

Determinants of Distribution

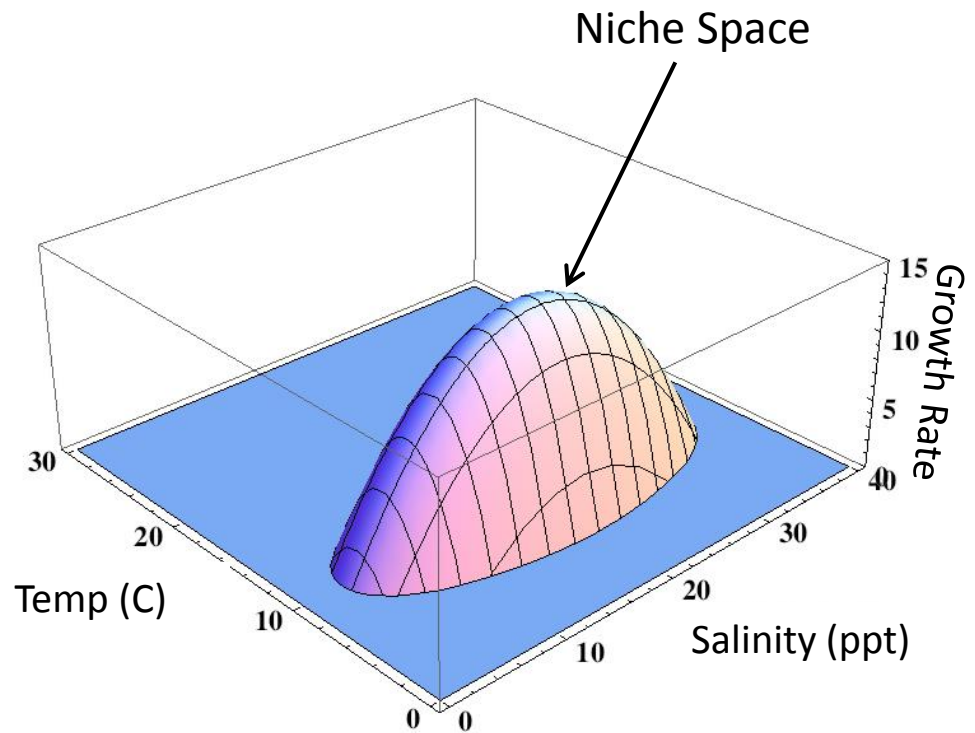
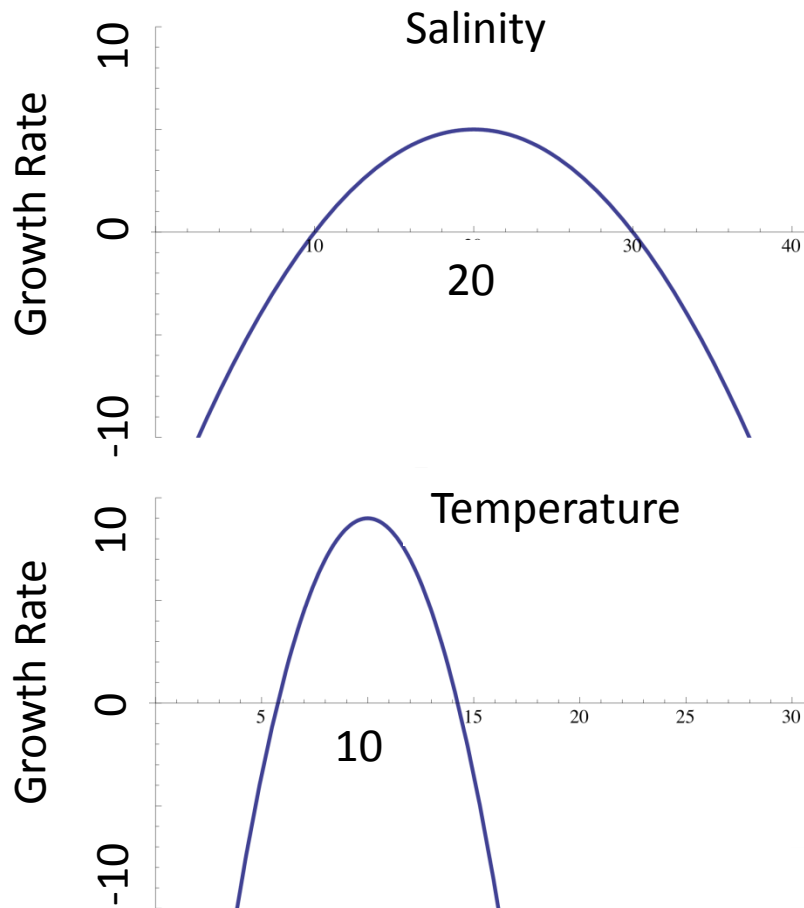
1) The Niche

Fundamental Niche: total range of *abiotic* environmental conditions in which a taxon can *survive* and *reproduce*

From Hutchinson (1957) the *n*-dimensional hypervolume (or multidimensional space) that describes the range of *abiotic* environmental conditions in which a taxon can *survive* and *reproduce* (each abiotic factor is a single dimension).

Determinants of Distribution

1) The Niche



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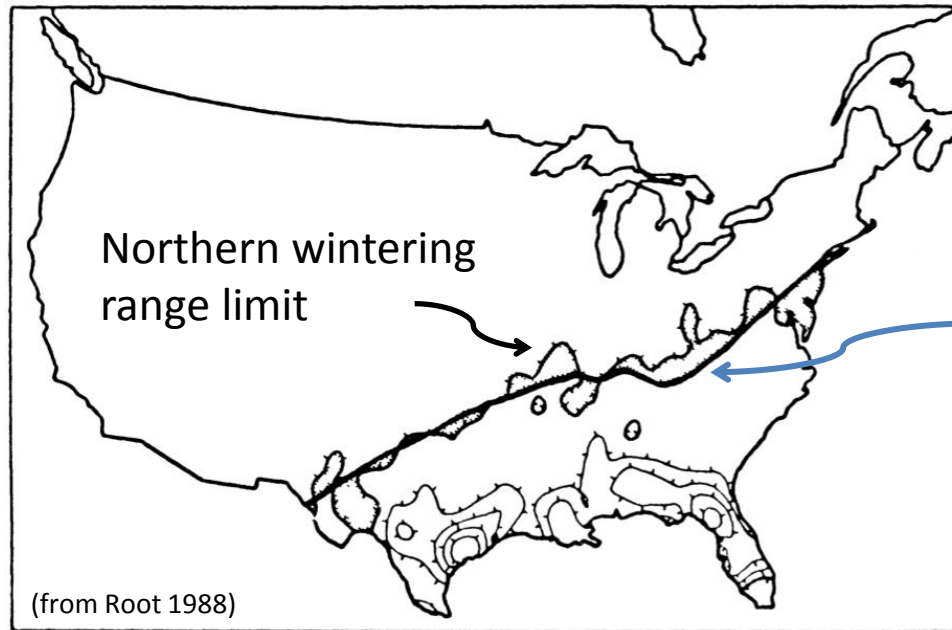
1) The Niche

When do range boundaries coincide with the fundamental niche?

Eastern Phoebe



http://upload.wikimedia.org/wikipedia/commons/c/c7/Eastern_Phoebe1.jpg



-4°C January minimum isotherm

Northern range limit is correlated with metabolic costs (multiples of basal metabolic rate): $MR = 2.64 \times BMR$

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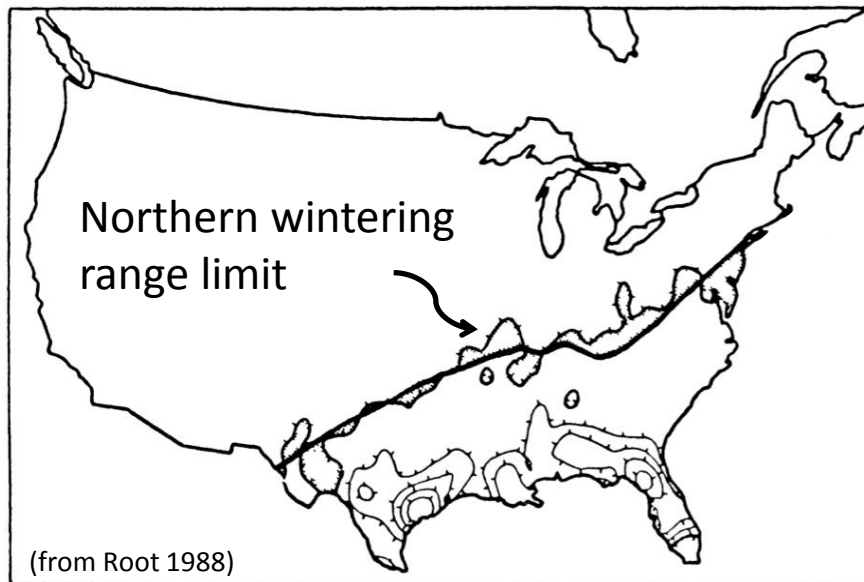
1) The Niche

When do range boundaries coincide with the fundamental niche?

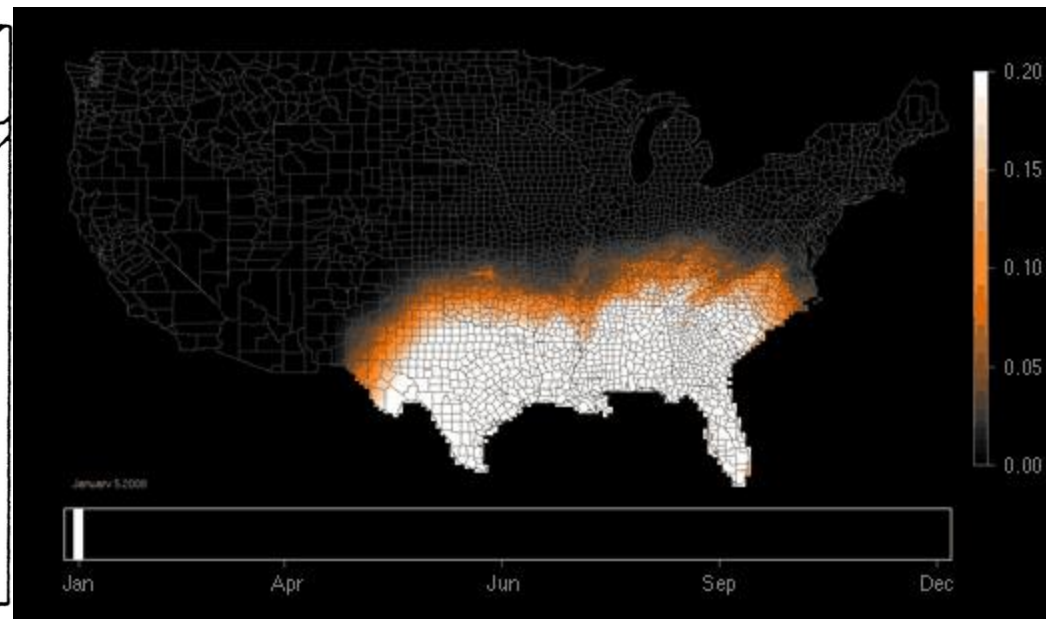
Seven other passerine birds' Northern wintering limits coincide with $\sim 2.45 \times \text{BMR}$



Eastern Phoebe



http://upload.wikimedia.org/wikipedia/commons/c/c7/Eastern_Phoebe1.jpg

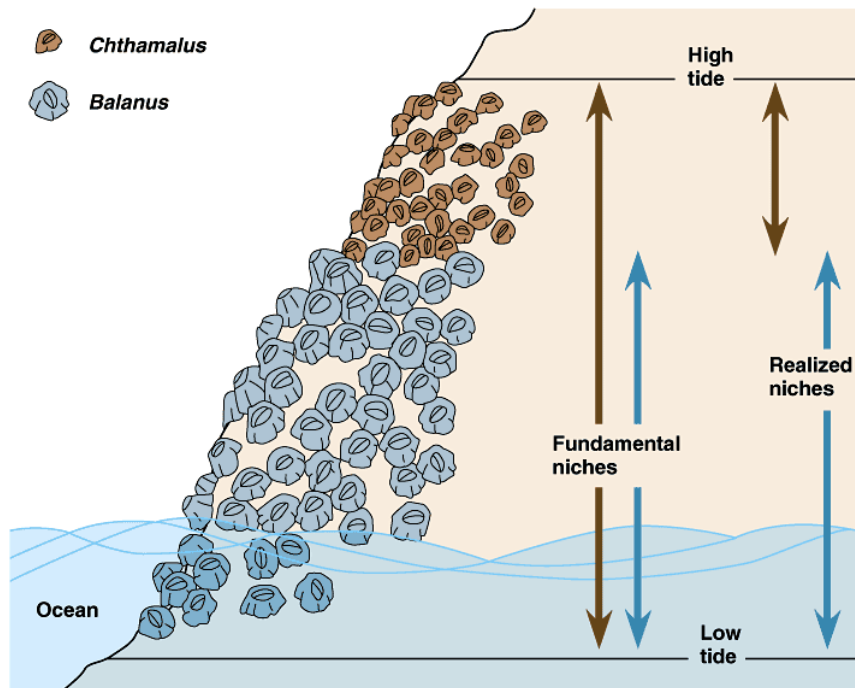


<http://ebird.org/plone/ebird/news/patterns-from-ebird-eastern-phoebe>

Determinants of Distribution

1) The Niche

Realized Niche: A *subset* of the fundamental niche comprising the actual environmental conditions in which a taxon survives and reproduces in nature, including biotic factors (competition, predation, mutualism, etc).



Balanus: realized niche ~ fundamental niche

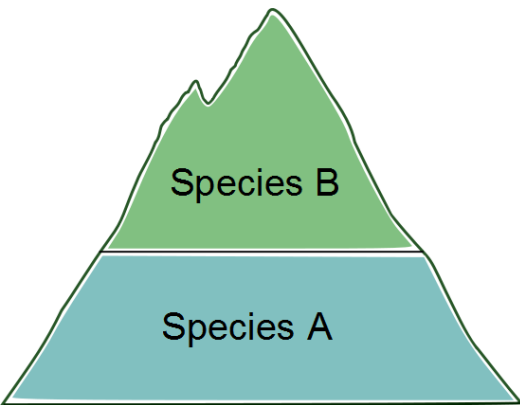
Chthamalus: constrained by competitive interactions to narrower realized niche

How could we test this experimentally?

Determinants of Distribution

1) The Niche

Realized Niche: A *subset* of the fundamental niche comprising the actual environmental conditions in which a taxon survives and reproduces in nature, including biotic factors (competition, predation, mutualism, etc).



A natural experiment...

Species A and B are closely related ~ similar niche

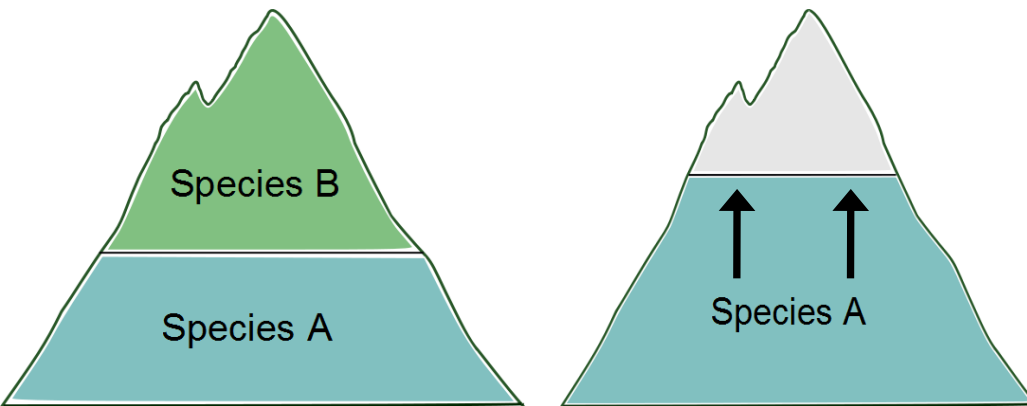
In the central Andes:

- both species present
- ranges do not overlap

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1) The Niche

Realized Niche: A *subset* of the fundamental niche comprising the actual environmental conditions in which a taxon survives and reproduces in nature, including biotic factors (competition, predation, mutualism, etc).



In a range isolated from the Andes:

- low elevation species present, high elevation species absent
- low elevation species expands its range upward

Ecological release: expansion of the realized niche of a species where few competitors exist but an undiminished range of resources and habitats is present

Determinants of Distribution

1) The Niche

Important caveats to the niche as the main determinant of a species' range:

a) Species may occupy unfavourable areas

b) Species may be absent in favourable areas

Determinants of Distribution

1) The Niche

Important caveats to the niche as the main determinant of a species' range:

a) Species may occupy unfavourable areas

- $r = b + i - d - e$
- populations can be either *source* (birth rate exceeds death rate; $b > d$) or *sink* (death rate exceed birth rate; $d > b$) populations
- sink populations depend on immigration (i) from source populations
- peripheral populations of a species range are often sink populations

b) Species may be absent in favourable areas

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b) Species may be absent in favourable areas

- due to geographic barriers or isolation

Determinants of Distribution

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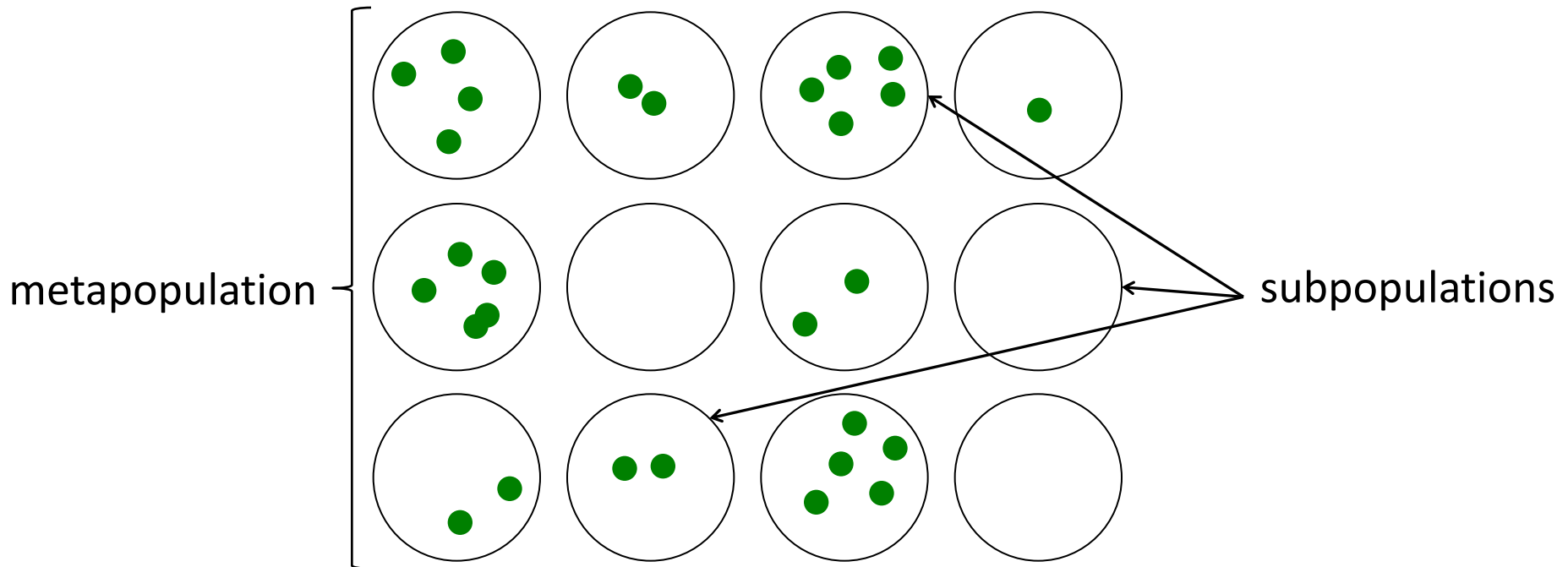
c) Metapopulation structure

- often found when suitable niche space is patchy
- some patches may be occupied only intermittently

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2) Metapopulation structure

Metapopulation: a population consisting of a set of subpopulations linked by a cycle of alternating colonization and extinction (Levins 1970)



Determinants of Distribution

2) Metapopulation structure

Metapopulation: a population consisting of a set of subpopulations that are linked by a cycle of alternating colonization and extinction (see Levins 1970)

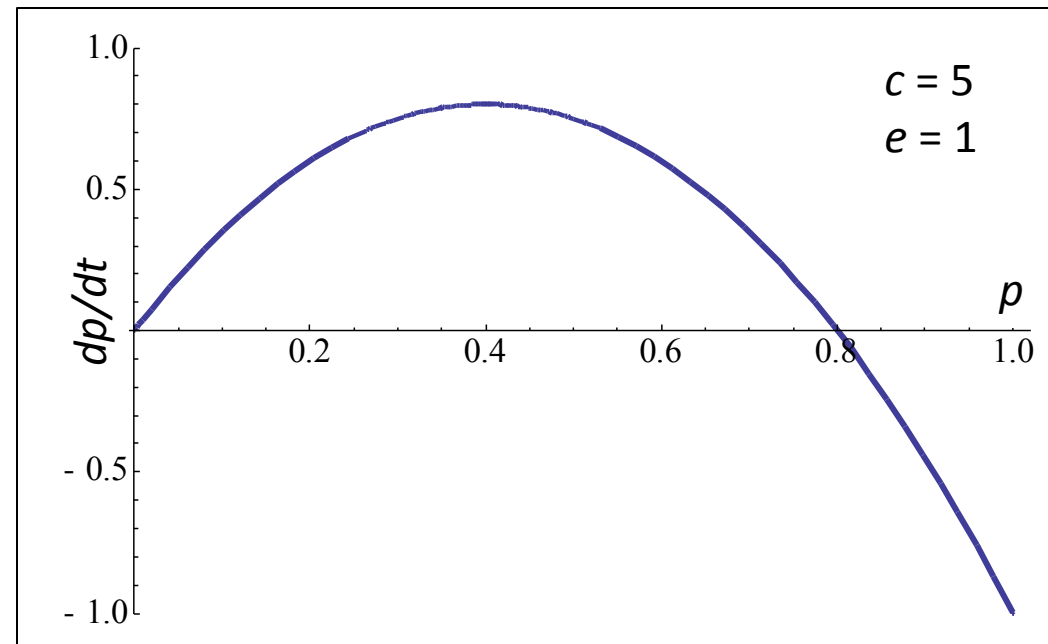
$$\frac{dp}{dt} = cp(1-p) - ep$$

p = proportion of patches occupied

c = colonization rate

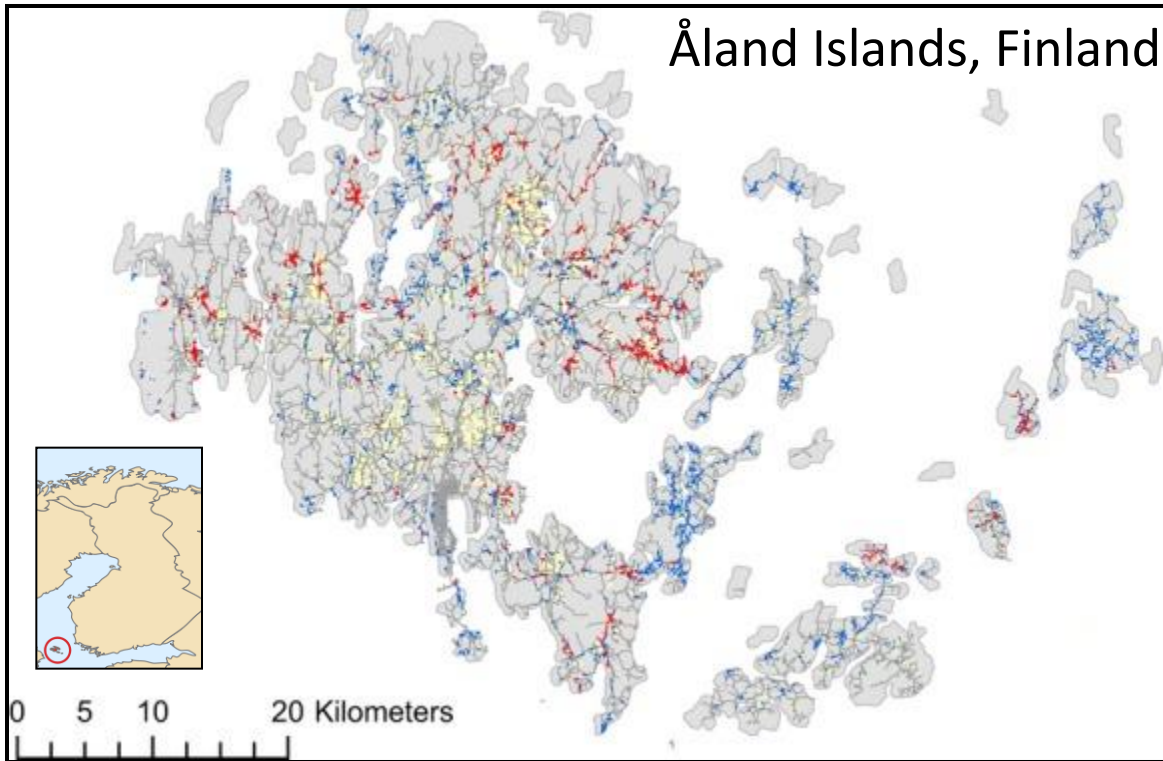
e = extinction rate

dp/dt = rate of change in p



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2) Metapopulation structure



Glanville fritillary butterfly
(*Melitaea cinxia*)

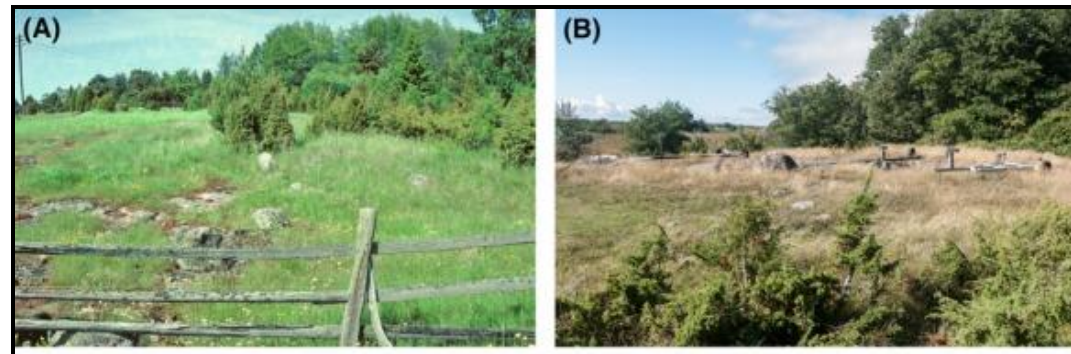


Photograph courtesy of Hannu Aarnio.

~ 4000 dry meadows in 2012

Red = occupied

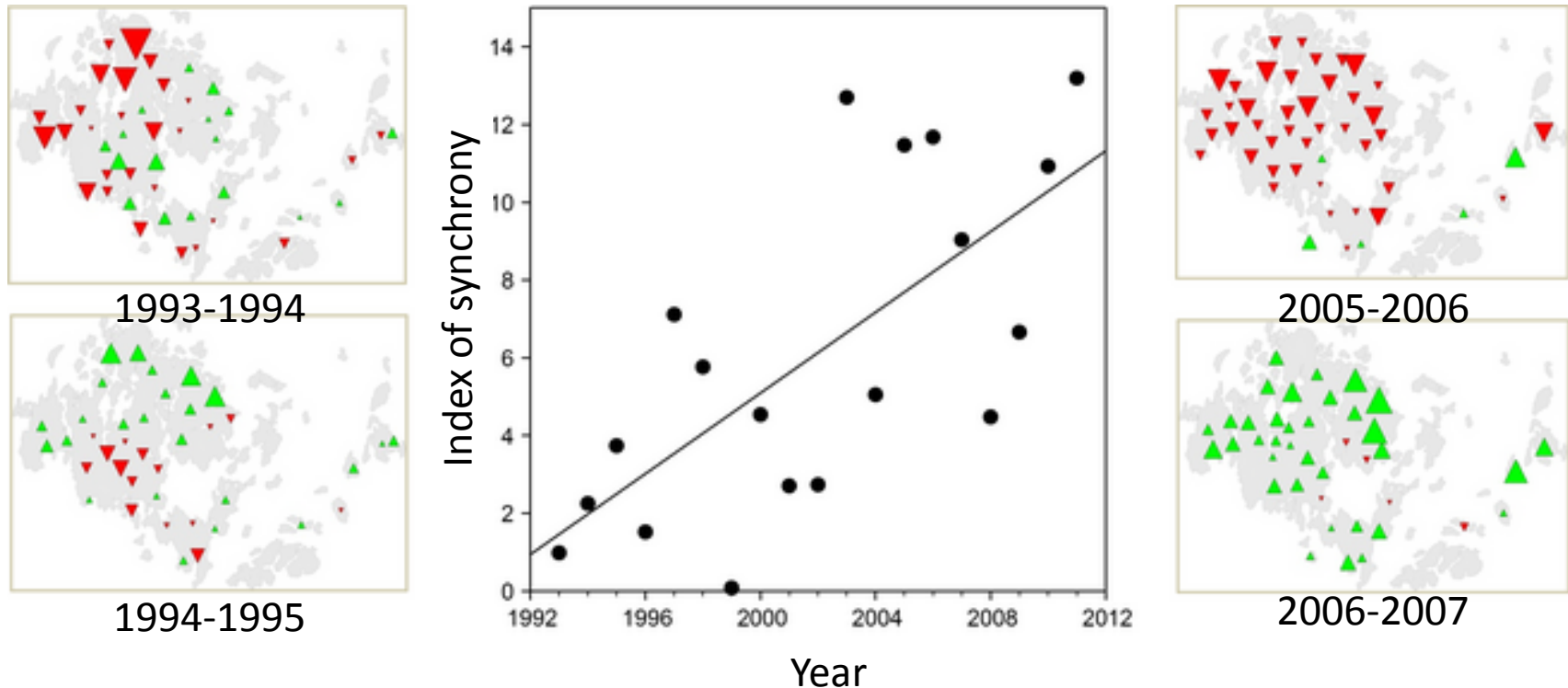
Blue = unoccupied



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2) Metapopulation structure

Glanville fritillary on the Åland Islands became more synchronous over time:



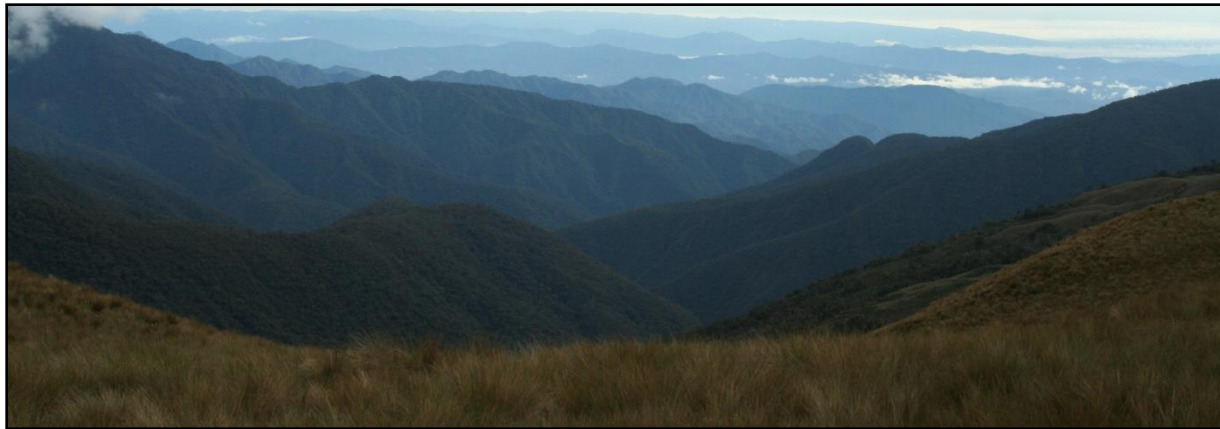
Red down-pointing triangles = decline; Green up-pointing triangles = increase
Size of the triangle ~ magnitude of per capita change

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3) Disturbance

Habitat disturbance can cause abrupt range limits.

Countless examples, but one in our research is the high Andean treeline:



Highland communities in Peru set fire to forest and grass to maintain fresh sprouts for cattle

Anthropogenic treeline at ~ 3400 m, upper limits of forest species



High-elevation species that move upslope with climate change hit “grass ceiling”

Determinants of Distribution

3) Disturbance

Disturbance-adapted animals? Urban adapters?



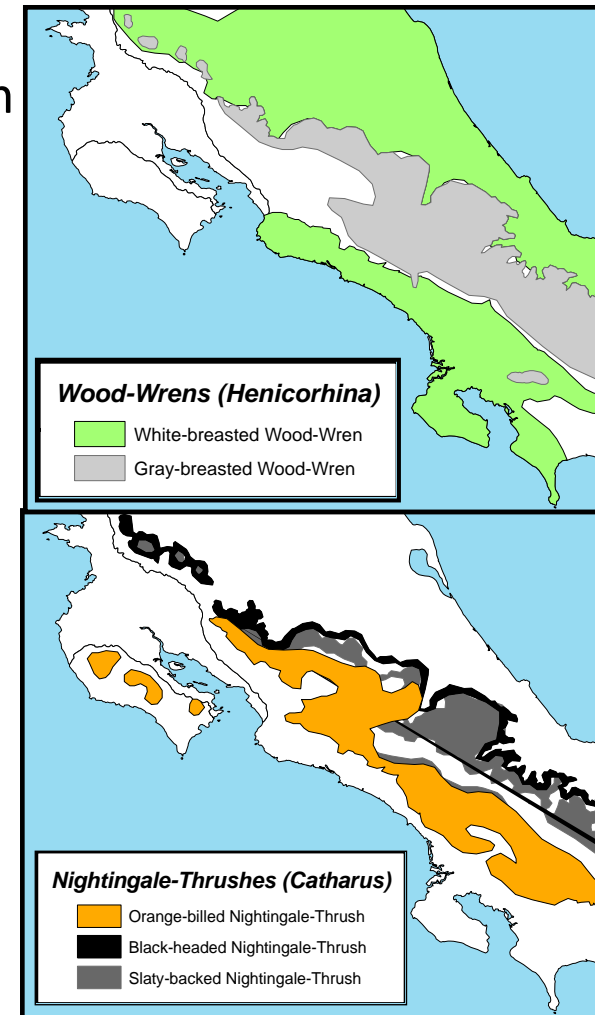
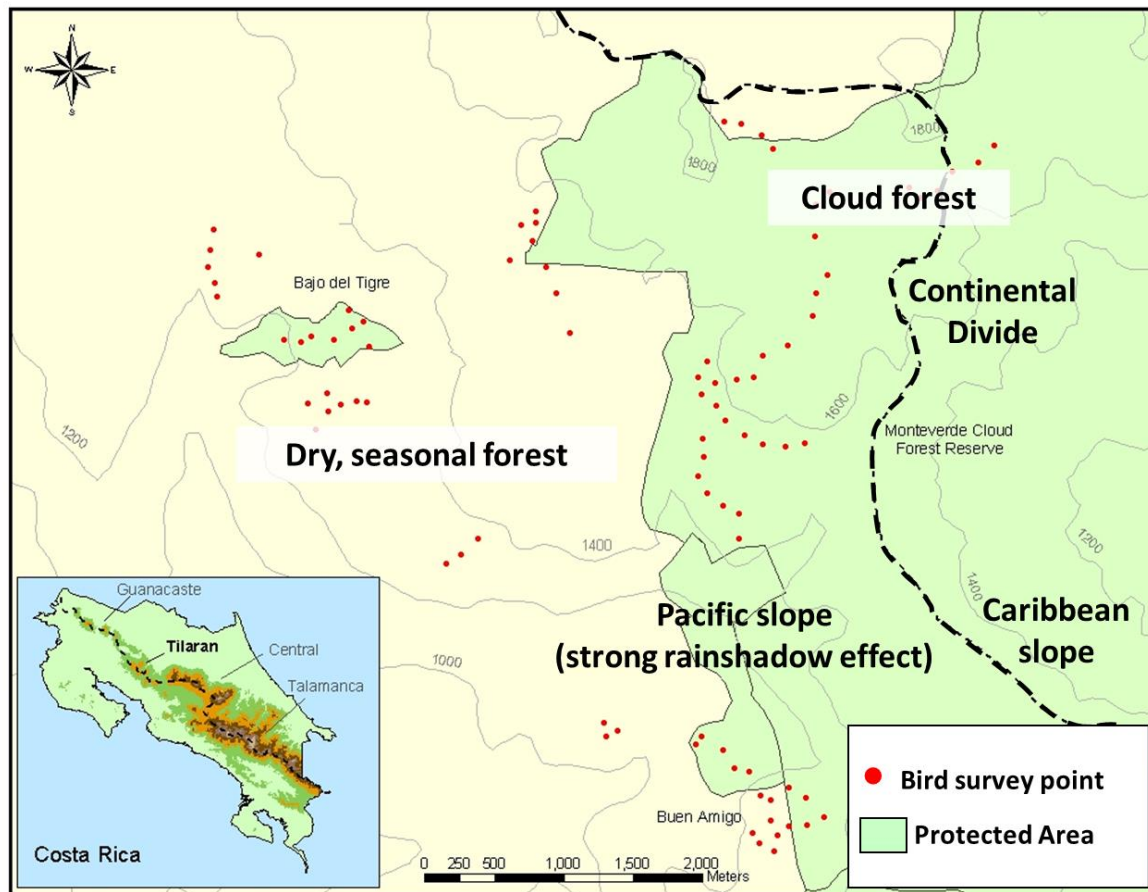
Crow (*Corvus brachyrhynchos*)

Starling (*Sturnus vulgaris*)

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4) Biotic Interactions: Direct Competition

Direct competition – testing species replacements
Monteverde, Tilarán Mountains, Costa Rica 1100-1800m



Determinants of Distribution

4) Biotic Interactions: Direct Competition

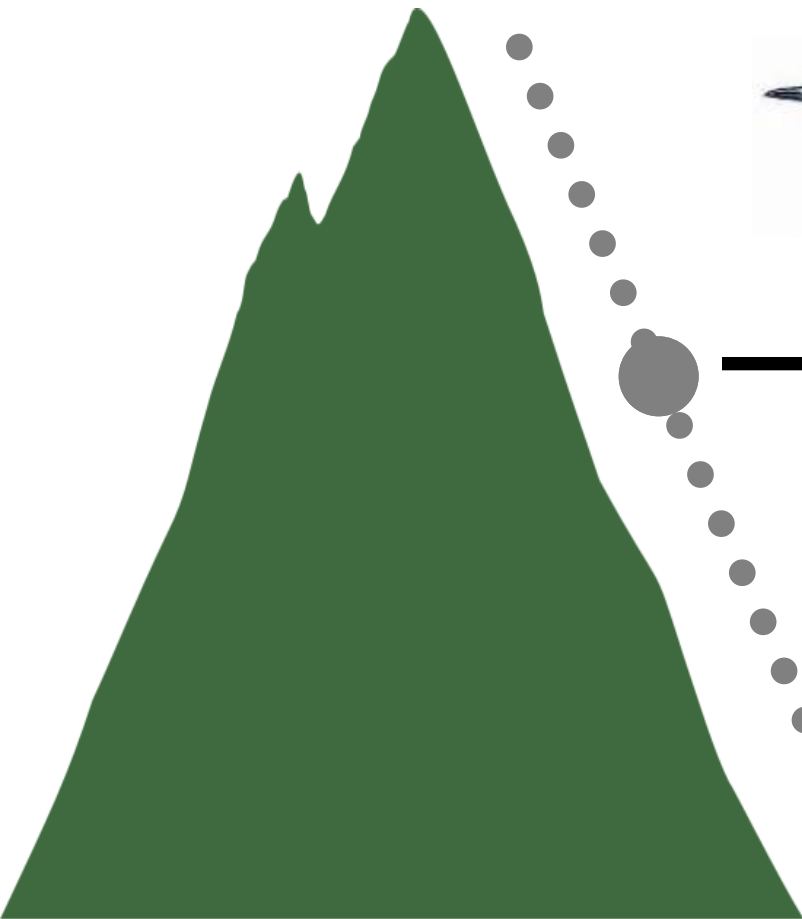
Target species: Wood-Wrens



Gray-breasted
Wood-Wren



White-breasted
Wood-Wren



Determinants of Distribution

4) Biotic Interactions: Direct Competition

Target species: Nightingale-Thrushes



Slaty-backed
Nightingale-Thrush



Black-headed
Nightingale-Thrush

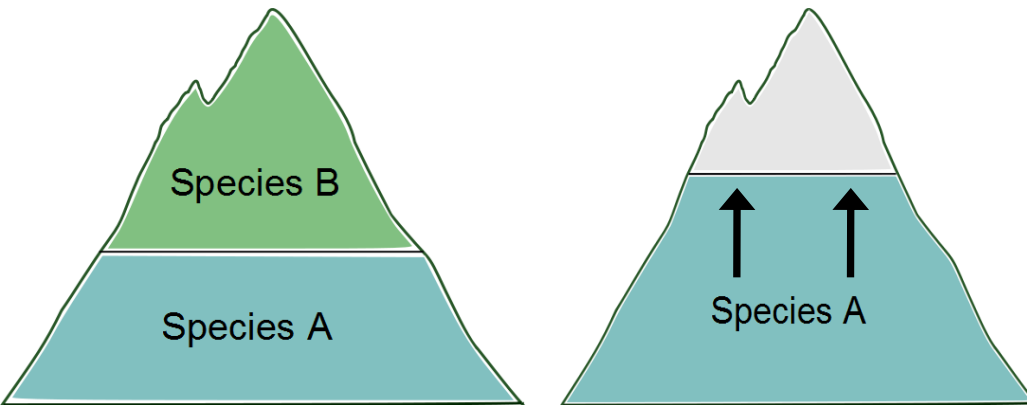


Orange-billed
Nightingale-Thrush

Determinants of Distribution

4) Biotic Interactions: Direct Competition

Our previous example of species replacements and competition was a “natural experiment” with observational evidence of ecological release.



For birds that defend territories using song...

we can use territory defense as a behavioural metric of competitive interactions

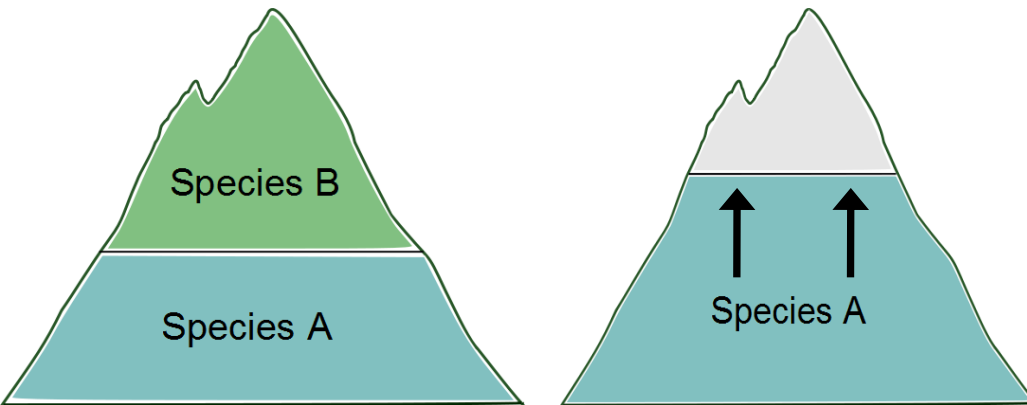
...and design an experiment

Does interspecific competition reinforce range boundaries of species along elevational gradients?

Determinants of Distribution

4) Biotic Interactions: Direct Competition

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For birds that defend territories using song...

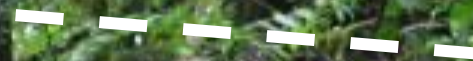
we can use territory defense as a behavioural metric of competitive interactions

...and design an experiment

Does interspecific **aggression** reinforce range boundaries of species along elevational gradients?

Behavioral responses recorded:

- Closest approach to speaker (meters)
- Latency to approach speaker (seconds)
- Average length of inter-song intervals

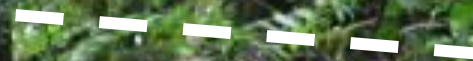


#@*!?



Behavioral responses recorded:

- **Closest approach to speaker (meters)**
- Latency to approach speaker (seconds)
- Average length of inter-song intervals



#@*!?



Determinants of Distribution

4) Biotic Interactions: Direct Competition

If species are interspecifically aggressive at contact zones, this supports the hypothesis of direct competition

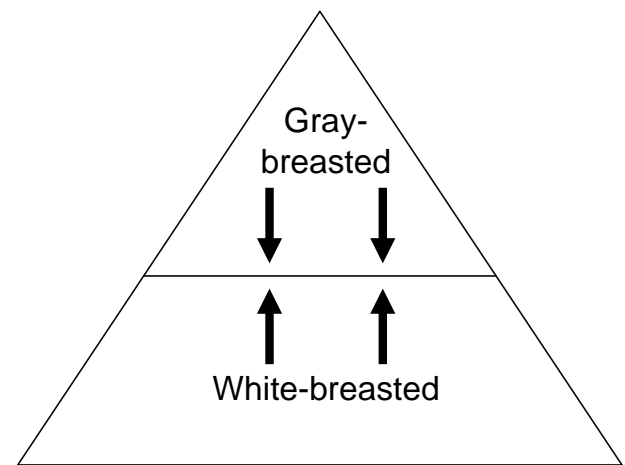
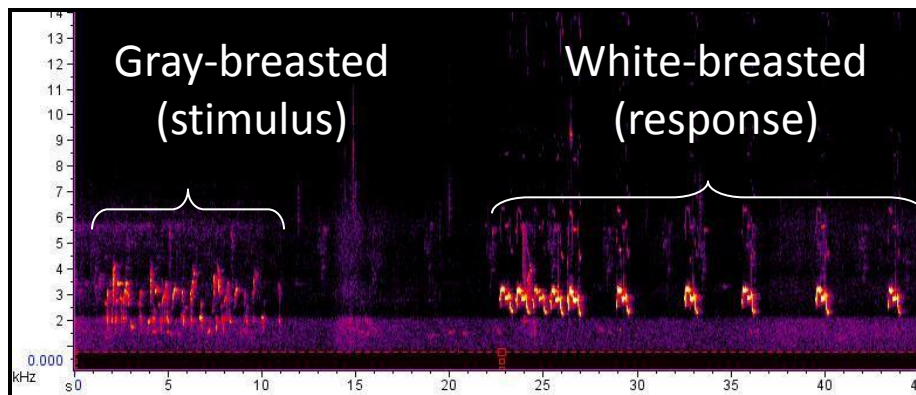
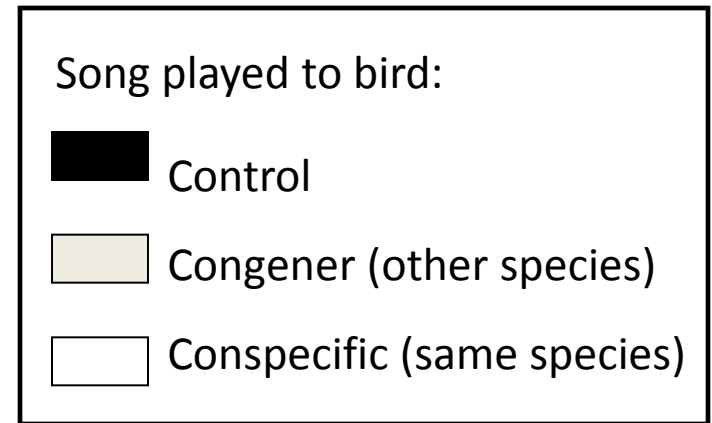
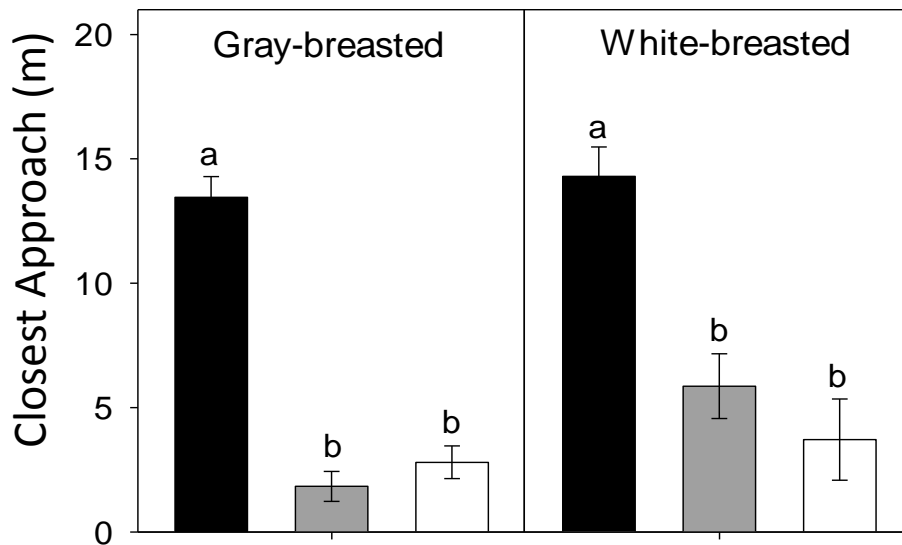
Playback protocol to test species aggressive responses:

Trial 1		Trial 2	
Observation (Control)	Playback (Congener/ Conspecific)	Observation (Control)	Playback (Congener/ Conspecific)
8 min. obs	3 min. song, 5 min. obs	8 min. obs	3 min. song, 5 min. obs

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4) Biotic Interactions: Direct Competition

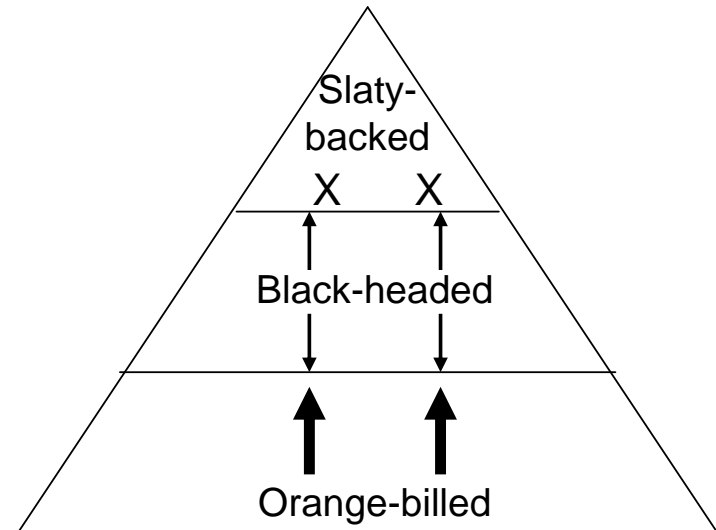
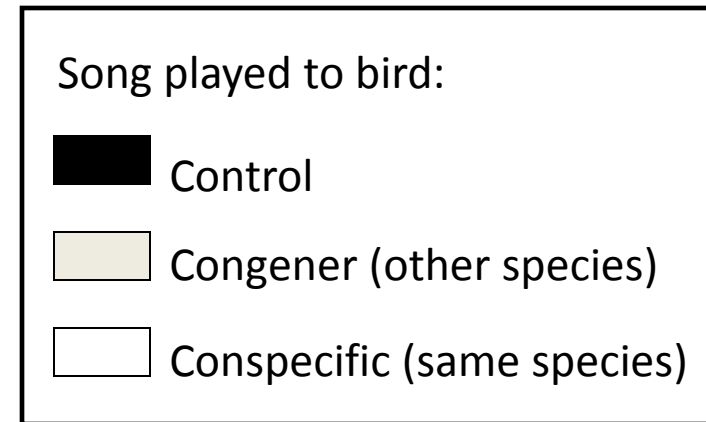
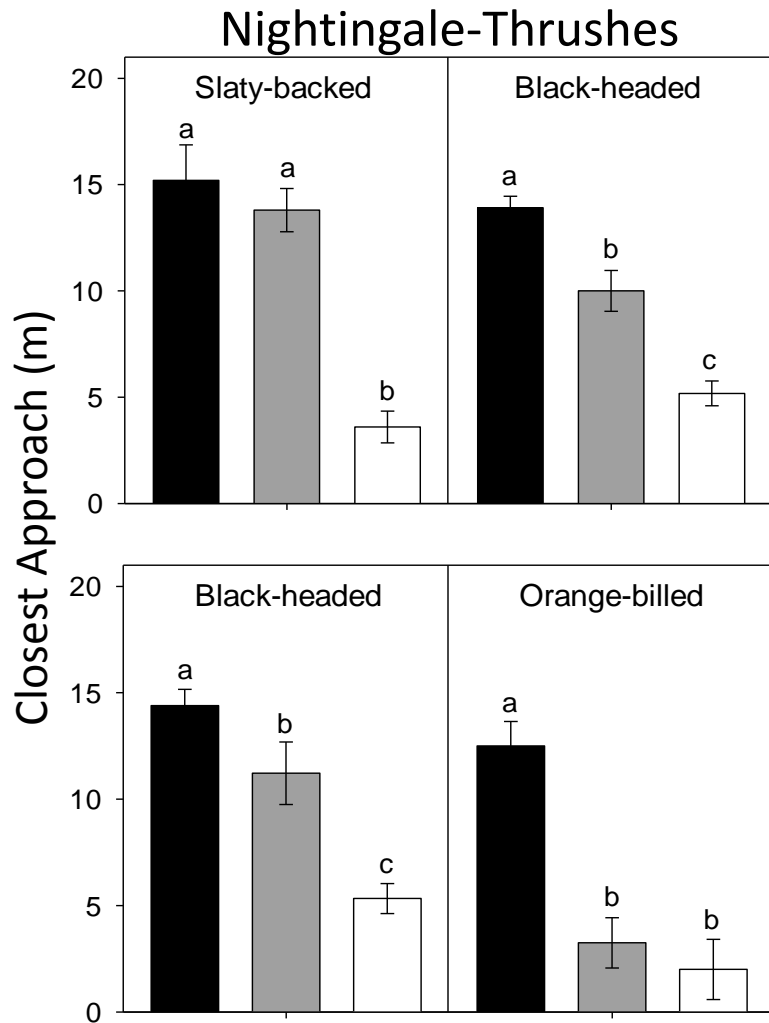
Wood-Wrens



Jankowski et al. 2010, *Ecology*

Determinants of Distribution

4) Biotic Interactions: Direct Competition



Determinants of Distribution

4) Biotic Interactions: Diffuse Competition

Diffuse competition: the combined effect of competition with many other species – one species is negatively affected by numerous other species that collectively cause significant depletion of shared resources (MacArthur 1972).

Add more nest boxes (i.e., cavities) → more cavity nesters → less open cup nesters



Western bluebird (*Sialia mexicana*)



American robin (*Turdus migratorius*)

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5) Biotic Interactions: Predation



For tropical birds, nest predation is a major source of mortality

In Manu, Peru, we are gathering data to understand:

1) how nest predation changes with elevation?

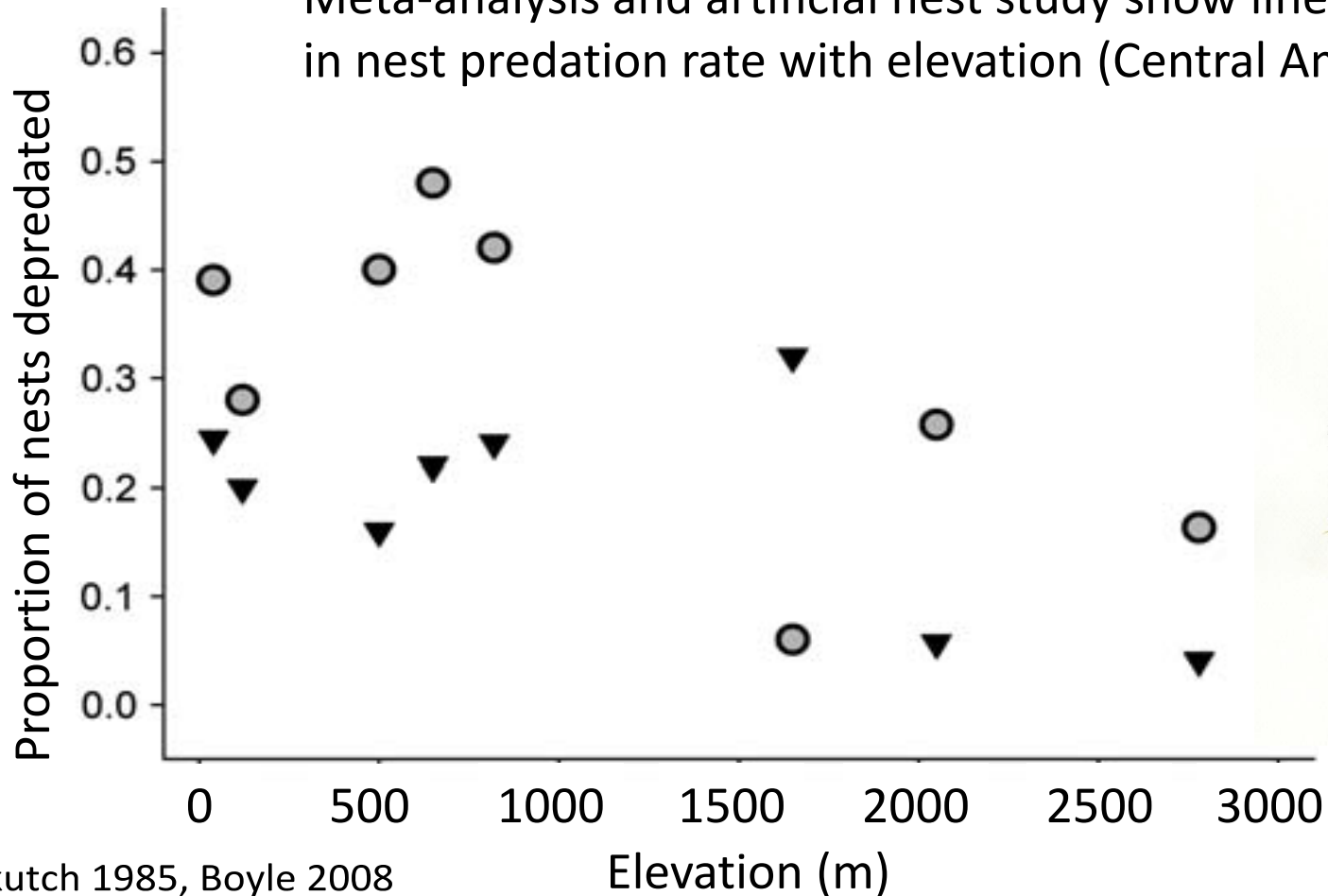
2) how does the nest predator community change with elevation?



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5) Biotic Interactions: Predation

Meta-analysis and artificial nest study show linear decrease in nest predation rate with elevation (Central America)



Skutch 1985, Boyle 2008

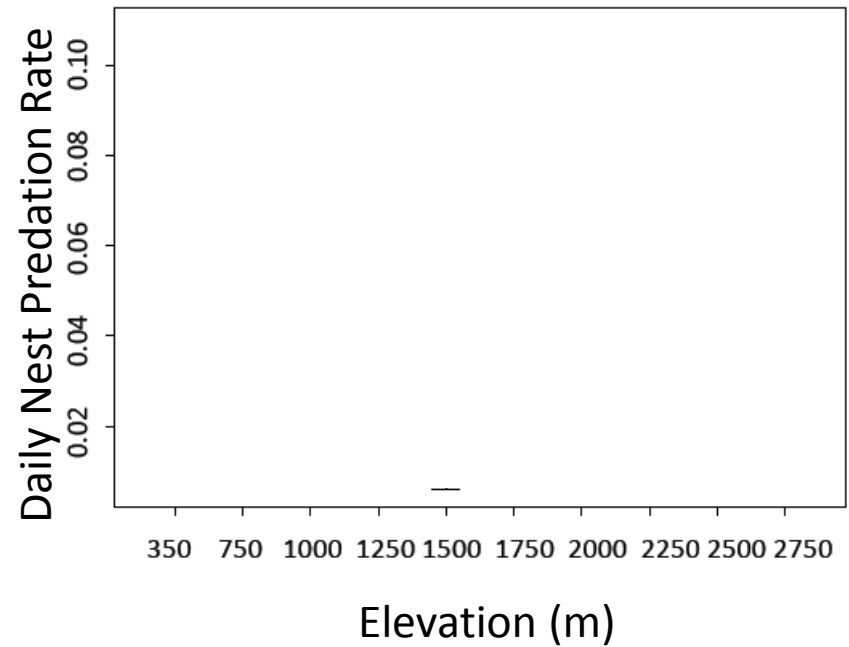


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5) Biotic Interactions: Predation



How do rates of nest predation change with elevation in Manu National Park, Peru?

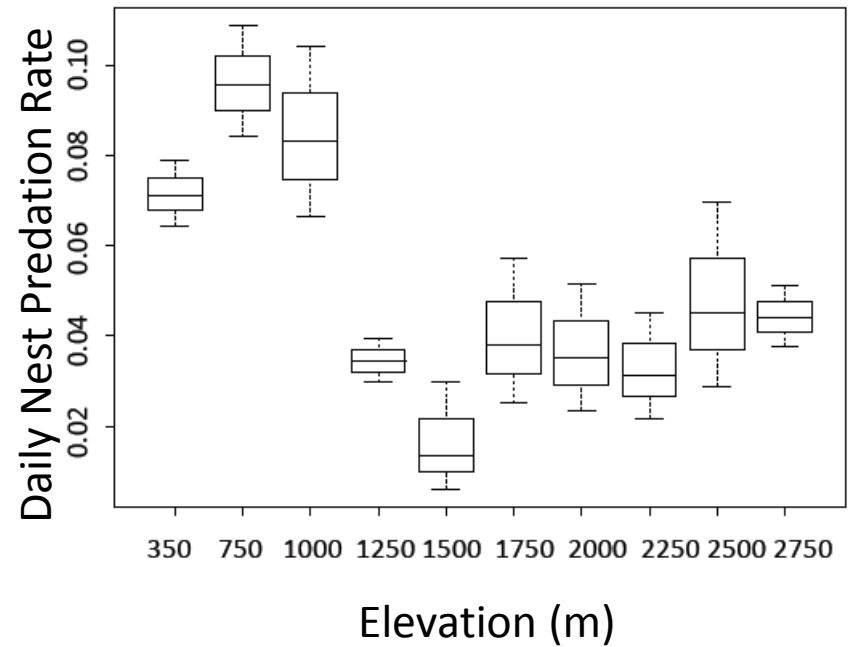


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5) Biotic Interactions: Predation



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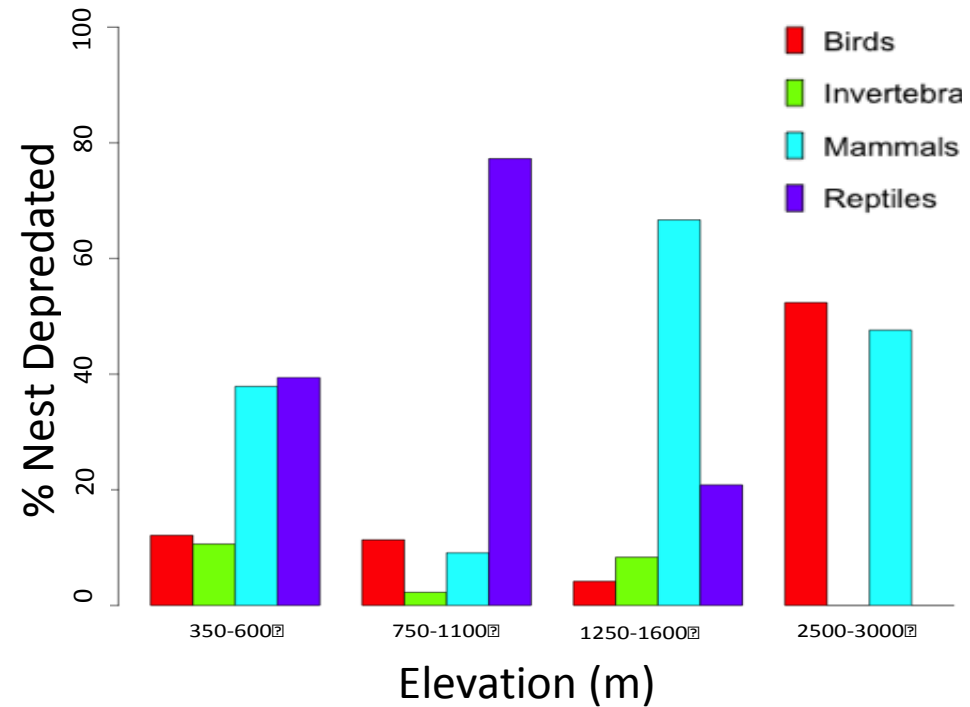


Determinants of Distribution

5) Biotic Interactions: Predation



How does the nest predator community change with elevation in Manu National Park, Peru?



Determinants of Distribution

5) Biotic Interactions: Predation



Catching the culprits...



Saguinus Geotrygon.m4v



Aracari_Geotrygon.m4v



Ocelote.m4v



Pseutes_schistocicla_2010 (2).m4v



Determinants of Distribution

5) Biotic Interactions: Predation



Learning lots about the natural history of tropical birds...including who eats whom

Cock-of-the-Rock nestling and adult
(*Rupicola peruviana*)

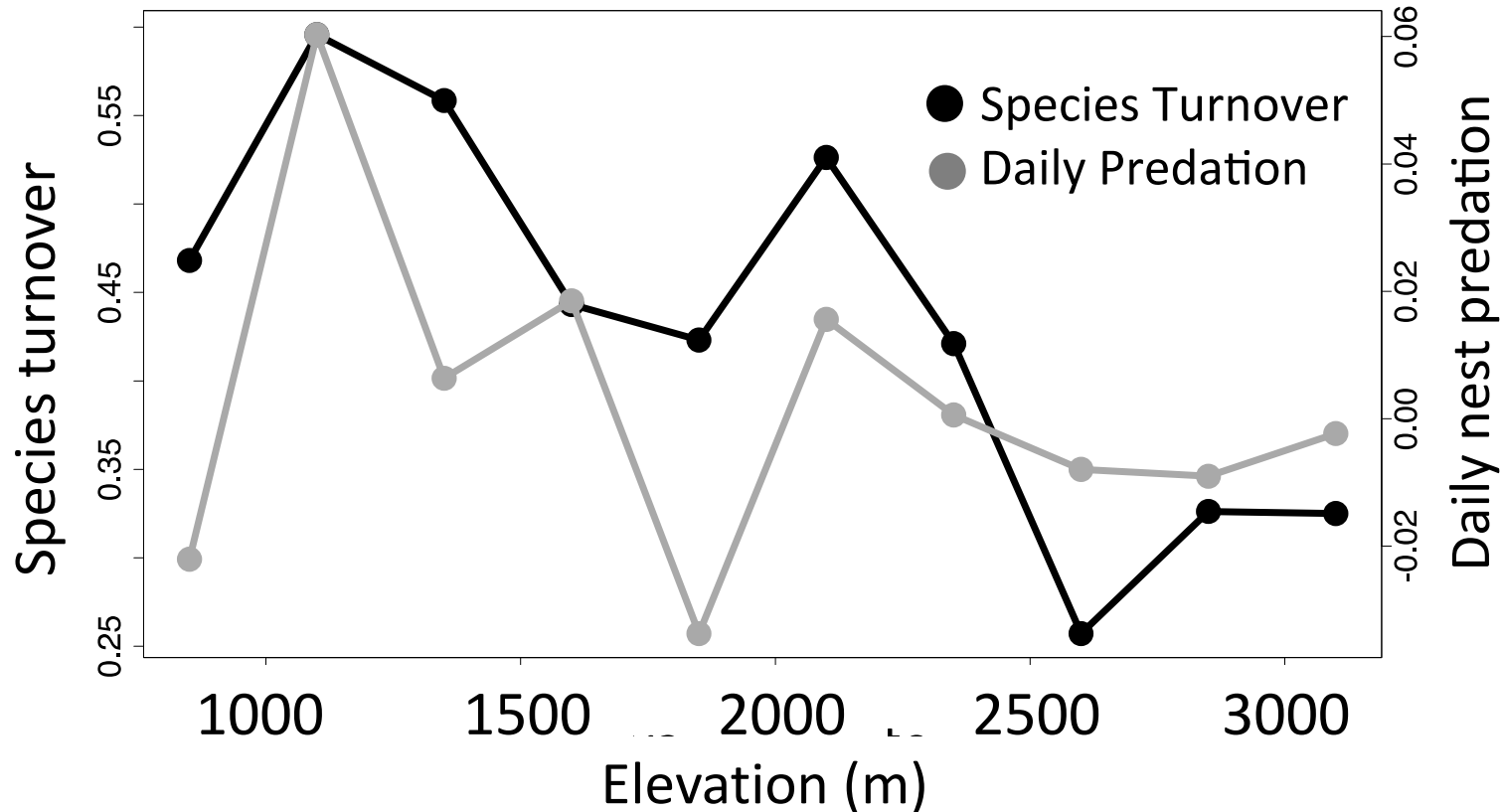


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5) Biotic Interactions: Predation

Species turnover is high = many species in the community have range boundaries in the same place

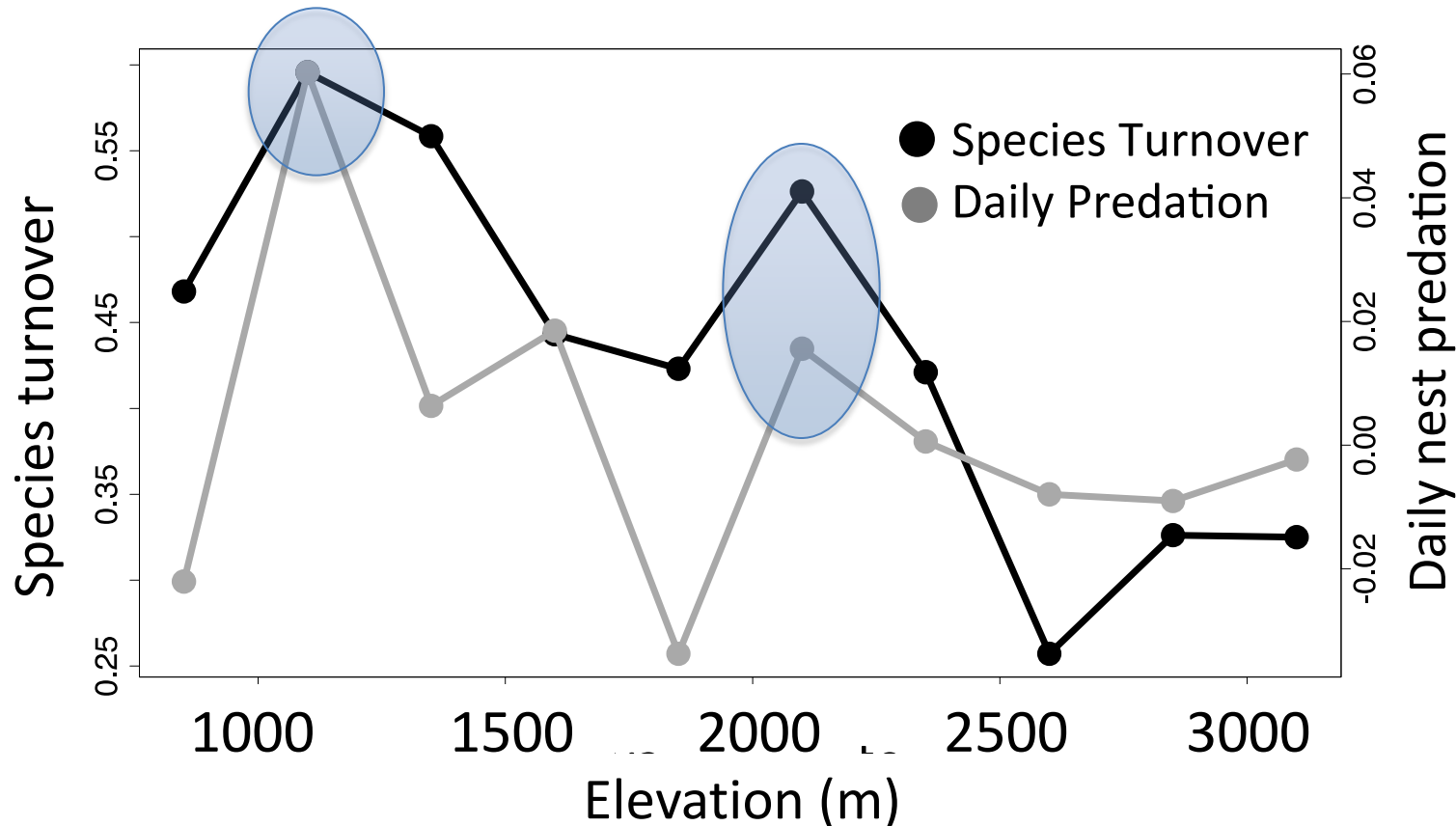


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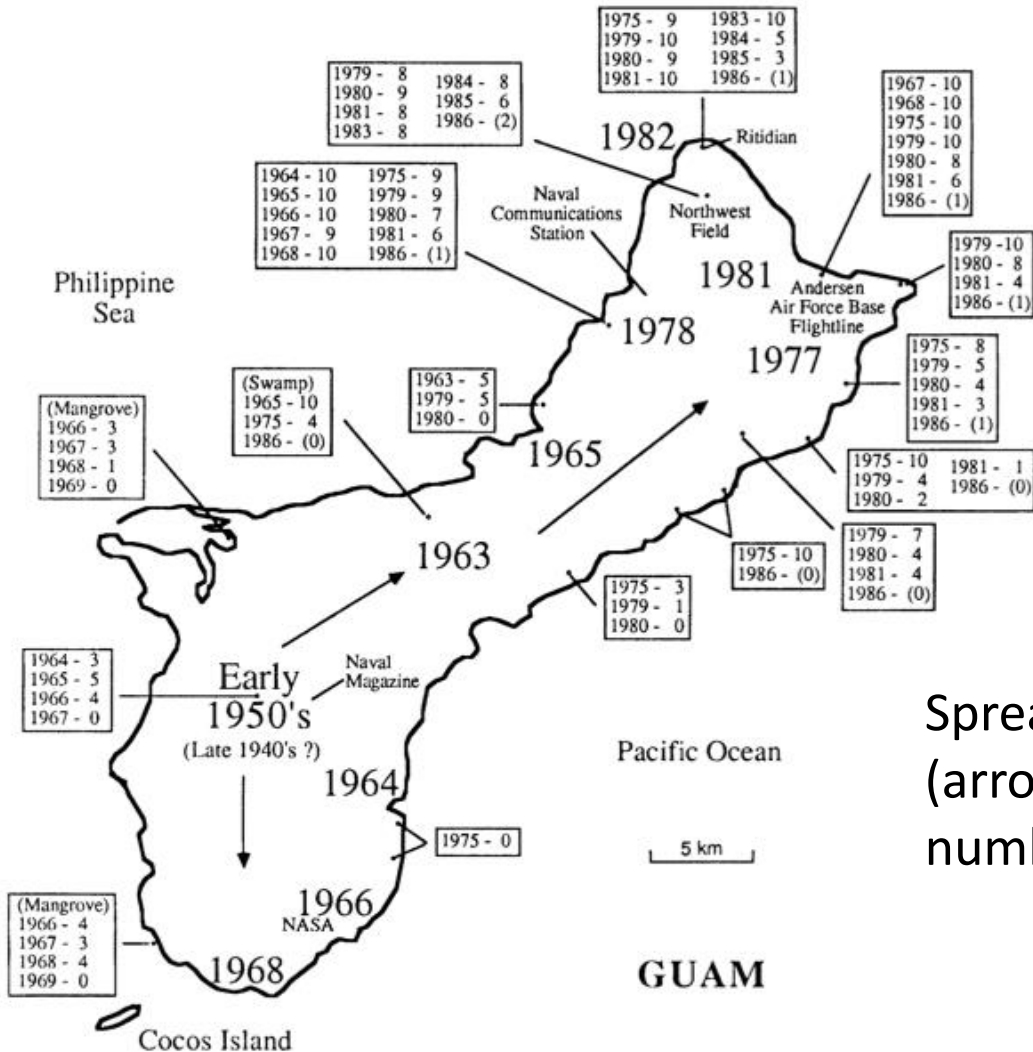
5) Biotic Interactions: Predation

Highest change in species composition (species turnover) corresponds with the highest rates of daily nest predation



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5) Biotic Interactions: Predation

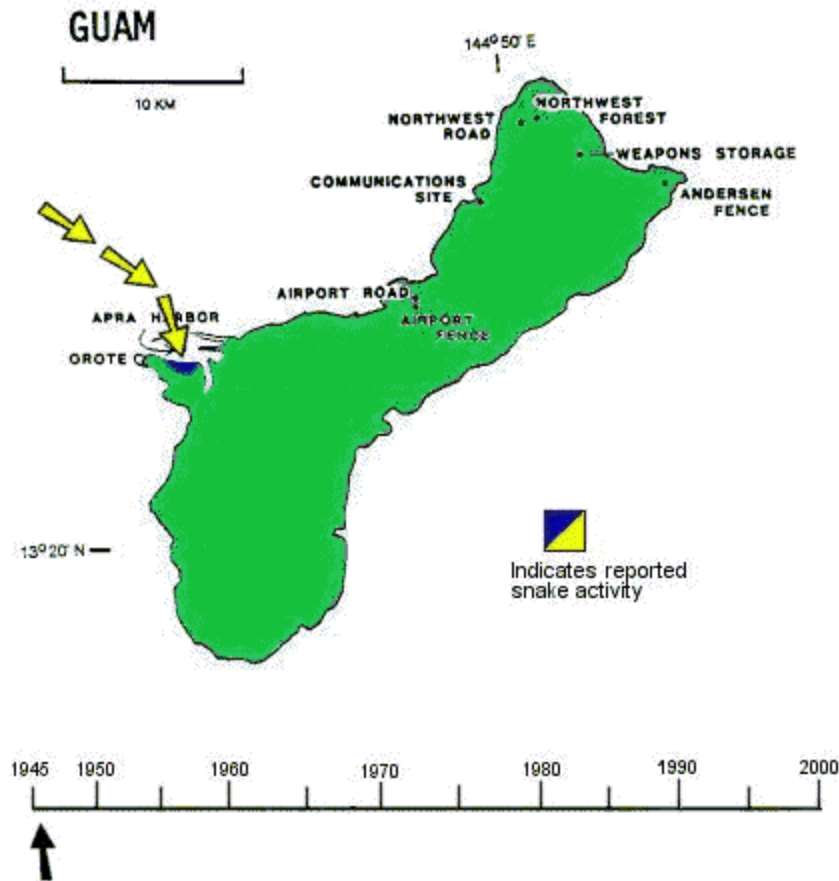


Brown tree snake (*Boiga irregularis*)

Spread of brown tree snake on Guam (arrows) and subsequent declines in numbers of native birds across years

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5) Biotic Interactions: Predation



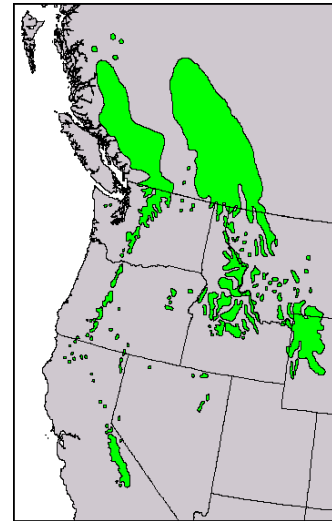
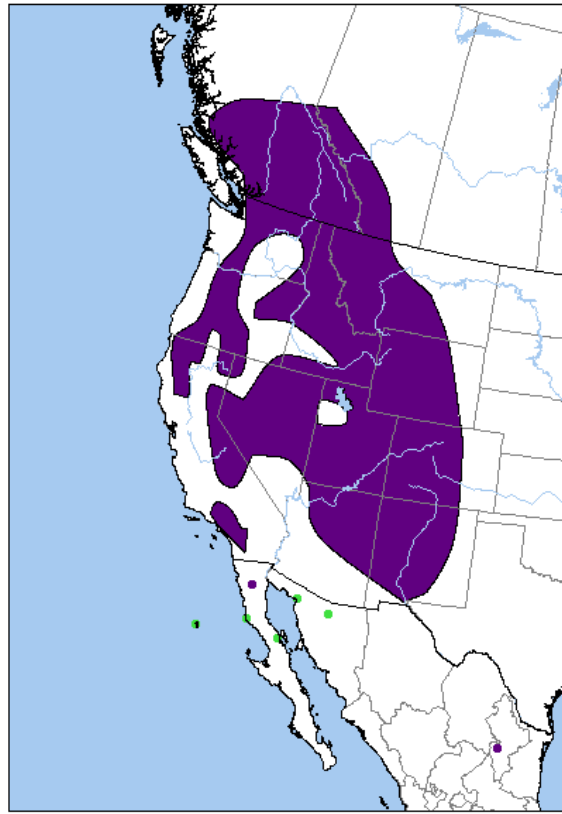
Brown tree snake (*Boiga irregularis*)

USGS Timeline of the Brown tree snake travel across Guam

Determinants of Distribution

6) Biotic Interactions: Mutualism

Clark's nutcracker (*Nucifraga columbiana*) and whitebark pine (*Pinus albicaulis*)



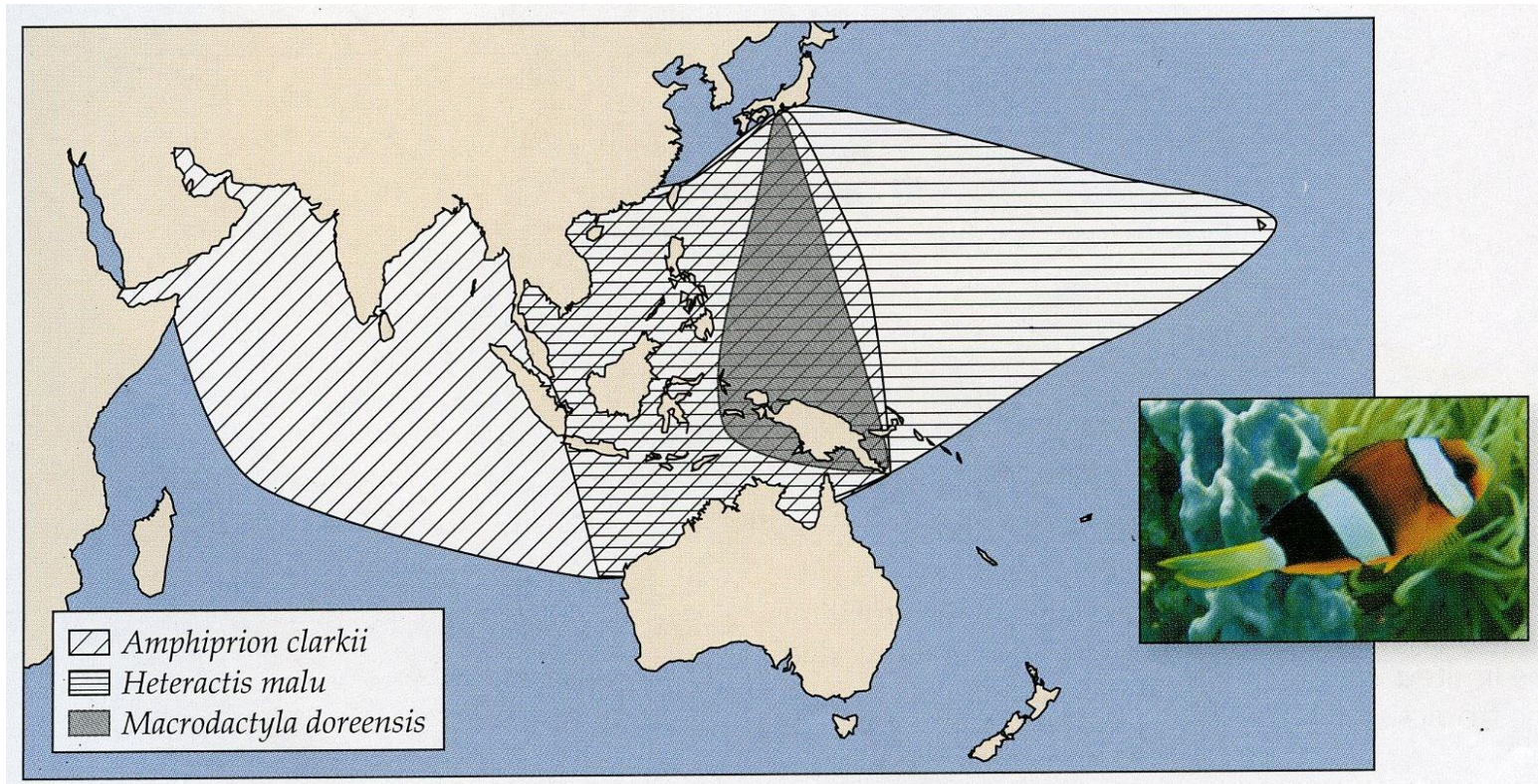
Whitebark, limber, Colorado pinyon, single-leaf pinyon and southwestern white pines depend on nutcrackers for seed dispersal

This interaction has changed the trees' seeds, cones, and even overall shape in comparison with other wind-dispersed pine species

Determinants of Distribution

6) Biotic Interactions: Mutualism

Indo-Pacific clownfish (*Amphiprion clarkii*) and two sea anemones (*Heteractis malu* and *Macrodactyla doreensis*)

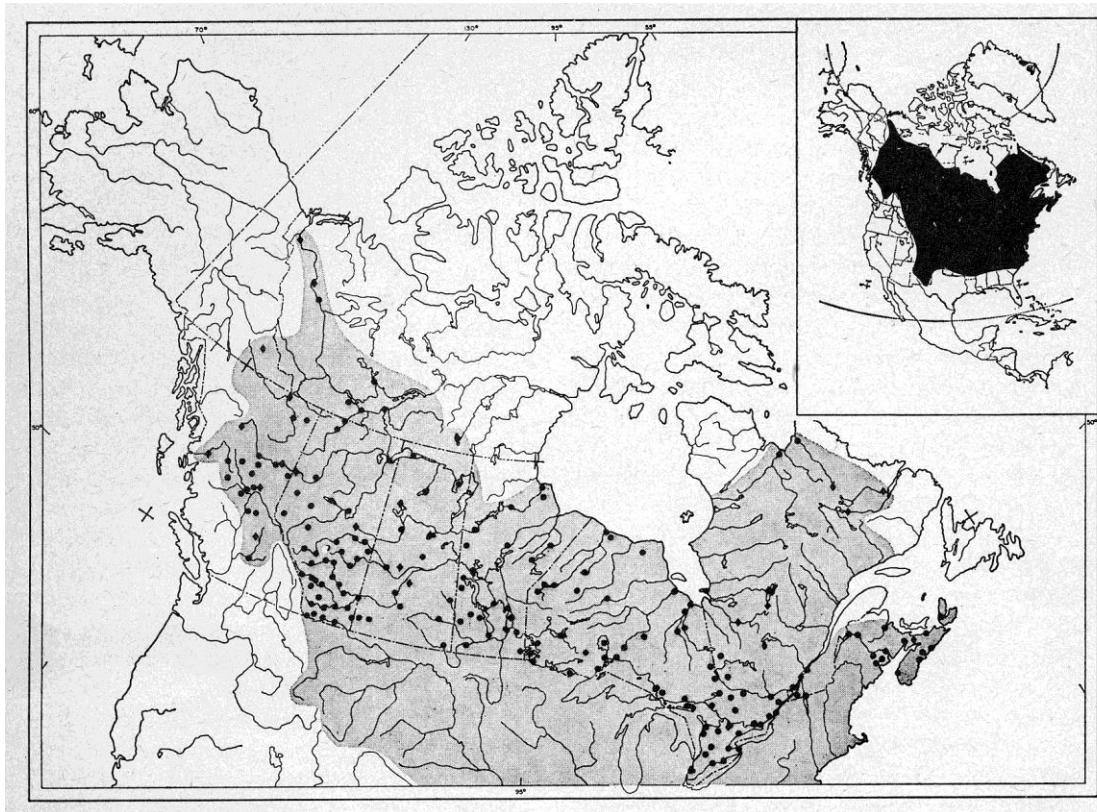


Mutualisms are NOT perfect predictors of distribution.

Determinants of Distribution

7) Historical Factors

The white sucker (*Catostomus commersoni*) is found in the Fraser and Skeena rivers, but not in the Columbia River.



from *Freshwater Fishes of Canada* by Scott and Crossman (1973)

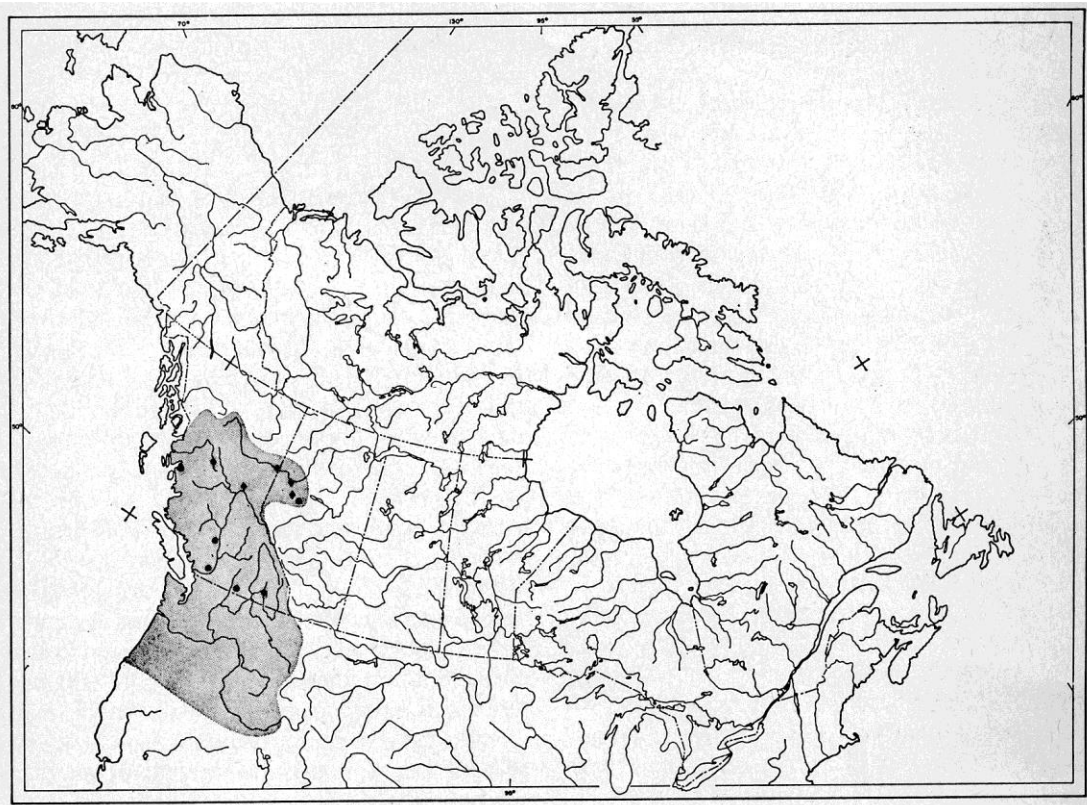


Why do white suckers have a limited distribution west of the Rockies?

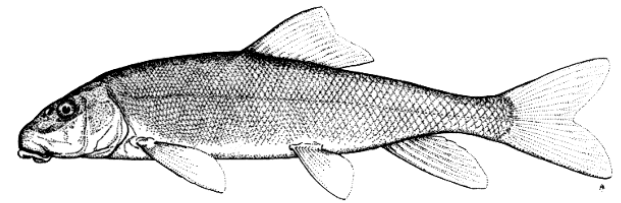
Determinants of Distribution

7) Historical Factors

The largescale sucker (*Catostomus macrocheilus*) is found throughout the west, but not on Vancouver Island.



from *Freshwater Fishes of Canada* by Scott and Crossman (1973)



Why do largescale suckers have a limited distribution east of the Rockies?

Why aren't they found on Vancouver Island?

Determinants of Distribution

7) Historical Factors

Several species of NA birds have geographical divides in the rockies

Sphyrapicus spp.



Vermivora spp.



Vireo spp.



Oporornis spp.



Dendroica spp.



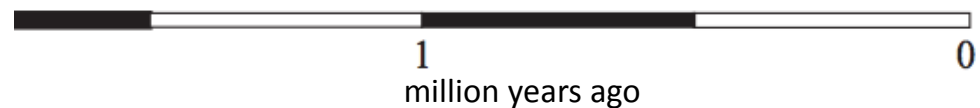
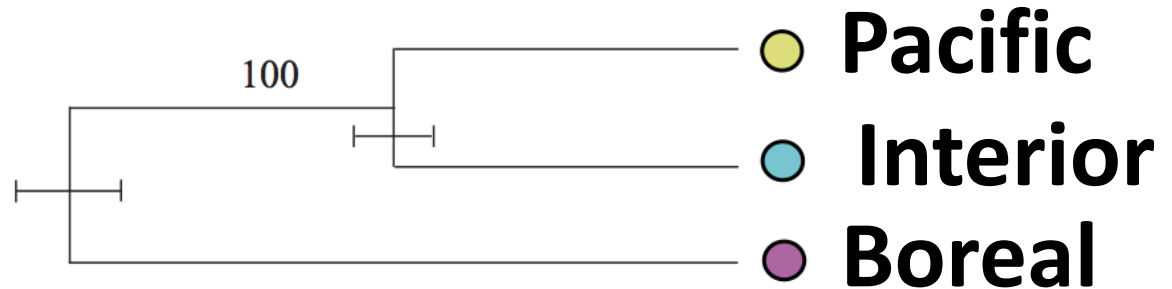
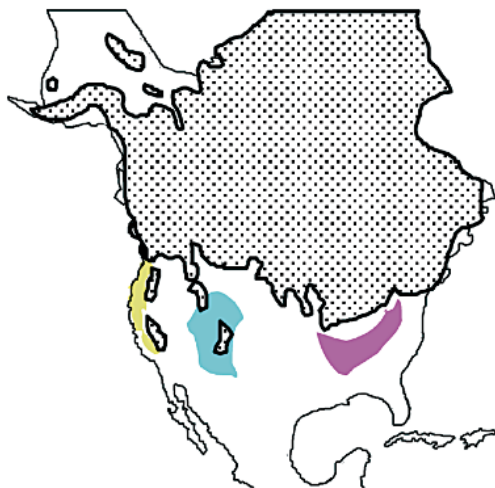
Passerella spp.



Empidonax spp.

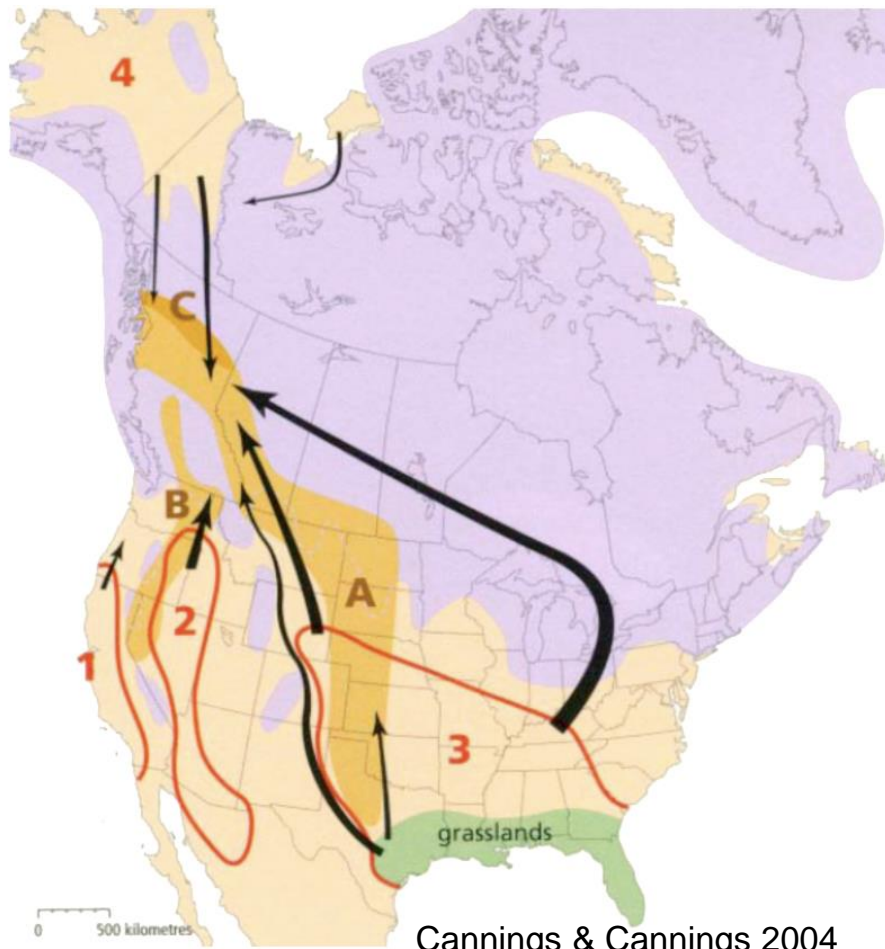


Poecile spp.



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7) Historical Factors



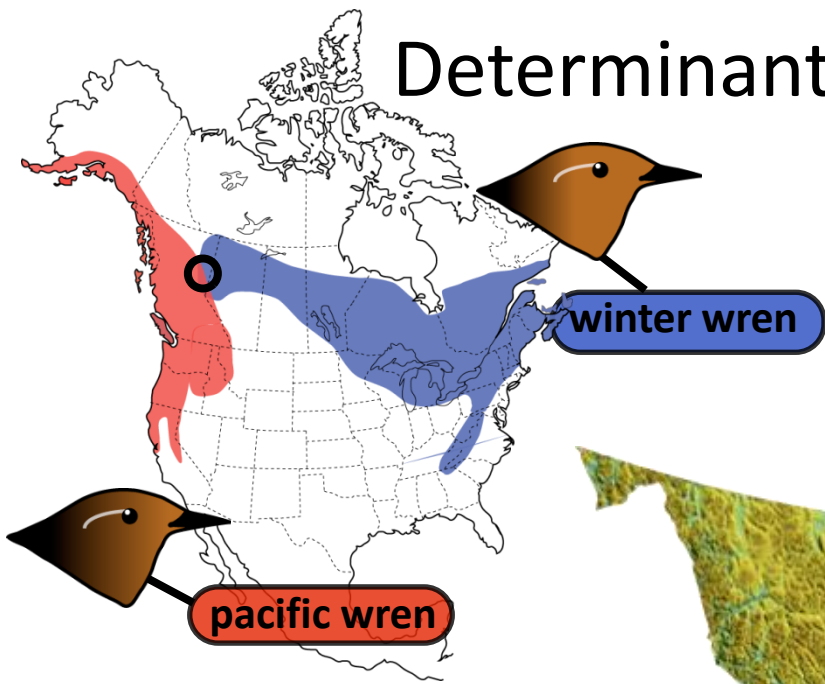
Several areas with high concentration of species with secondary contact with range expansion following glacial retreat

■ - Ice Cover

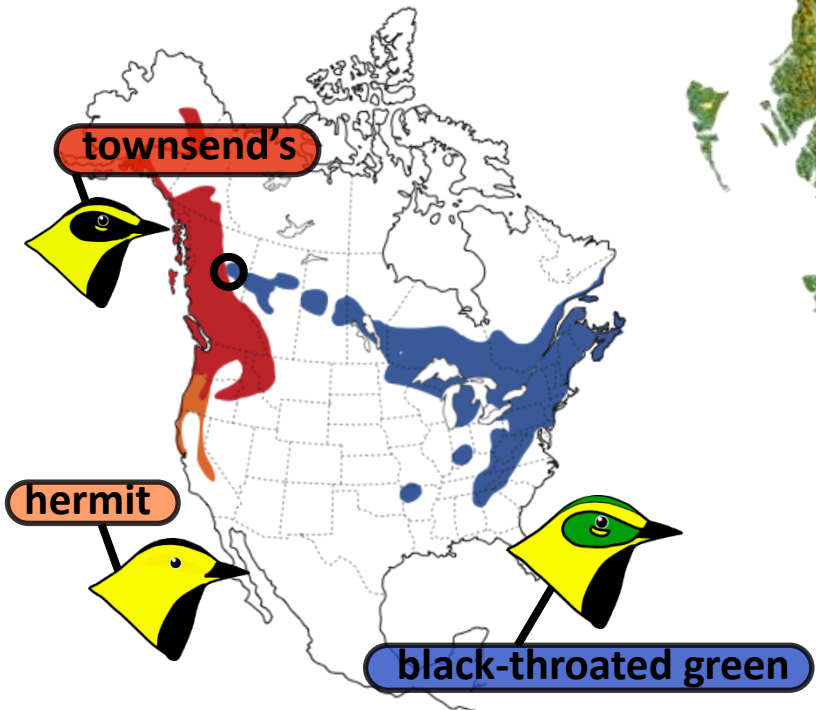
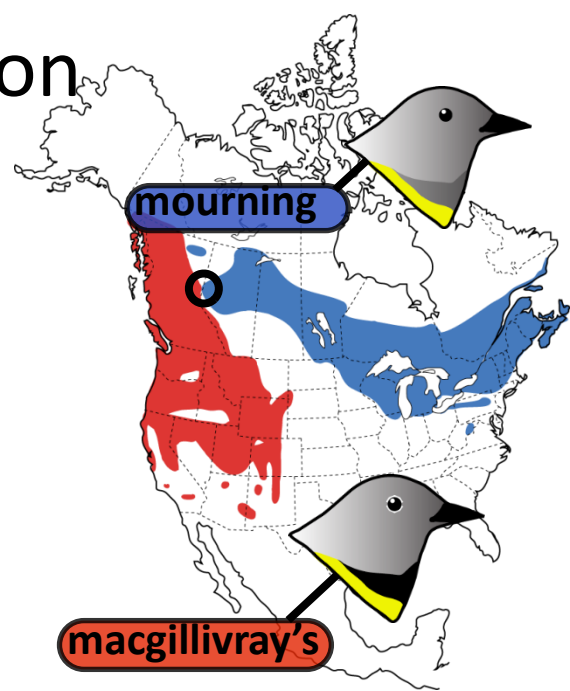
1 - 4 - Refugia

A - C - 2^o Contact

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Bird species with contact zones in the BC rockies



Toews et al. 2011

