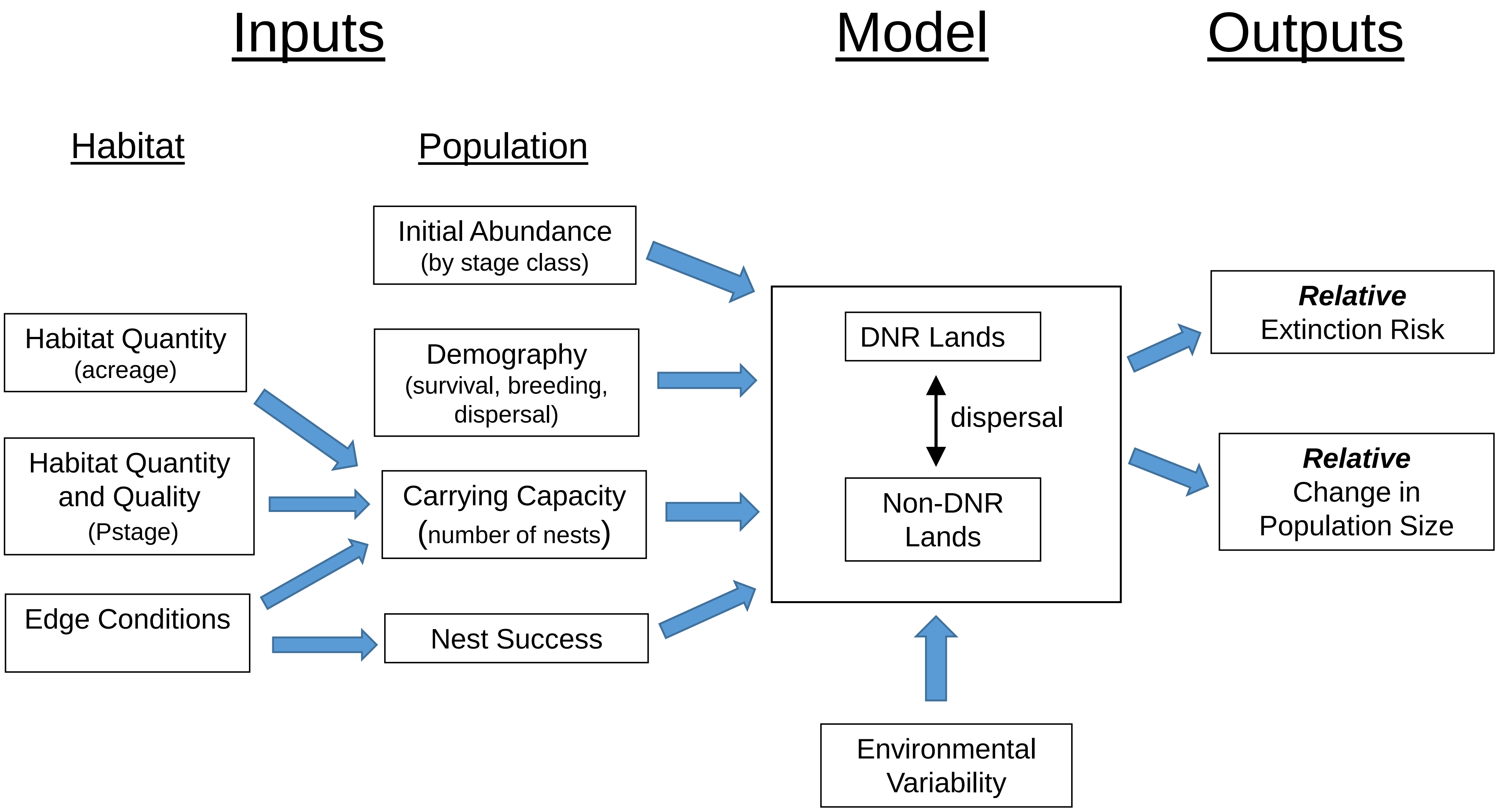
Habitat Conditions and the Landscape Scale

- Current habitat conditions were aggregated across each landownership to determine:
  - Nesting carrying capacity
  - Nest success
- Habitat conditions on DNR lands projected forward in time (50 years) using the Forest Vegetation Simulator
- Assumed no change in habitat on non-DNR lands

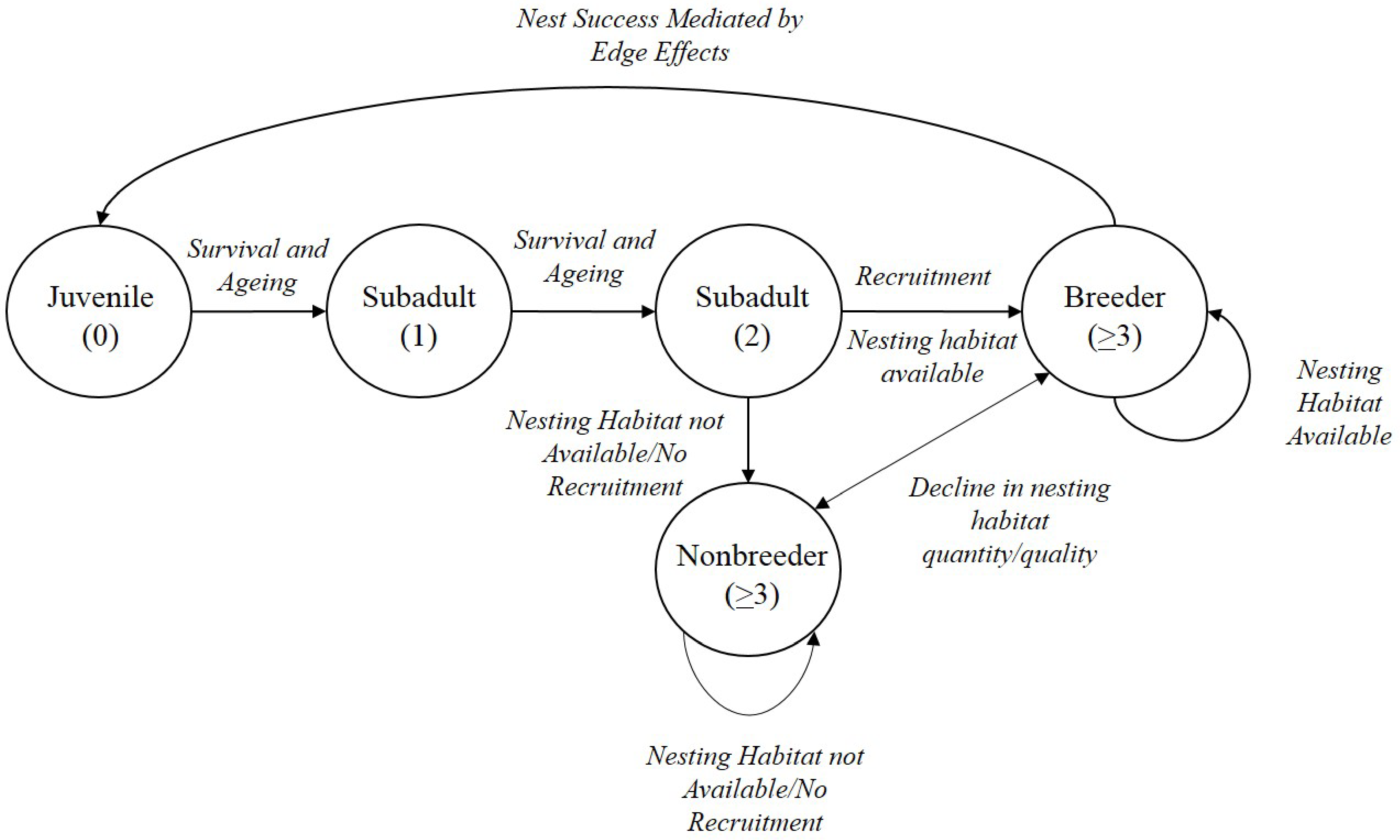


cc: M. Hobson

A Conceptual Representation of the PVA Model



Demographic Submodel



Some Additional Model Rules and Assumptions

- New breeders do not preferentially select high-quality habitat
- Breeders stay in the same landownership unless they are displaced by habitat loss
- Displaced breeders become nonbreeders for at least one year
- Displaced breeders become breeders again if nesting habitat becomes available

Matching the Model to Reality

The Reality

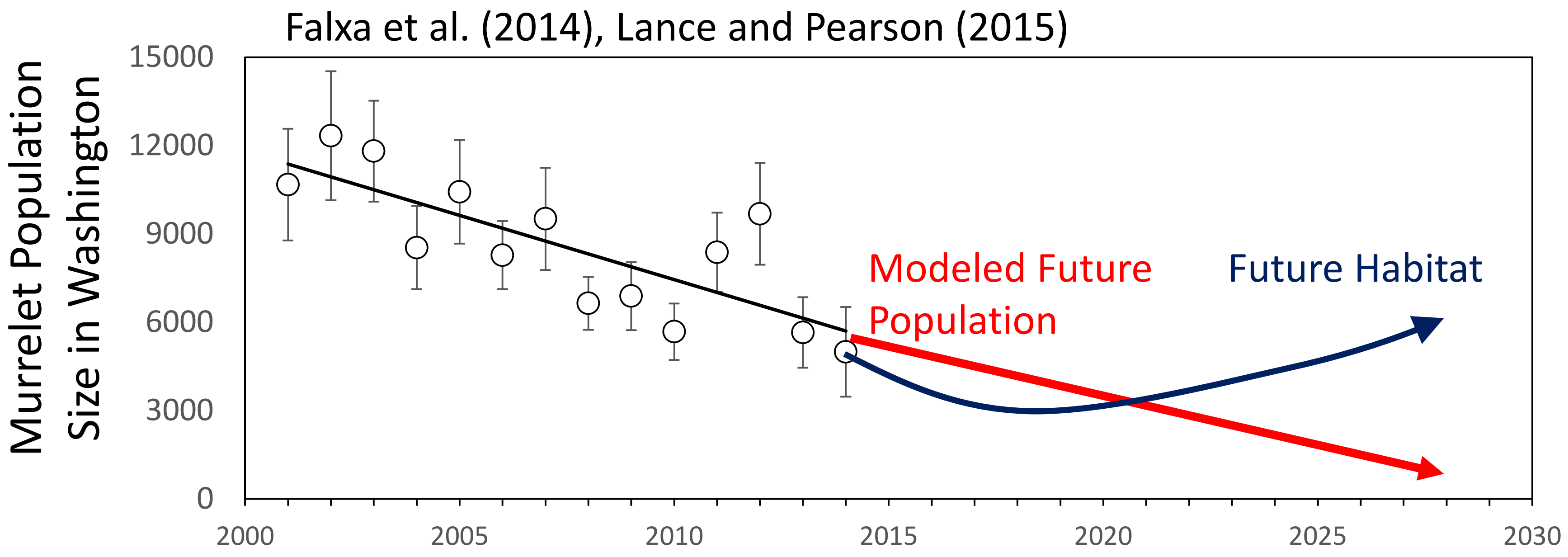
- At-sea monitoring indicates ~5% annual declines in WA from 2001 to 2014

The Problem

- Using values for survival and reproductive rates that yielded 5% declines resulted in little ability for recruits to "fill into" potential new nesting habitat

The Solution

- Conduct parallel "Population Risk" and "Enhancement" analyses with different capacities for murrelets to fill into new nesting habitat



Risk vs Enhancement Analyses

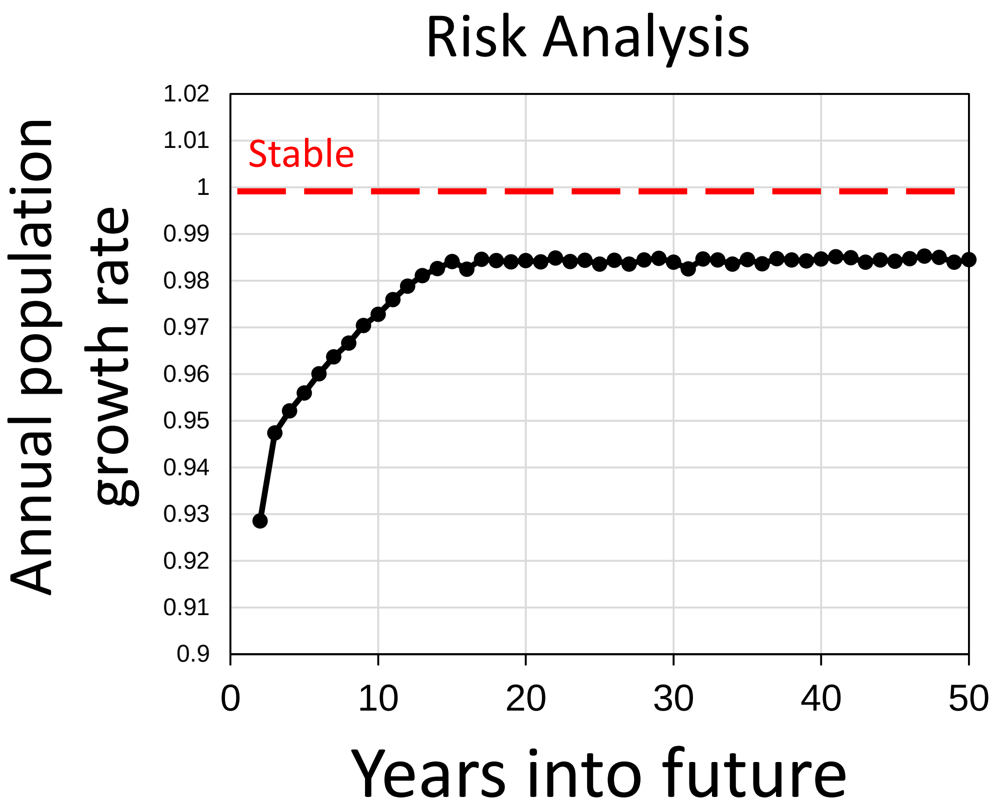
<u>Risk analysis</u>:

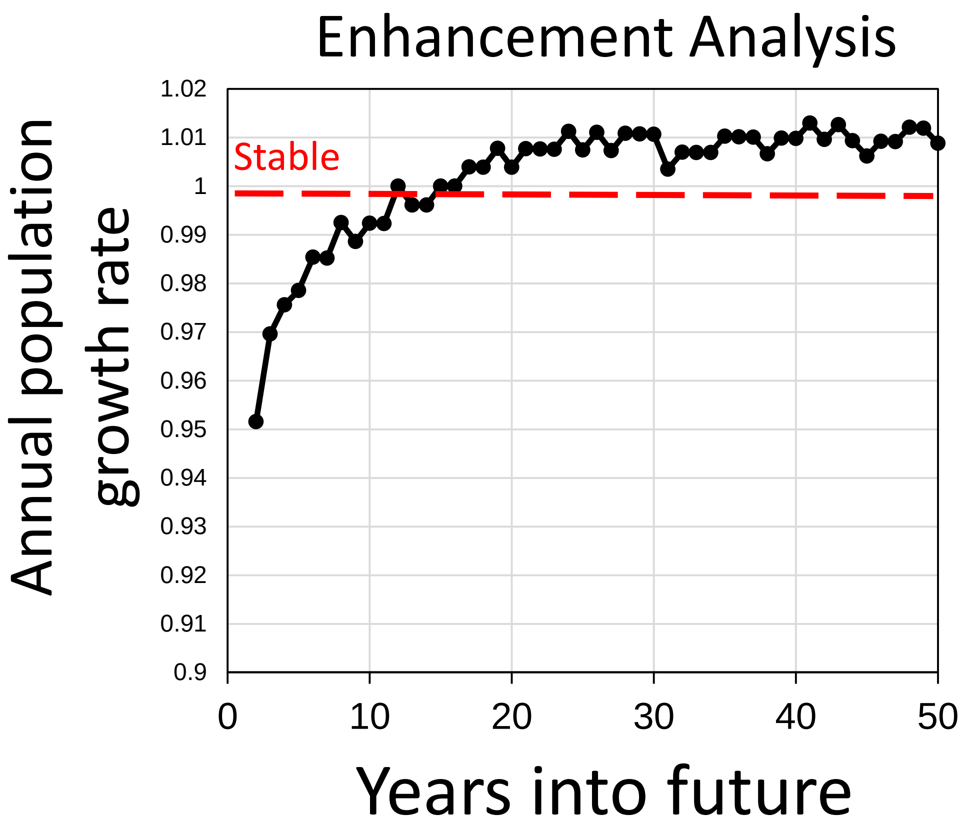
- *How do the alternatives differ in their effects on **risk** to regional (WA) and local (DNR) murrelet populations?*
- Assumes both nesting habitat loss ***and*** chronic environmental stressors caused murrelet population declines
- Uses a relatively “pessimistic” values for adult survival (0.87)
- Less capacity for new recruits to fill into new nesting habitat
- Assumes number of breeders > nesting carrying capacity

<u>Enhancement analysis</u>:

- *How do the alternatives differ in ability to **enhance** regional (WA) and local (DNR) murrelet populations?*
- Assumes nesting habitat loss is the primary factor cause of murrelet population declines
- Uses a relatively “optimistic” values for adult survival (0.90)
- Greater capacity for new recruits to fill into new nesting habitat
- Assumes number of breeders > nesting carrying capacity

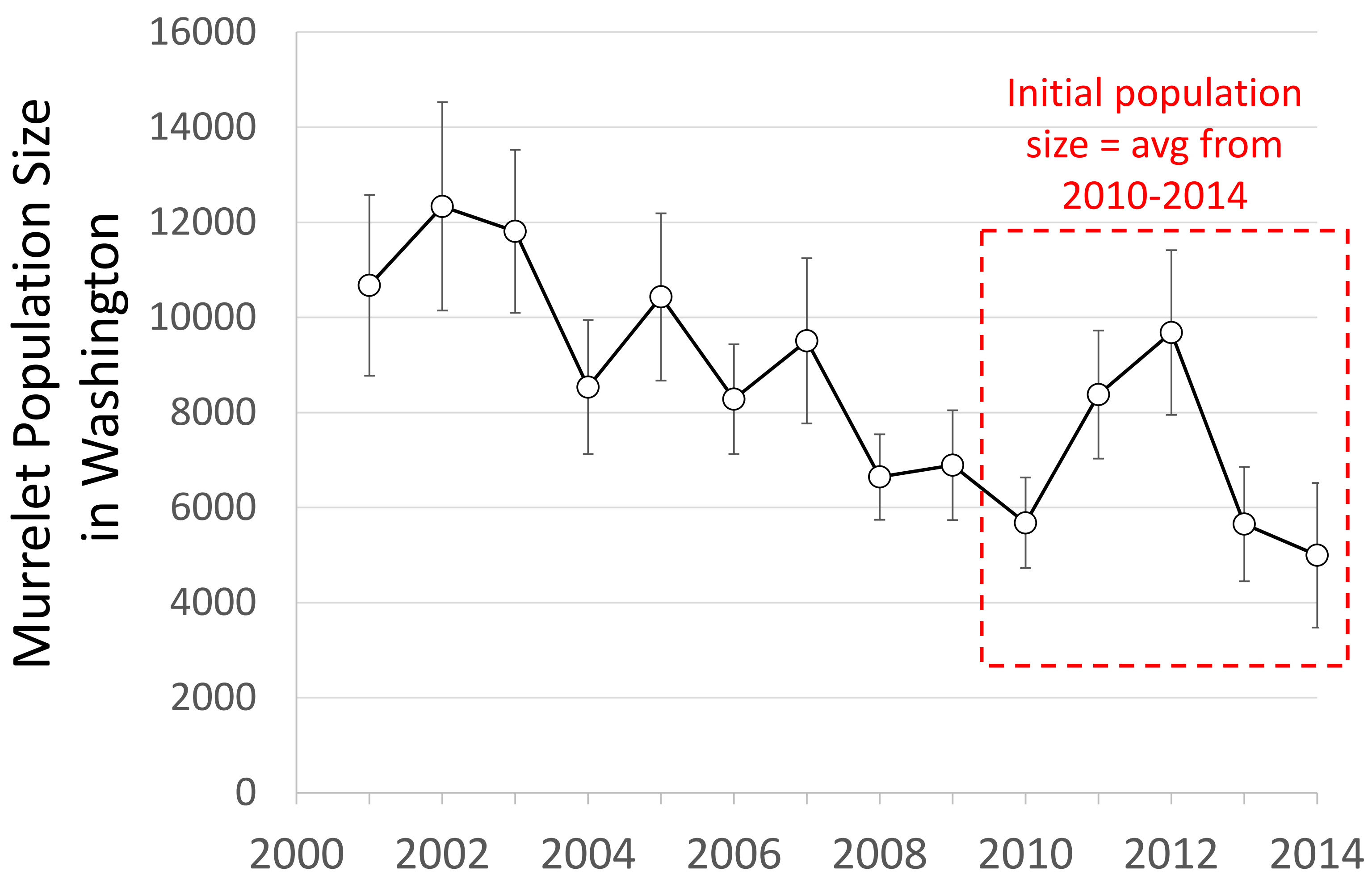
Deterministic Expectations under the “Risk” and “Enhancement” Analyses





Incorporating Stochasticity

- Estimated amount of annual variation in population size from at-sea monitoring
- Used this variation to determine how much survival and reproductive rates should vary from year to year

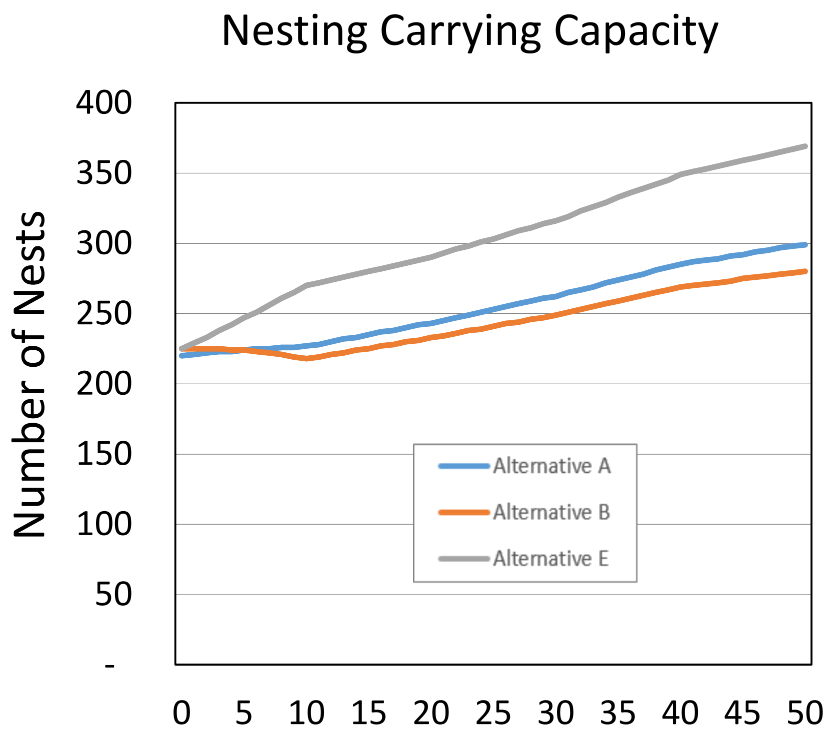


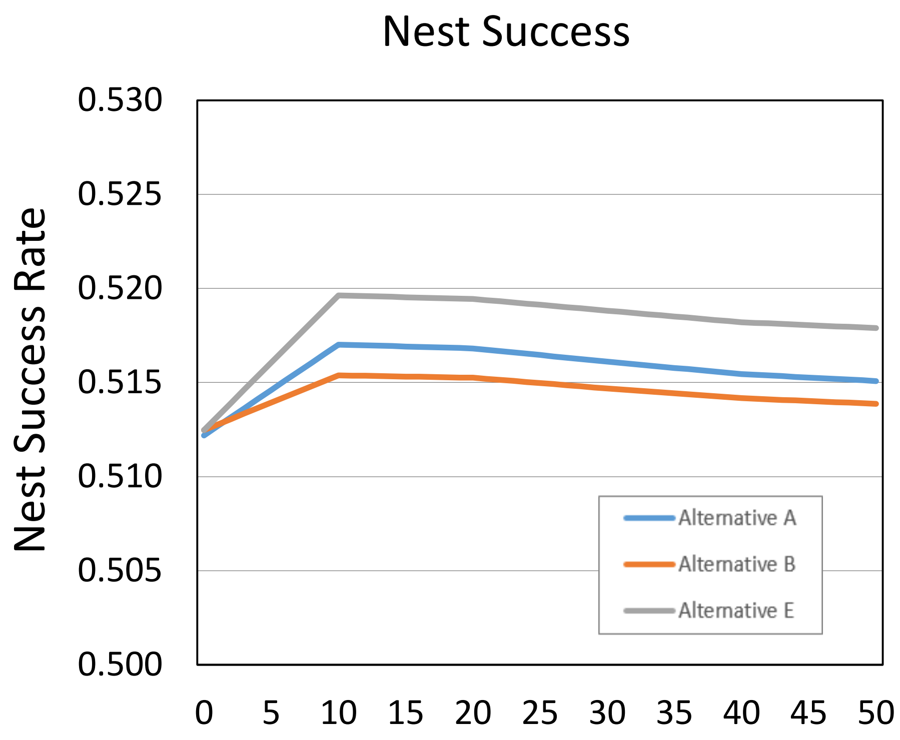
Falxa et al. (2014), Lance and Pearson (2015)

Parameters Used (non-reproductive)

Parameter	Risk	Enhancement
Annual non-juvenile survival rate	0.87	0.90
Annual juvenile survival	0.70 x non-juvenile	
Annual dispersal rate	DNR → non-DNR = 0.91 non-DNR → DNR = 0.09	WA: DNR → non-DNR = 0.91 non-DNR → DNR = 0.09 DNR: 0
Initial female population size	DNR: 311 non-DNR: 3,129	
Initial nesting carrying capacity	40% > Initial number of females of breeding age	
Variance in reproductive rates	0.012	
Variance in survival rates	0.003	

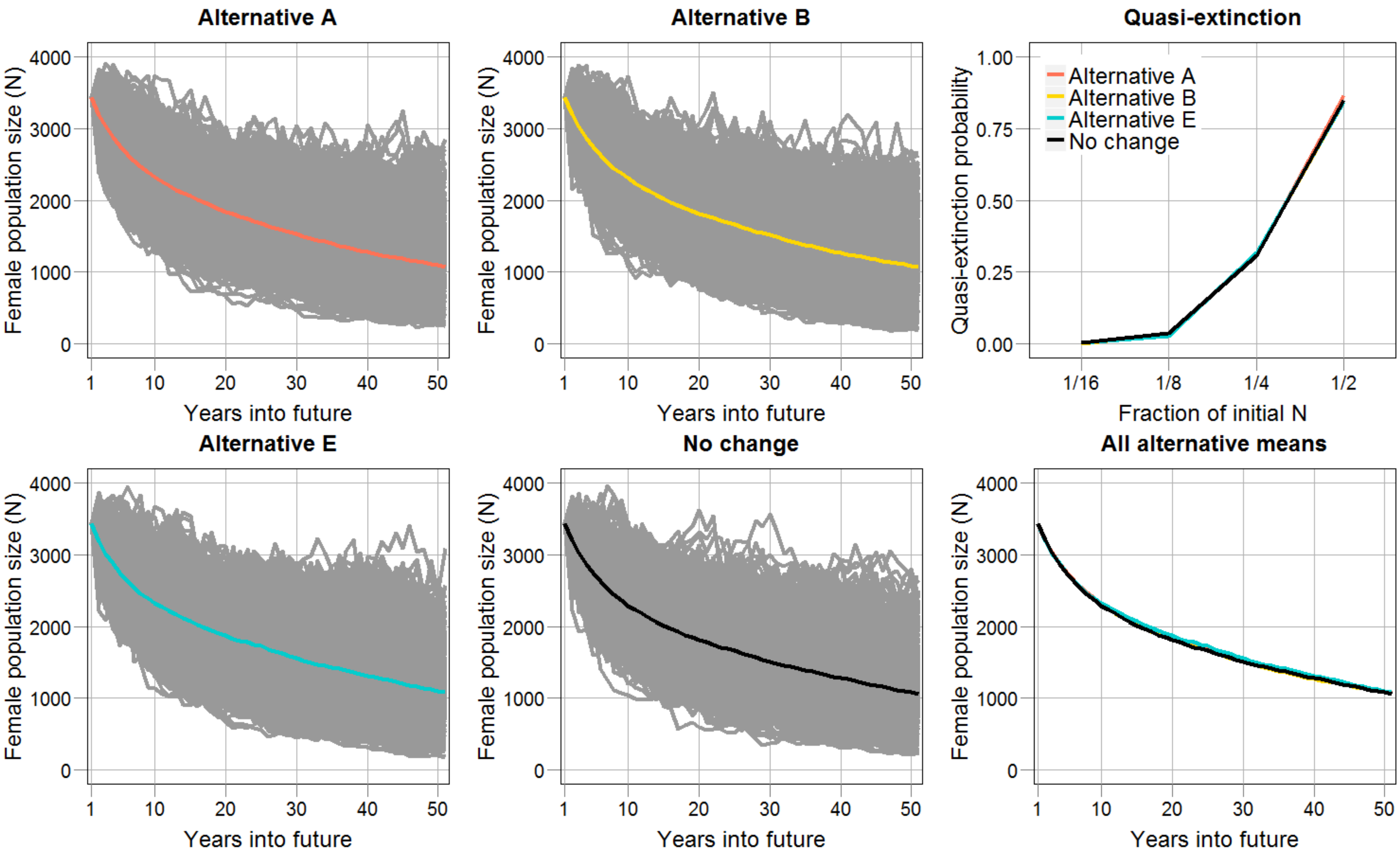
Management Alternatives Considered (DNR-managed Lands)



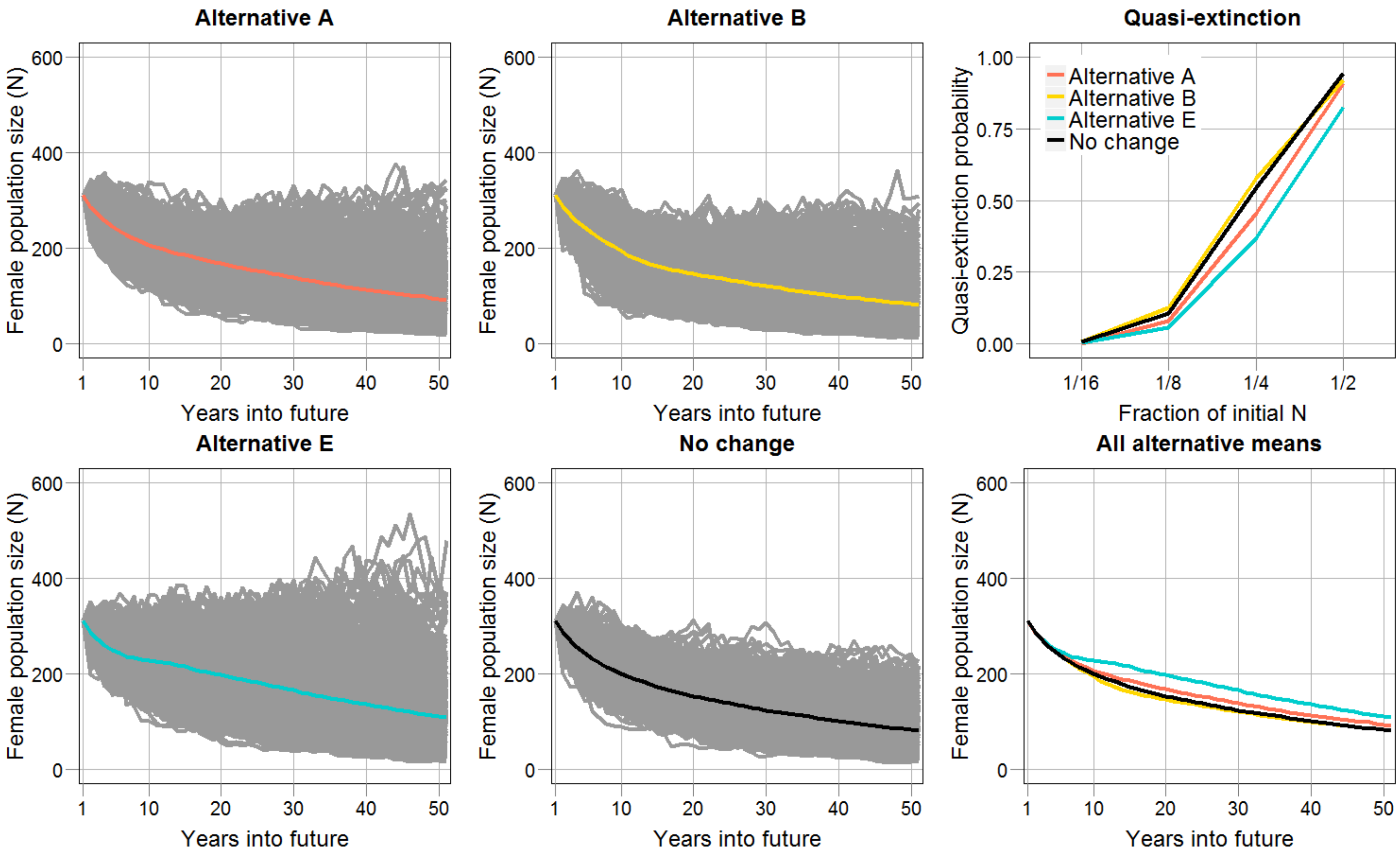


Years into the Future

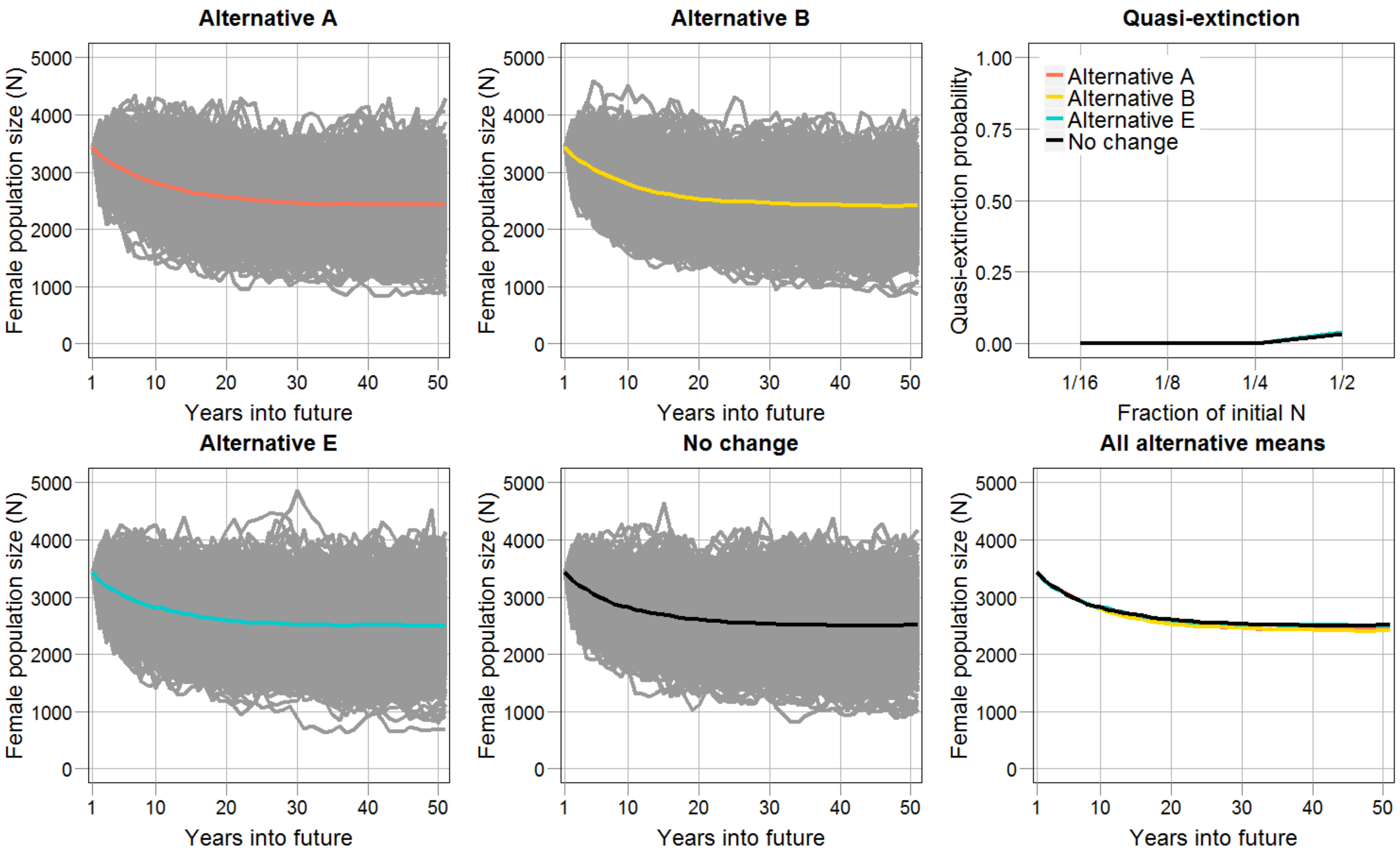
Risk Analysis – State of Washington



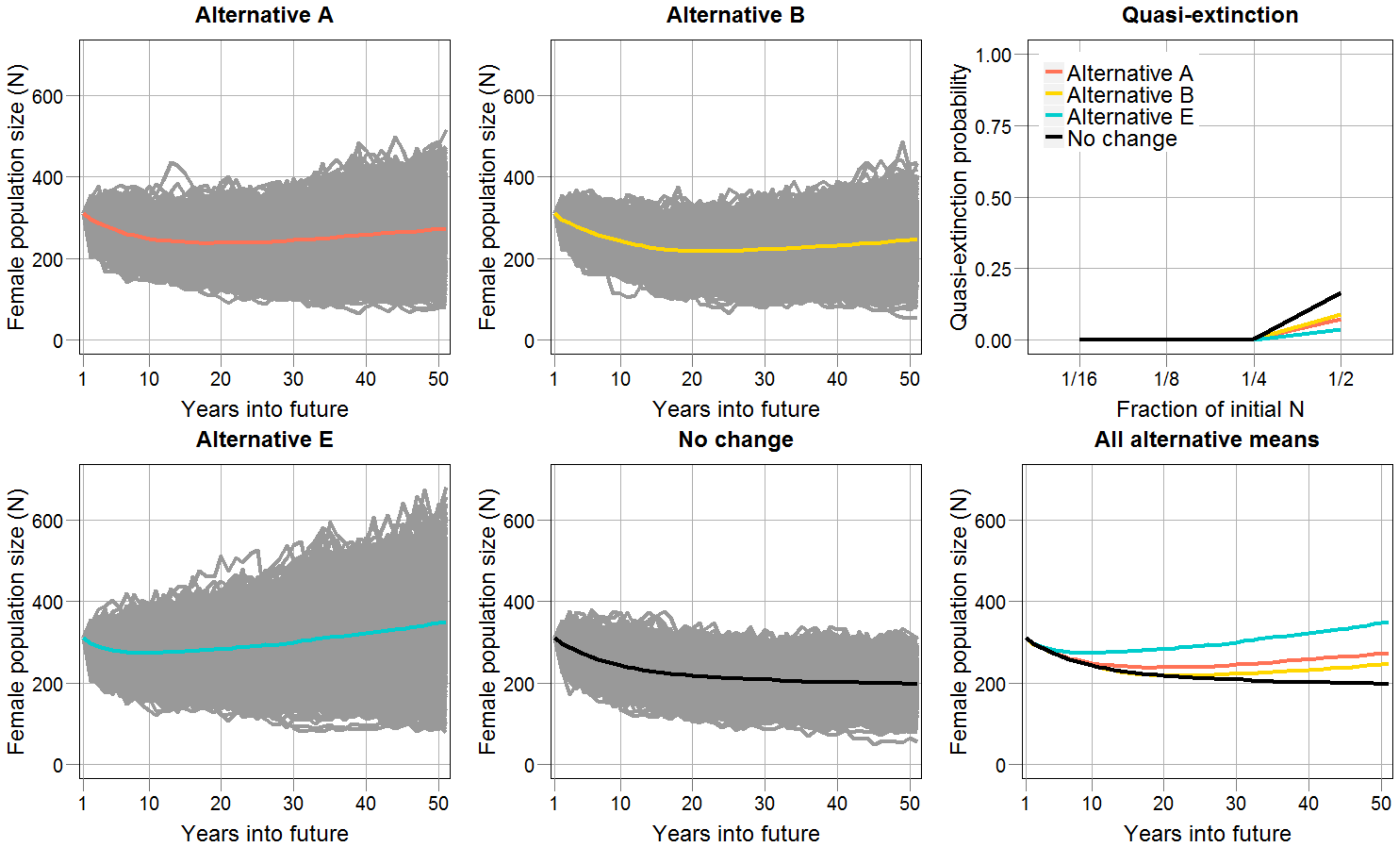
Risk Analysis – DNR Lands Only



Enhancement Analysis – State of Washington



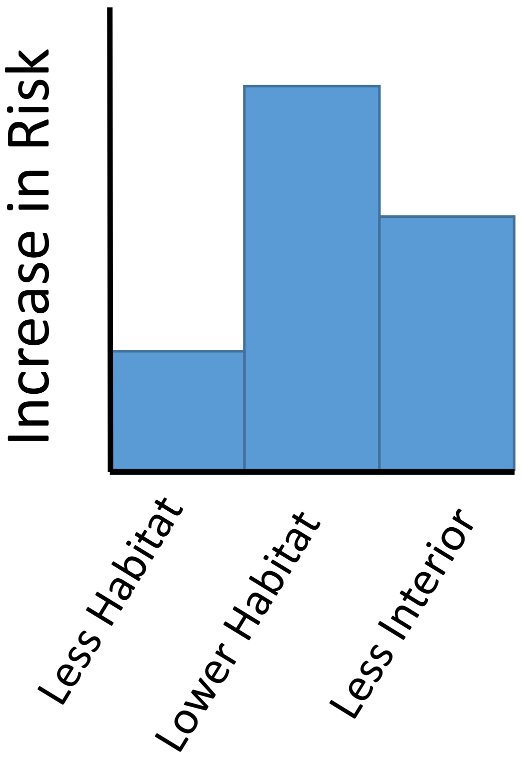
Enhancement Analysis – DNR Lands Only (no dispersal)



Proposed Sensitivity Analyses

- What are the most important habitat conditions?
  - Habitat amount
  - Habitat quality
  - Edge-interior configuration
- How sensitive are result to model uncertainties?
- What are the consequences of less nesting habitat development than predicted?

(*for illustration purpose only, analyses in progress*)



Preliminary Thoughts on PVA Results

- Differences in **state-level risk** were small among the four alternatives considered
- While differences were small**, Alternative E** reduced state-level risk the most
- The ability to contribute to **state-level enhancement** was very similar among alternatives
- **Alternative E** led to "somewhat more" murrelets on **DNR lands** than other alternatives under the **enhancement** analyses
- Greater risk was estimated for the "**no change**" scenario than for other alternatives under some assumptions and at some scales

Next Steps

- Model Alternatives C and D
- Formalize and conduct sensitivity analyses
- Write report and manuscript for publication
- Peer review both documents