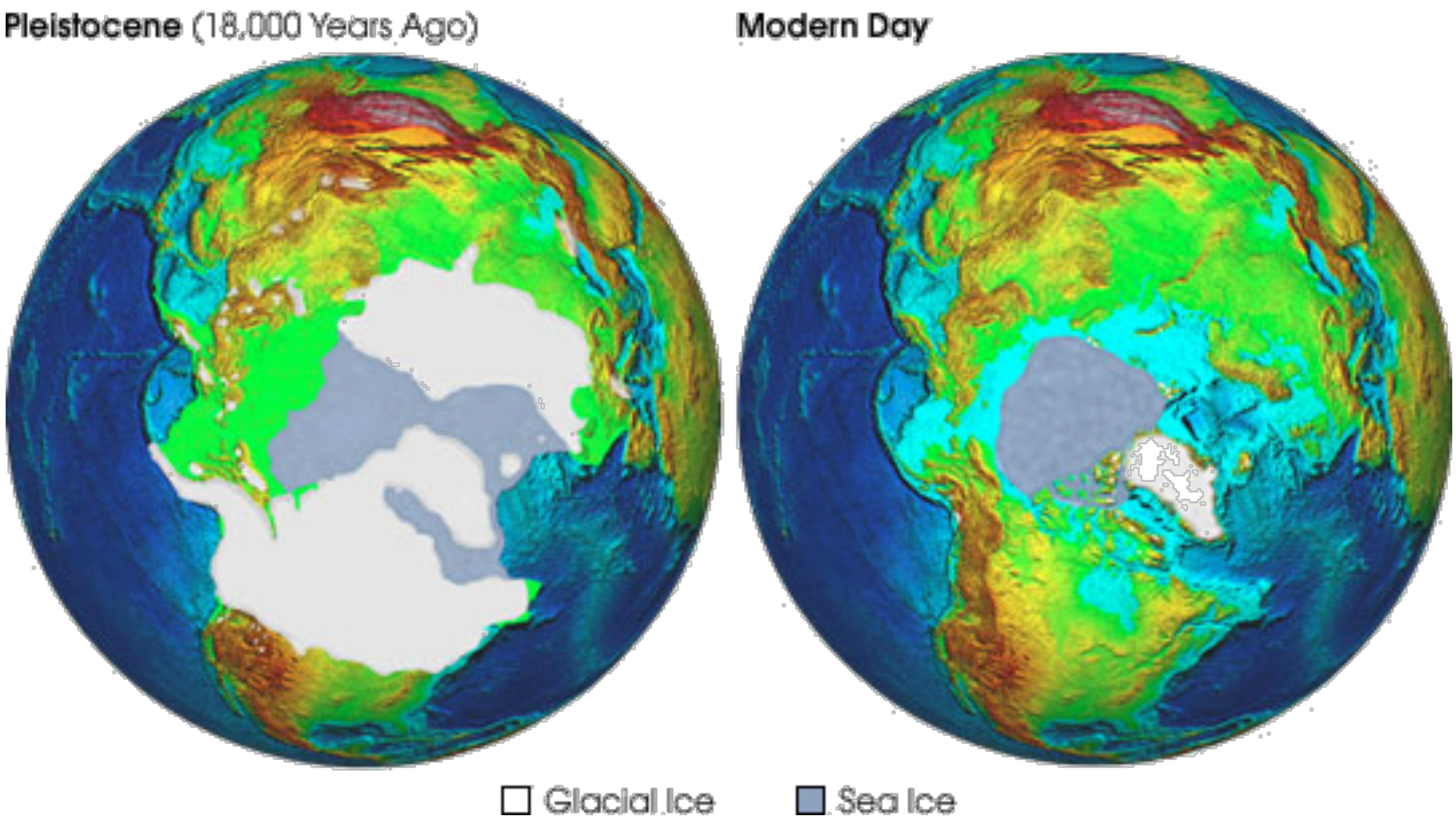
Evolution of Distributions

Evolution of the fundamental niche

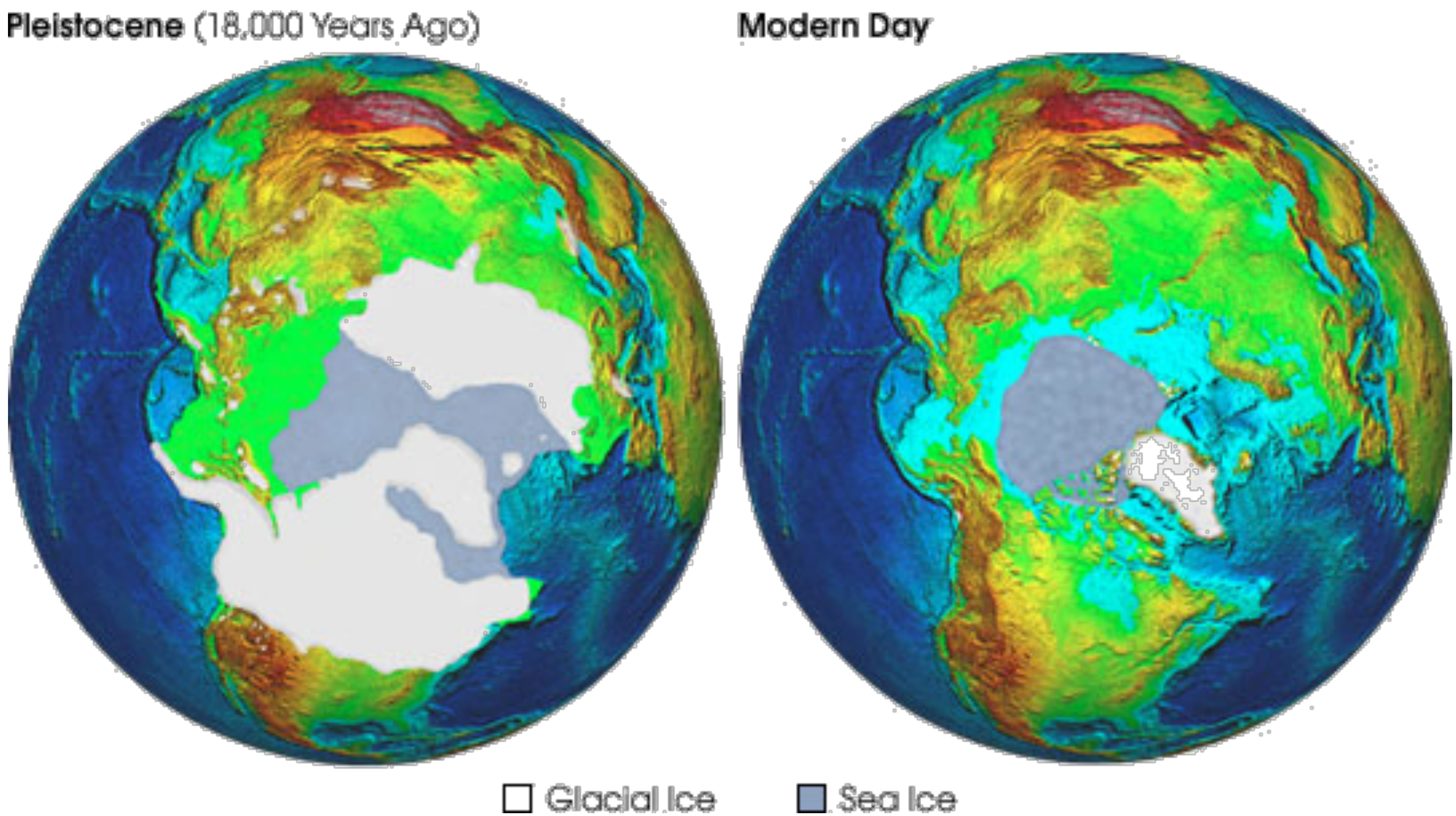
Species geographic ranges are dynamic over space and time



Evolution of Distributions

Evolution of the fundamental niche

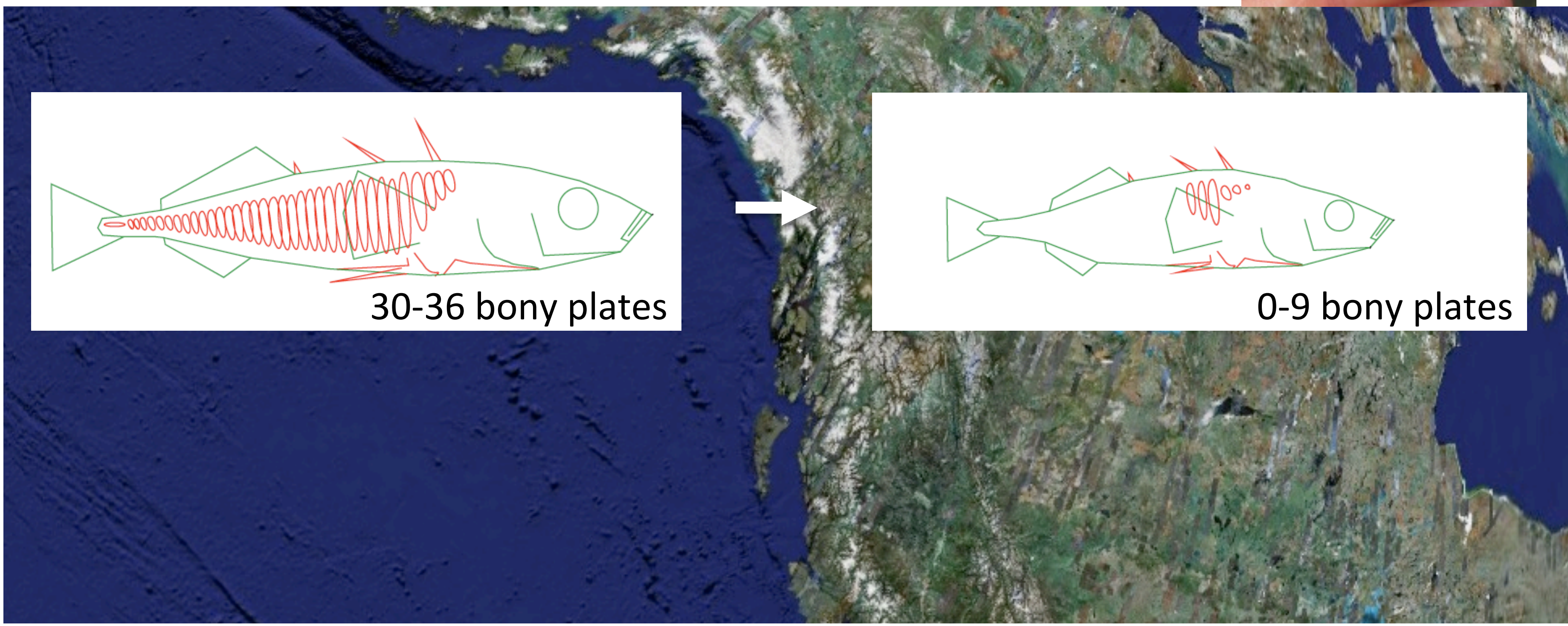
End of last ice age led to availability of new freshwater and terrestrial habitats



Evolution of Distributions

Evolution of the fundamental niche

Adaptation to freshwater in stickleback

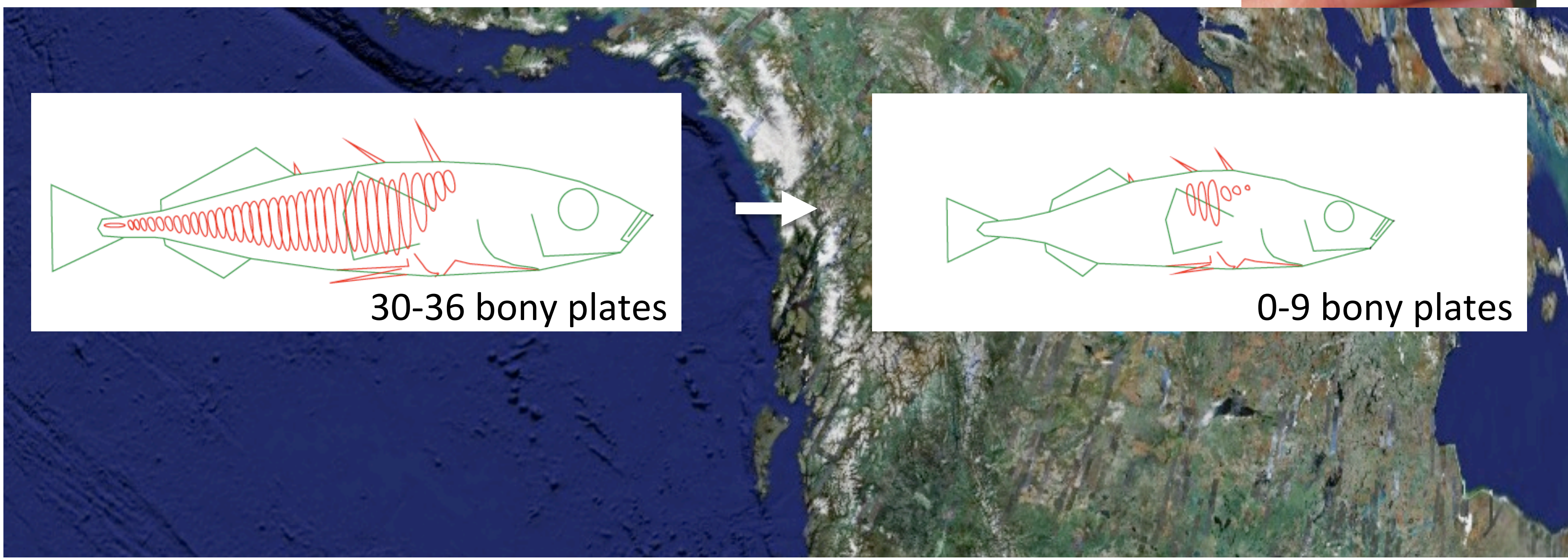


Freshwater threespine sticklebacks (*Gasterosteus aculeatus*) originated from marine populations that invaded newly created coastal lakes and streams throughout the Northern Hemisphere following the last ice age.

Evolution of Distributions

Evolution of the fundamental niche

Adaptation to freshwater in stickleback

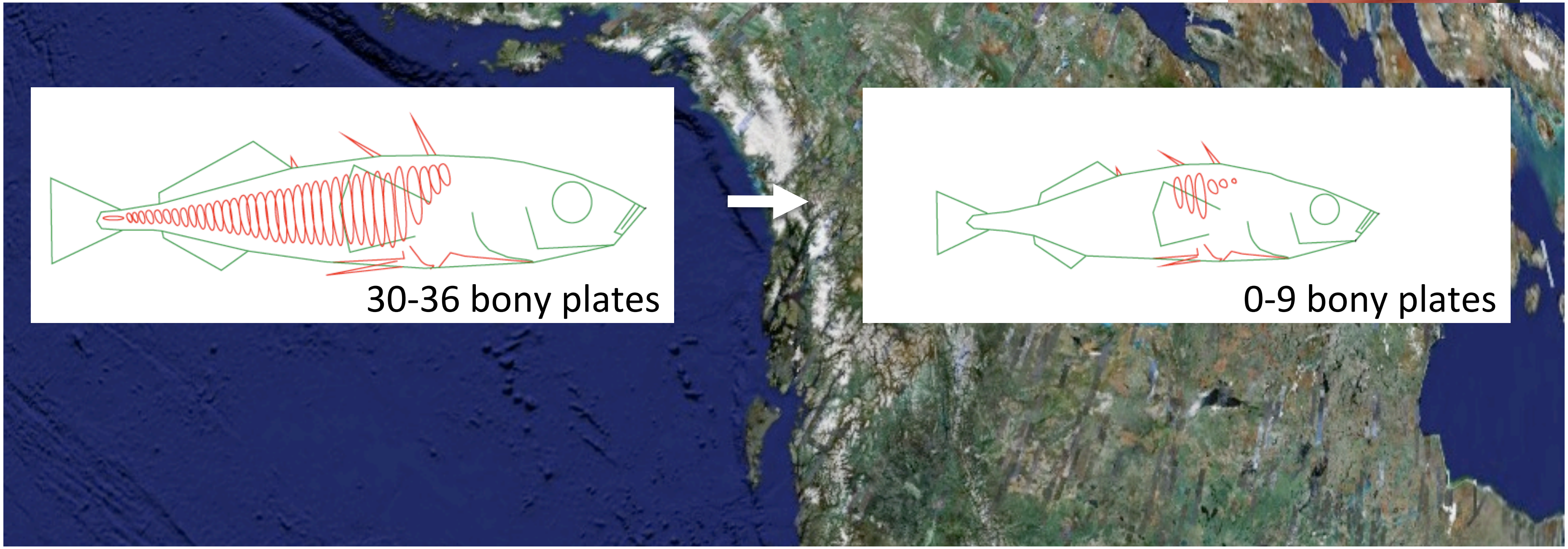


Within the past 20,000 years, freshwater populations repeatedly lost their bony armor plating. Reduction of armor following freshwater colonization evolved rapidly from the fixation of several alleles of the *Ectodysplasin* gene (the *Eda* low allele).

Evolution of Distributions

Evolution of the fundamental niche

Adaptation to freshwater in stickleback

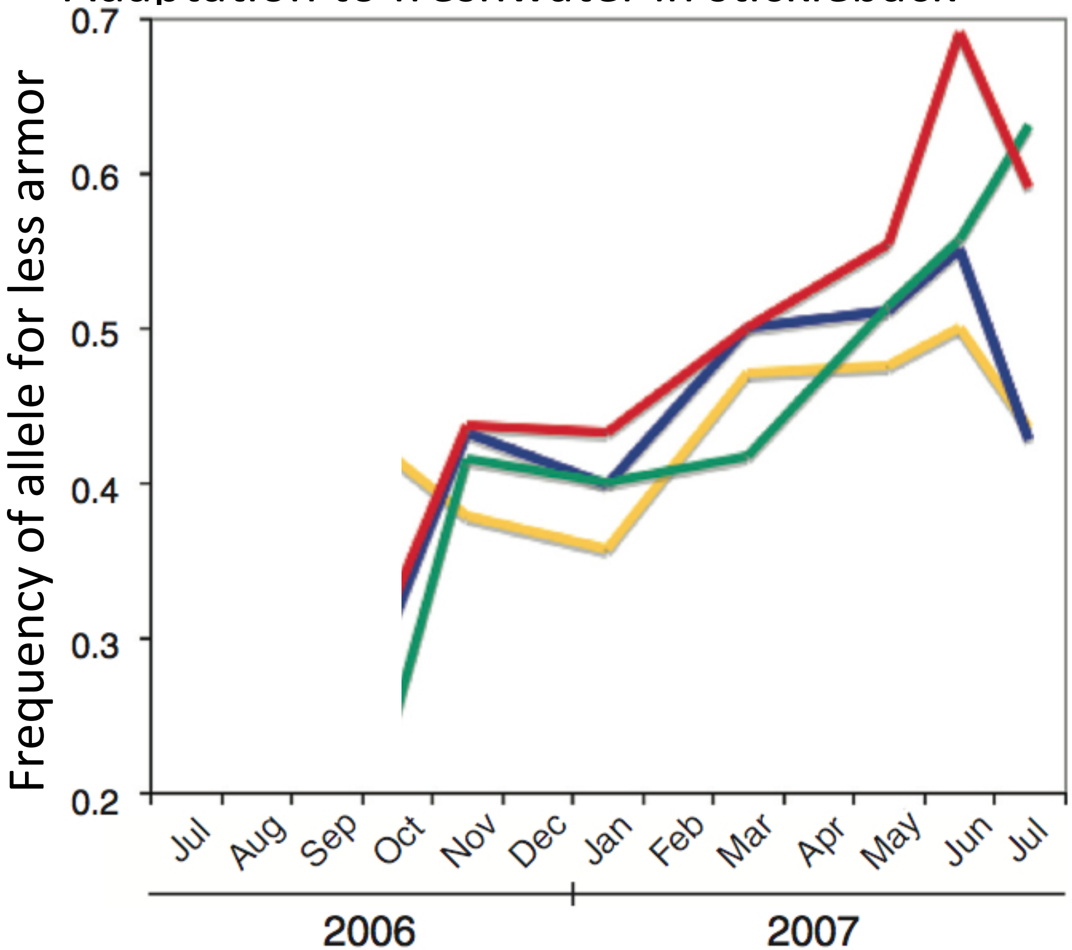


This allele is rare (~1%) in the ocean. Because EDA was fixed repeatedly in different freshwater lakes and rivers, it suggests the allele has undergone positive selection, with a strong correlation between phenotype and environment.

Evolution of Distributions

Evolution of the fundamental niche

Adaptation to freshwater in stickleback



(Barrett 2008)

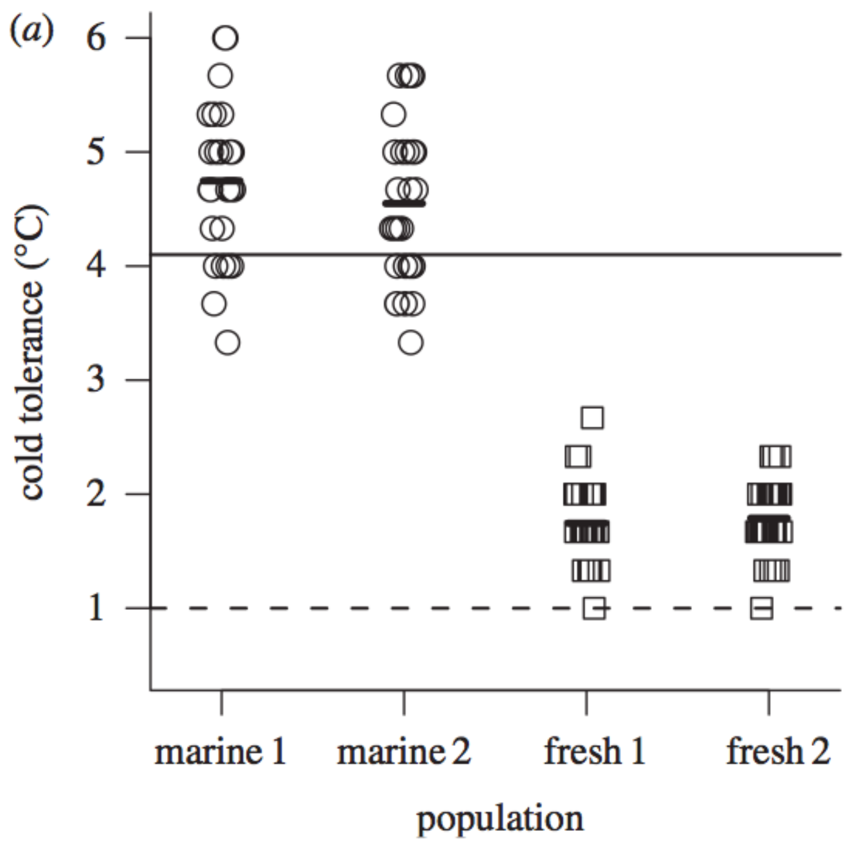
Transplanted marine sticklebacks carrying both alleles (for more and less armor) to freshwater ponds and tracked genotype frequencies over a generation.

Figure shows frequency of low EDA allele in 4 replicate ponds (different colored lines)

(Research by Rowan Barrett and Dolph Schluter at UBC!)

Evolution of Distributions

Evolution of the fundamental niche

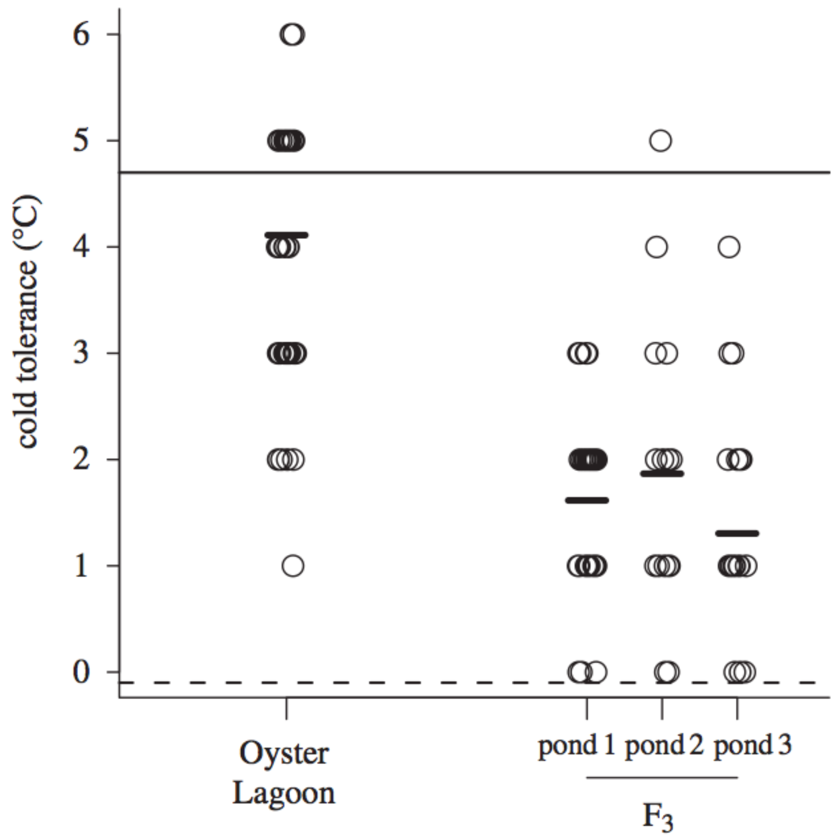


Min temperature experienced by marine populations like Oyster Lagoon (solid line) is higher than that experienced by freshwater populations (dashed lines).

Barrett *et al.* 2011

Evolution of Distributions

Evolution of the fundamental niche



Sticklebacks from Oyster Lagoon evolved higher cold tolerance after just three generations in freshwater ponds

Barrett *et al.* 2011

Evolution of Distributions

Animals differ in their ability to adapt to new habitats (and expand their distribution) because of:

1. Evolutionary constraints

2. Gene flow from the center of the range

3. Trade-offs

Evolution of Distributions

1. Evolutionary constraints

Species may lack required "evolutionary potential" to facilitate adaptation. For evolution by natural selection, there are three requirements:

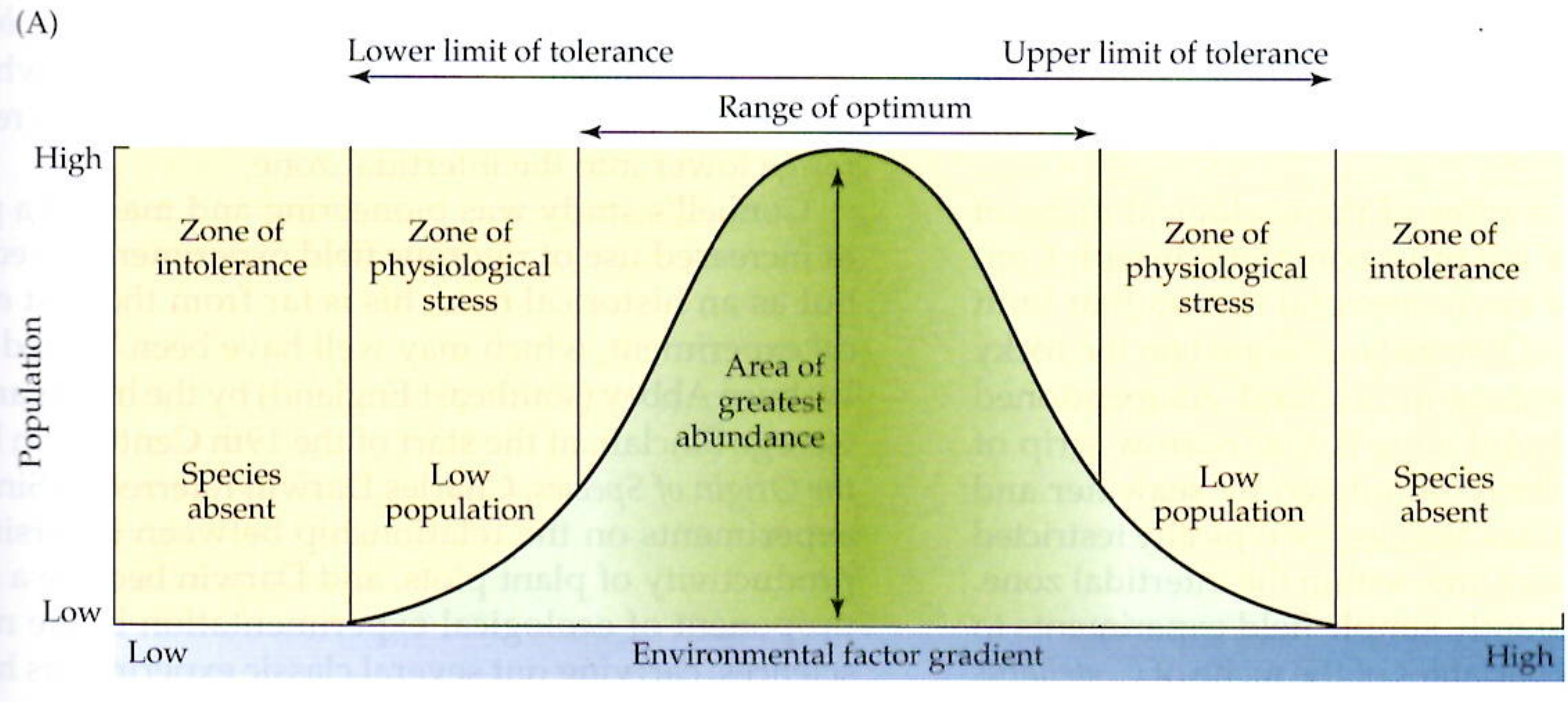
1. Individuals in a population have different morphologies, physiologies, and behaviors **(phenotypic variation)**
2. Different phenotypes have different rates of survival and reproduction in different environments **(differential fitness)**
3. There is a correlation between parents and offspring in the contribution of each to future generations **(fitness is heritable)**

about 50 million years

Evolution of Distributions

2. Gene flow from the center of the range

Recall: we typically expect species to show a Gaussian distribution along a given environmental gradient: the "abundance-center hypothesis"

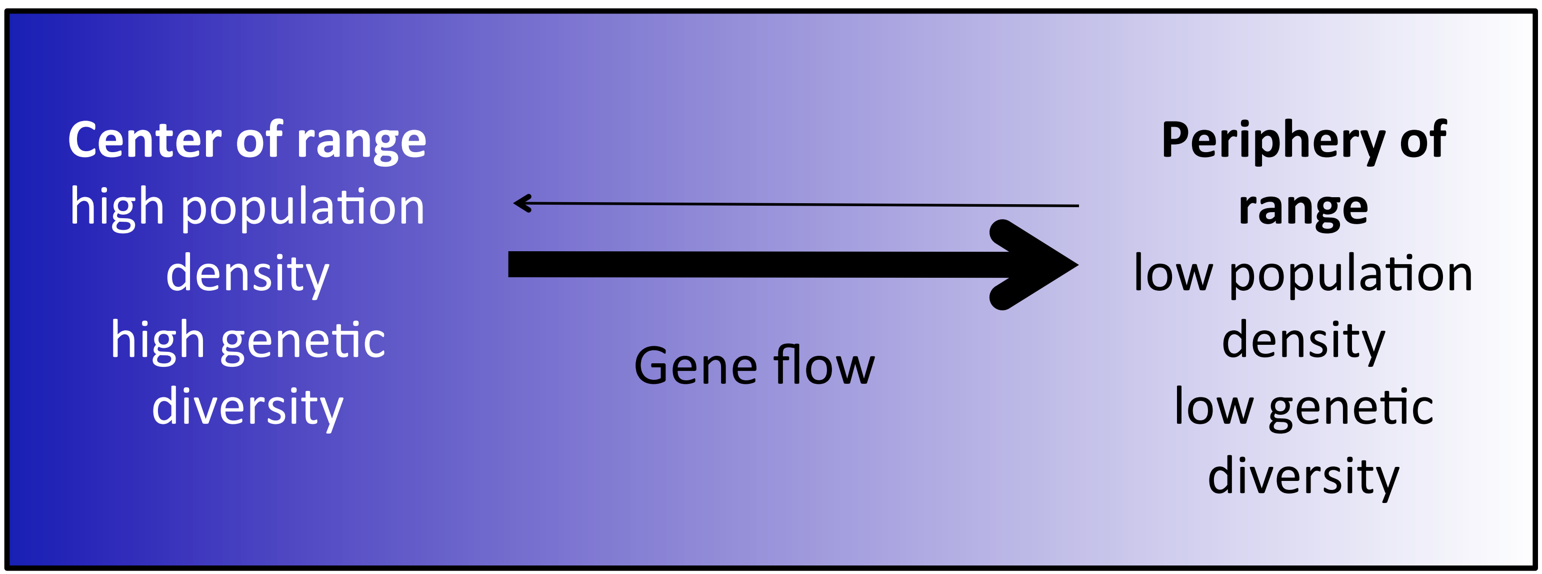


Evolution of Distributions

2. Gene flow from the center of the range

Adaptation at periphery of range can be hindered by lack of necessary genetic variation

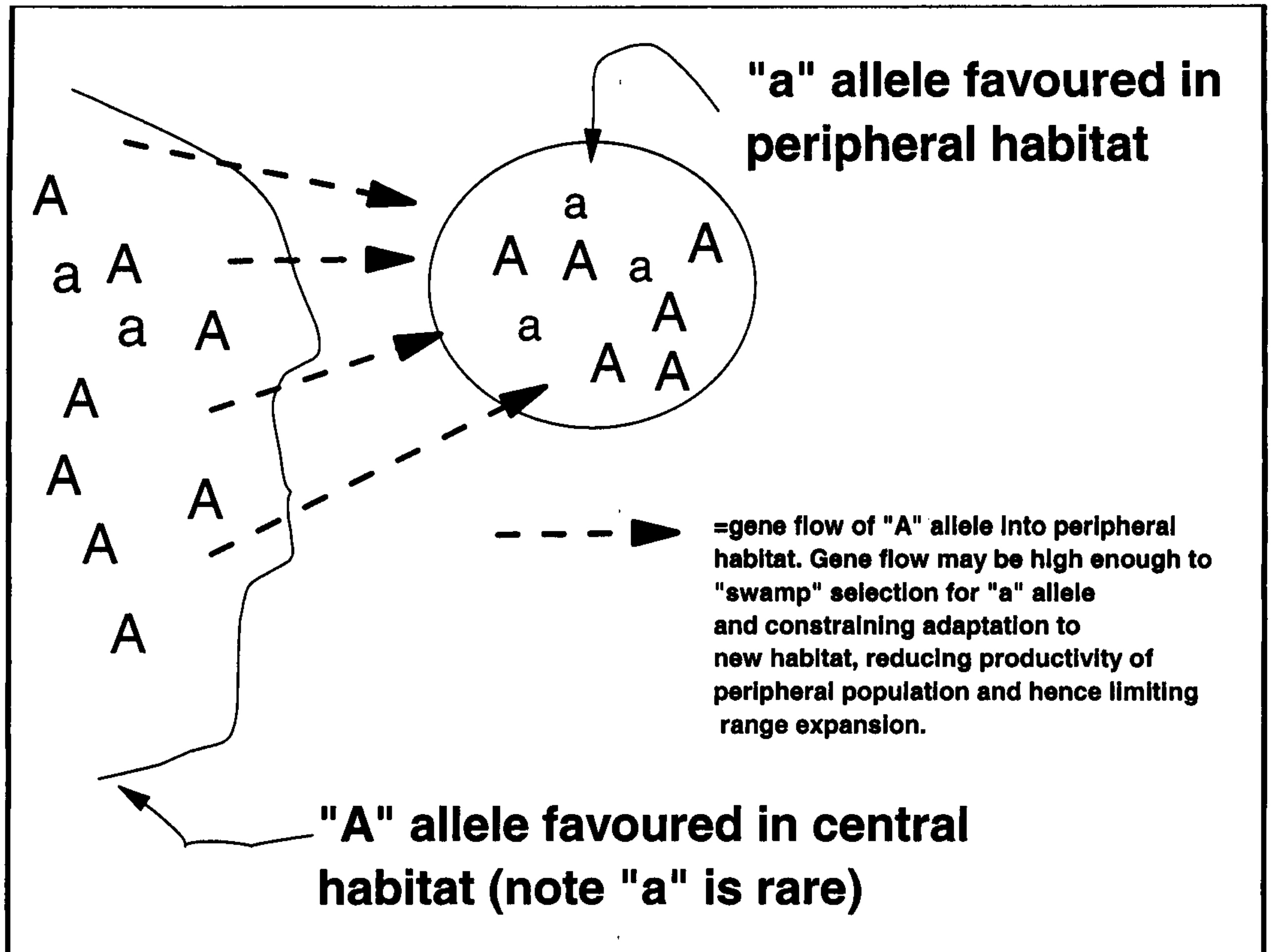
This could be facilitated by a combination of small population size at range margins and high gene flow from range center



Environmental Gradient

Evolution of Distributions

2. Gene flow from the center of the range



Evolution of Distributions

2. Gene flow from the center of the range

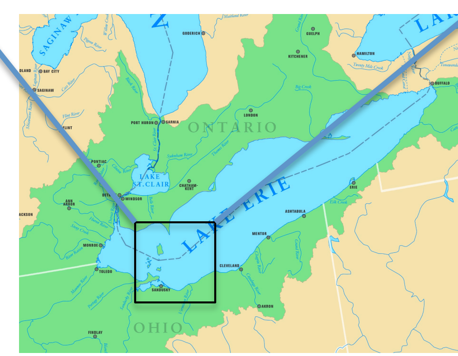
Species in the *Nerodia* genus
(10 species and various subspecies)

Nerodia sipedon – Northern water snake

Nerodia sipedon insularum –
Lake Erie water snake subspecies (LEWS)

Once endangered due to human development and declining frog populations on island, populations are now stable with protection by US FWS and local awareness

The Lake Erie water snake is found only in the western Lake Erie waters of Ohio and Canada.



(from King & Lawson 1997, reptile-database: http://www.reptile-database.org/)

Evolution of Distributions

2. Gene flow from the center of the range

Gray unbanded snakes blend in with limestone and dolomite shorelines of the islands

Avian predators (typically visual hunters) like gulls, herons and raptors less likely to detect unpatterned snakes

Regularly patterned snakes favoured in heavily vegetated mainland habitats

Frequency of regularly patterned individuals on islands is higher among younger than among older snakes

(from King & Lawson 1997)

Lake Erie island habitat

Mainland habitat

Evolution of Distributions

2. Gene flow from the center of the range

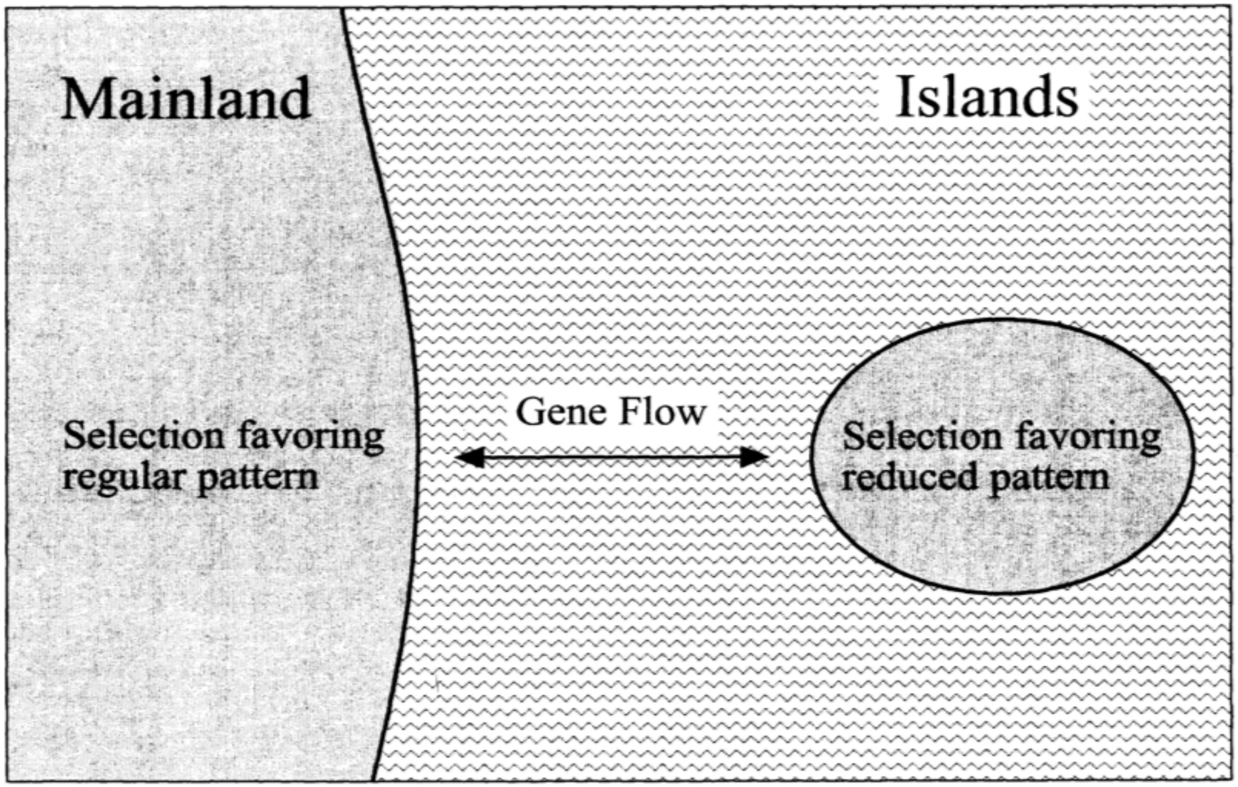


Figure 4. Effects of natural selection and gene flow in Lake Erie water snake populations. Although selection on islands favors snakes with reduced color pattern, gene flow from nearby mainland populations results in the persistence of regularly patterned snakes.

Gene flow from mainland results in persistence of regular pattern on islands

(from King & Lawson 1997)

Evolution of Distributions

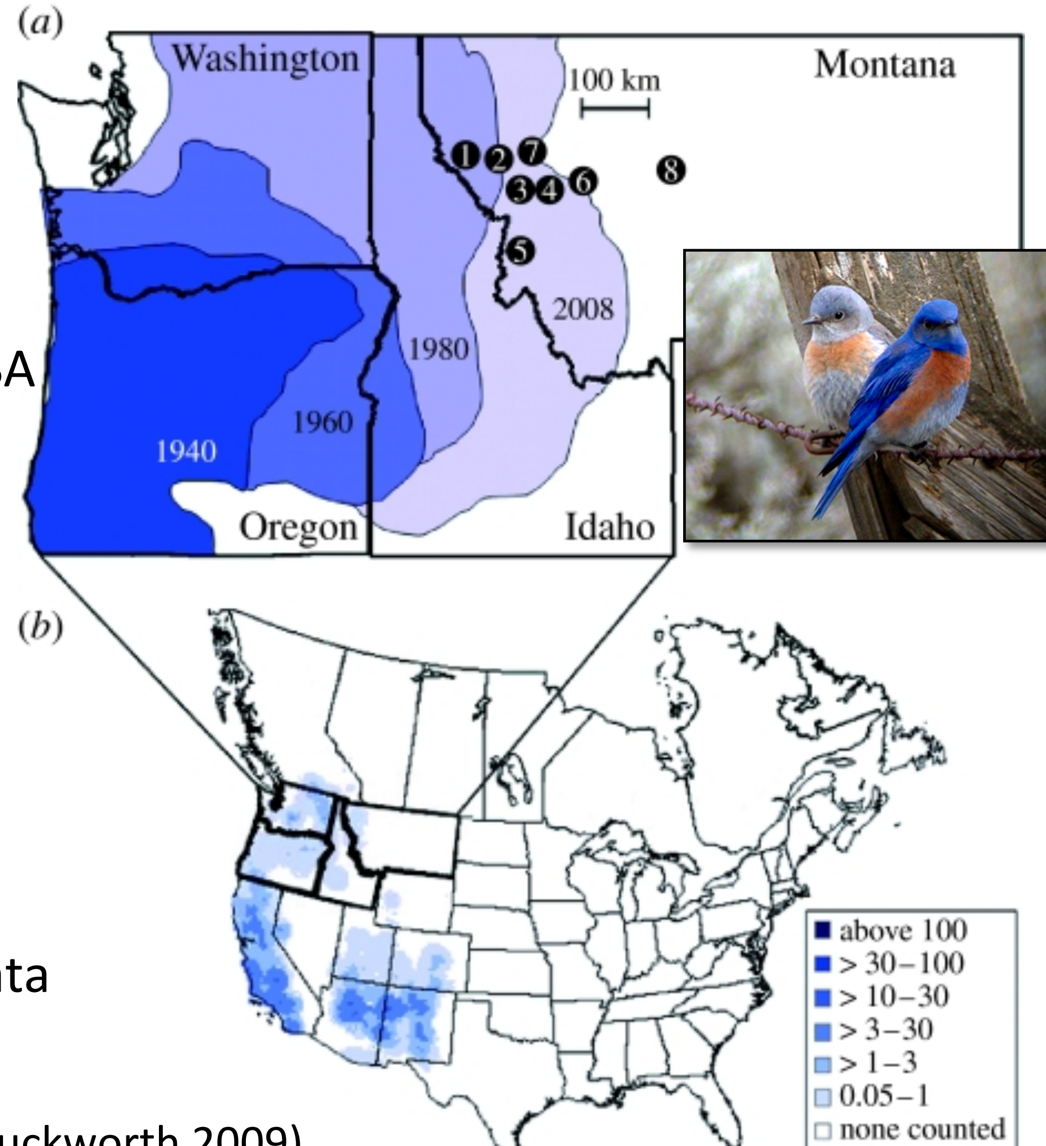
3. Trade-offs

Range expansion of Western Bluebirds

Inset shows changes in western bluebirds breeding range in NW USA

Black circles = 8 study populations where aggressive behaviour was measured

Larger map shows breeding distribution of western bluebirds from Breeding Bird Survey (BBS) data 1994 - 2003



http://www.u.arizona.edu/~rad3/ (Duckworth 2009)

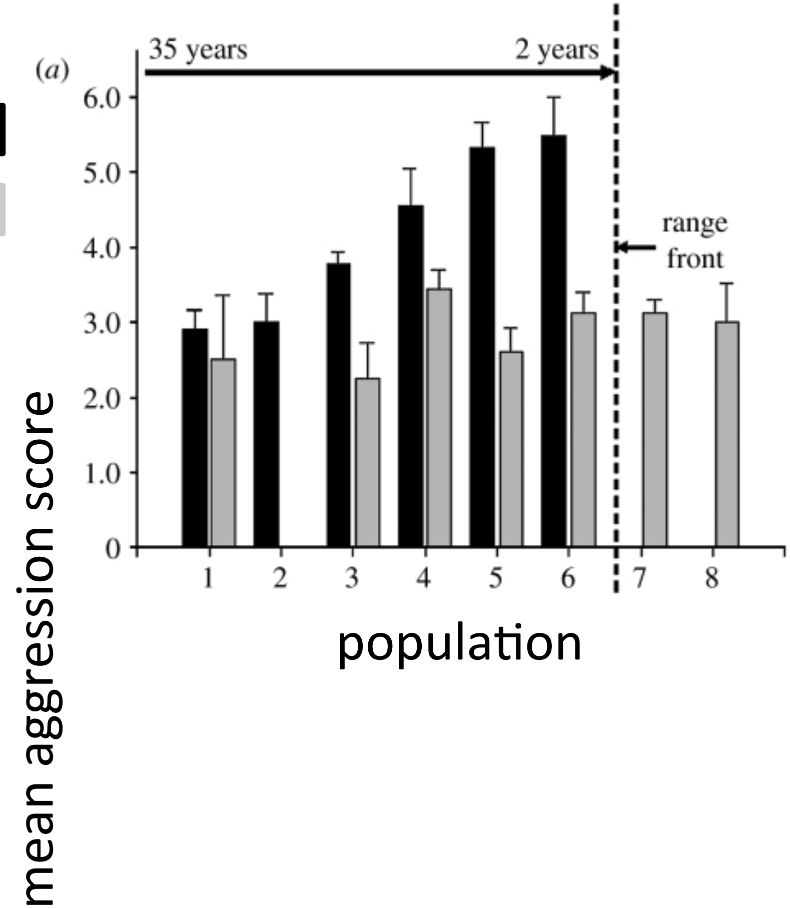
Evolution of Distributions

3. Trade-offs

Range expansion of Western Bluebirds

Western

Mountain



Rapid shifts in aggression associated with western bluebird range expansion

Aggression differs significantly among western bluebird populations in Montana and was related to time since colonization.

Mountain bluebirds are less aggressive overall, and are displaced by western bluebirds

Evolution of Distributions

3. Trade-offs

Range expansion of Western Bluebirds

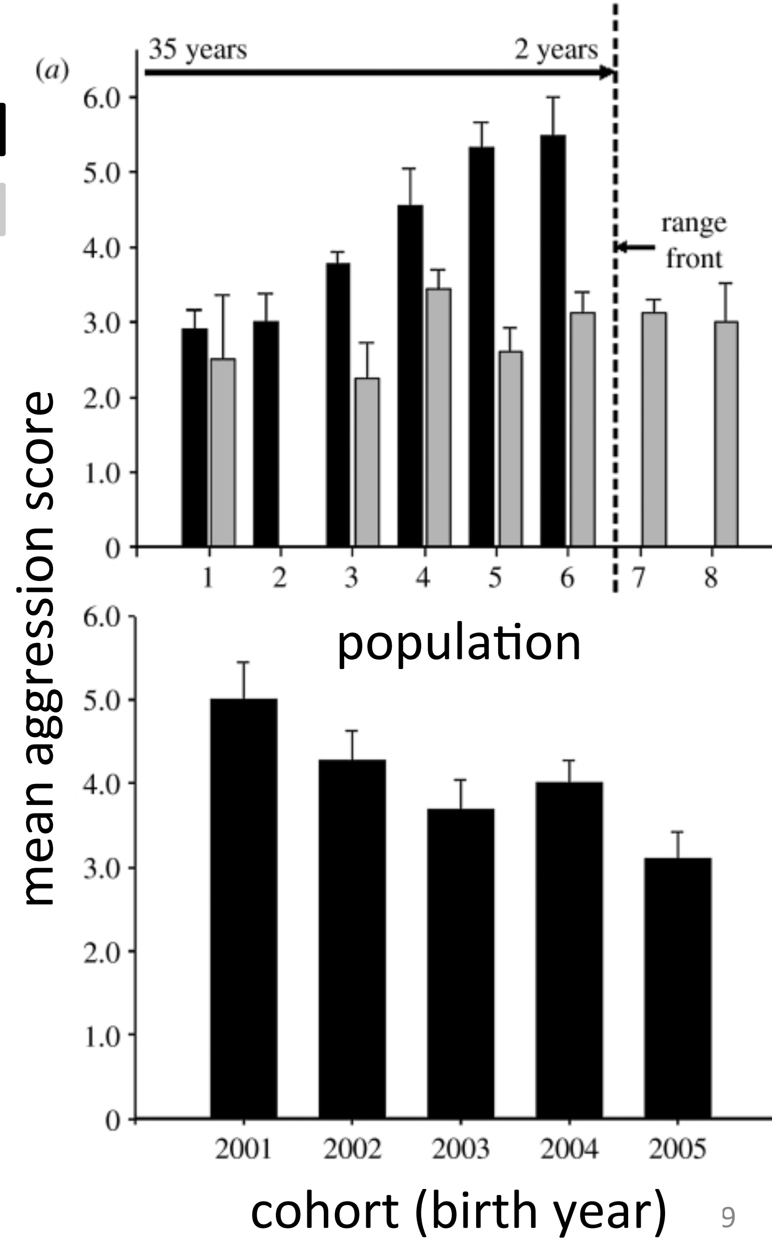
Western

Mountain

Rapid shifts in aggression associated with western bluebird range expansion

Aggression differs significantly among western bluebird populations in Montana and was related to time since colonization.

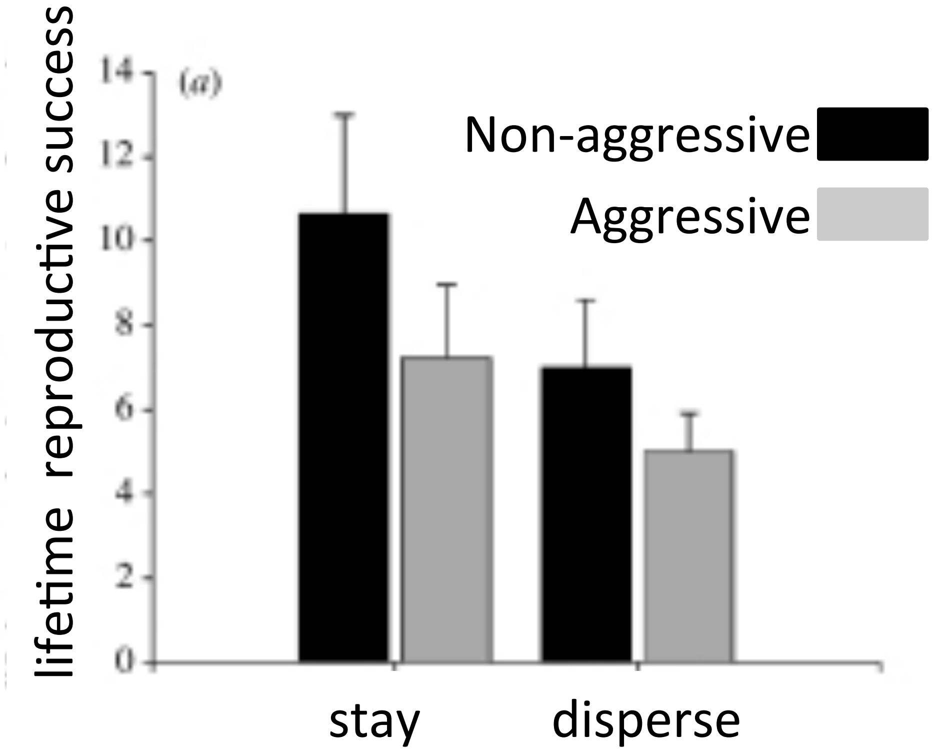
Aggression in western bluebirds decreases across cohorts, (i.e., within a population over time)



Evolution of Distributions

3. Trade-offs

Range expansion of Western Bluebirds



Non-aggressive males that stay in their natal population to breed have higher fitness than both aggressive males and males that dispersed

http://www.u.arizona.edu/~rad3/

(Duckworth 2009)

Species Distributions Review

- Should consider spatial scale in context of species distributions
- Maps give us many different kinds of information about species distributions but oversimplify them in some way
- Distributions are dynamic in space and time, but in all cases, ranges can be described by basic parameters: $r = b + i - d - e$
- Determinants of distribution are numerous, including abiotic, biotic and historical factors, acting alone or in combination (fundamental vs. realized niche)
- Ranges evolve over time: evolutionary potential, gene flow and trade-offs can influence the evolution (expansion/contraction) of species distributions

Final thoughts on distributions…

- We've reached an incredible point in time in our capability to gather and link different kinds of data to understand the ecology, evolutionary history and dynamics of species distributions

- Our challenges are to use these tools to predict how distributions, and the factors underlying them will change, so we can develop effective conservation strategies

  - How do we accurately depict the distributions of species?
  - How does their use of space vary within the range?
  - How does this depend on the natural history of different species?

Species Distributions

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