Introduction

* P1
  + In 1967 Janzen published “Why Mountain passes are higher in the tropics” (Janzen 1967).
  + In the past 50 years, Thousands of studies (ref), including three recent reviews (ref, ref, ref), and papers with new, related, hypothesis (ref, ref, ref) have stemmed from Janzen’s original essay.
  + Janzen’s Hypothesis and his related observations continue to be of interest to researchers in fields x, y, and z (ref).
  + The central idea of Janzen’s 1967 paper is a straightforward and intuitive observation that climate, topography, and evolutionary history interact to shape variation in the dispersal of organisms across the landscape.
  + With variation in the ability of organisms to disperse across the landscape being of central importance to many ecological and evolutionary questions. (list examples maybe? Metacommunities, range filling, speciation)
  + More specifically, Janzen argues that Montane barriers to dispersal are more effective in the tropics.
  + To fully understand this statement, first need to understand (1) why mountains are barriers to dispersal and also (2) why the effectiveness of montane barriers is expected to vary with latitude.
* P2
  + Why are mountains barriers to dispersal?
    - Mountains are not physical barriers; they are physiological barriers.
    - More accurately, they are thermal barriers, representing temperature conditions beyond those to which a species is adapted or acclimated.
    - Mountains are thermal barriers because mean temperature varies with elevation. Higher elevations are colder on average than lower elevations.
    - Therefore, the more dissimilar the elevation, the greater the magnitude of the thermal barrier.
  + why are thermal barriers to dispersal more effective in the tropics?
    - The previous statement argues that elevational difference drives thermal barrier magnitude; how then are thermal barriers to dispersal more effective in the tropics?
    - This is not because mountain passes (i.e., elevational differences between sites) are physically higher in the tropics - although they may be.
    - It is instead because of variation in temperature seasonality with latitude.
    - Temperature varies less from month to month across the year in the tropics.
    - This has two consequences…
      * A: thermal zonation (elevational banding of temperature) is more pronounced in the tropics.
      * B: species are thermal specialists in the tropics because species physiological tolerances and acclimation capacities evolve to match the range of conditions that they experience.
    - So, contemporary temperature regimes and species evolved physiological tolerances interact causing mountains (elevational barriers) to be higher (harder to disperse across) for thermal specialists with evolutionary histories in the more thermally uniform tropics than for thermal generalists that have evolved in the thermally seasonal temperate zone.
* P3
  + Elevation and Temperature
    - Even though we are REALLY talking about thermal barriers, it seems like elevation may be a convenient proxy. Afterall, elevation is a primary driver of temperature. Additionally, while variation in temperature with elevation may be of primary importance to this hypothesis (according to Janzen), there could be other, unmeasured, variables associated with elevation that are not captured by looking at thermal data alone.
    - A valuable route would be to evaluate global variation in both elevational barriers AND global variation in thermal barriers. Subsequent comparison of the results will reveal whether the two variables are actually one-in-the-same or if there are insights that can be gained by looking at dispersal barriers under both contexts (i.e., Do global patterns of elevational and thermal barriers largely agree? Where are there discrepancies between the two? Are these discrepancies associated with features that Janzen points out? – mountain mass, proximity to the ocean, etc…).
  + What barriers?
    - Another important point to consider is that Janzen’s essay quantifies the thermal barrier between two points.
    - Janzen selects low and high elevation points on several mountain ranges in the new world to build his dataset and to illustrate his observations.
    - However, when organisms disperse they not only have a starting point and an ending point, but an entire path.
    - An interesting (and unexplored) question would be to see if the thermal / elevational barriers that organisms would ACTUALLY have to disperse across vary systematically with latitude or other factors mentioned in Janzen’s essay.
    - There are undoubtedly countless ways to do this, but one straightforward method would be to evaluate the magnitude of elevational / thermal barriers that separate known sister species pairs (i.e., species that are each others most recent relative). Here it is possible to select a subset of starting and ending points that ACTUALLY represent important target locations for individual organisms AND if a suitable subset of species are included in the dataset, it is also known (assumed) that the barrier separating the ranges of these two sister species is actually one that was effective in allowing speciation to occur (i.e., it was exactly impermeable enough to allow a new population to form on the other side but not so permeable that a single population exists).
    - Using these starting and ending points it is possible, by brute force point-to-point calculation, to characterize the magnitude of elevational / thermal barriers that actually separate extant sister species pairs, not just as a two-point calculation, but as a sum or cost along a least-cost-path from a point in the range of one species to the cheapest-to-disperse-to point in the other species range.
* P4
  + Here, we conduct a global-scale study assessing variation in the magnitude of elevational, thermal, and precipitation barriers that separate avian sister species (i.e., recent instances of speciation, assumed to have been influenced by the barrier measured).
  + We measure, via least-cost-path analysis the elevational, thermal, and precipitation barriers that separate 1064 avian sister species pairs and use this data to characterize patterns of variation in these barriers globally.
* Furthermore, Janzen’s overlap equation (ref equation), which is central to his argument and is used to assess the climate similarity among locations, makes strong assumptions about dispersal and species acclimation capacities.
  + With regards to dispersal, the equation as formulated assumes that dispersal occurs constantly at the same rate throughout the year AND that the route via which dispersal occurs is determined by the similarity of that route across the entire year (not during a specific window of dispersal).
    - It may be more realistic to assume that species disperse in the month (or period) that has the LOWEST cost for dispersal and that the route over which dispersal occurs is determined only by the costs during this period (rather than across all periods throughout the year when dispersal may not be occurring).
  + With regards to acclimation capacity, the equation as formulated assumes that species acclimate such that their physiological tolerances exactly match the conditions present at any given moment in time in their place of occurrence.
    - Again, this may not be the most realistic assumption for ALL species. It may be valuable to consider the other extreme as well – species physiological tolerances match the full annual range of conditions present in their place of occurrence. Under this framework there is no change in physiological tolerance from moth to month, but rather physiological tolerances are set by annual extremes.
* Here, we conduct a large-scale assessment of Janzen’s mountain pass hypothesis utilizing occurrence data for avian sister species coupled with global topography and climate datasets.
  + Using Janzen’s climate similarity equation, we measure the magnitude of the (1) elevational and (2) thermal barriers that separate avian sister species (recent speciation events) with a least-cost-path analysis.
    - We note general agreement between the results when barriers are measured as elevational barriers and when they are measured as thermal barriers.
    - We note locations where there are discrepancies and discuss potential reasons for these features.
  + When considering temperature, we explore four combinations of assumptions regarding dispersal and acclimation: (1) constant even dispersal, instant acclimation, (2) constant even dispersal, no acclimation, (3) single-period dispersal, instant acclimation, (4) single-period dispersal, no acclimation.