Version dated: April 16, 2018

RH: Phenological tracking

Phenological tracking in communities in stationary & non-stationary environments

Lizzie[1,2,3] & Megan[4]

[1] *Arnold Arboretum of Harvard University, 1300 Centre Street, Boston, Massachusetts, 02131, USA*

[2] *Organismic & Evolutionary Biology, Harvard University, 26 Oxford Street, Cambridge, Massachusetts, 02138, USA*

[3] *Forest & Conservation Sciences, Faculty of Forestry, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4*

[4] *Hawaii Institute of Marine Biology*

Corresponding author: XX, see [1,2] above ; E-mail:.

Abstract

Keywords: phenology, climate change....

Outline

So, there's a pretty basic structure to what we want to walk through:

1. In *stationary environments* ...
   (a) Describe R* and how species with lower R* always wins (intra-annual dynamics generally) ... need other axis of competition for coexistence
   (b) Moving onto interannual variation: in temporally variable environments species with τ_i closer to averae τ_P should always win
   (c) For variation in τ_i to exist, need other axis of coexistence (such as R*)
   (d) But what if τ_i is not a fixed species attribute? Introduce tracking...
   (e) Then speices with higher α should win
   (f) Unless you have another axis of coexistence (such as R* or τ_i)
2. In *nonstationary environments* ... (need some help with phrasing)
   (a) Earlier τ_i is favored more (R* versus τ_i runs: previously these coexisted via a higher R* and less ideal τ_i)
   (b) Tracking is favored more ... or effective τ_i is really favored more (τ_i vs. α runs)
   (c) Tracking is favored more (α versus R*)
3. But this all assumes that nonstationarity happens on only one dimension of the environment; just like species niches, the environment is multidimensional and nonstationarity in it may be multidimensional also.
   (a) Show what happens when R0 get smallers as τ_P gets earlier
4. And, we conclude.

Phenology & climate change paper

... below is from `VarEnv_notes`

Possible titles: 'Phenological tracking: It's more complicated than you think' (we hope) or 'Phenological tracking: Is it naive?'

1. Opening
    (a) Communities shifting due to climate change (species increasing and decreasing)
    (b) Phenology has been implicated in driving this
    (c) The theory goes that as seasons get earlier, earlier species win out over later species (don't get into tracking yet)
    (d) Yet no one to date has ever examined whether this hypothesis is supported through community coexistence theory and models
    (e) So here we provide the first test using a model that explicitly considers how within and between year dynamics can drive coexistence
2. Under this model climate change critically alters the environment in a couple ways
    (a) Climate change...
        i. τ_P gets earlier (i.e., start of season gets earlier)
        ii. $R_0 \downarrow$ (e.g., in systems started by a pulse of water from snowpack)
        iii. $var(R_0) \uparrow$
        iv. $\epsilon \uparrow$ (i.e., it gets hotter and resources like water evaporate quicker)
    (b) Of these, changes in τ_P are aguably the most observed and should be most important to impacts on coexistence via phenology thus we focus on how shifts in τ_P impact coexistence.
    (c) We first examine the role of phenology in a stationary environment ... then to X, Y, Z.
3. Under a stationary environment what trade-off is required with tracking to allow coexistence?
    (a) Two species (i, j) case
        i. Vary τ_P by drawing from a stationary distribution and let R^* and α also vary by being drawn from each of their own (non-joint) distributions, run a bunch of models of 2 species communities and extract co-existing ones.
        ii. Plot $\frac{\alpha_i}{\alpha_j}$ (or, perhaps better: realized proximity to τ_P) by $\frac{R_i^*}{R_j^*}$ for coexisting pairs of species (PhenTrackFig. 1, not currently shown here, see paper notes) – we expect a cloud of space where coexistence is possible.
    (b) Multi-species case

i. (Similar to above) Vary τ_P by drawing from a stationary distribution and let R^* and α also vary by being drawn from each of their own (non-joint) distributions for a $n > 2$ set of species, and pull out coexisting species from each run.

ii. Plot α (or realized proximity to τ_P) against R^* for each community of coexisting species (PhenTrackFig. 2, not currently shown here, see paper notes), measure the correlation and the noise around it.

iii. Examine the distribution of correlations (and maybe noise) for all communities (PhenTrackFig. 3, not currently shown here, see paper notes).

4. Under a non-stationary environment of earlier τ_P how: (1) does this trade-off change and (2) do communities change?[1]

   (a) Two species case: take the coexisting 2-species communities from part I and add nonstationarity in τ_P and ...

      i. see how long it takes to lose one species.

      ii. see which ones persist longest and mark on PhenTrackFig. 1 (e.g., re-do PhenTrackFig. 1 with bubble plots or such for how long the two species persist together).

   (b) Multi-species case: take the coexisting multi-species communities from part I and add nonstationarity in τ_P and ...

      i. stop at X timepoint and re-do PhenTrackFig. 2 and 3 to see how they have shiften (e.g., you may lose the middle species — those that are not the best competitors nor the best trackers ...).

      ii. extract timepoints when 10% and/or 50% of species are lost.

      iii. extract when each species is lost in a community and order the species loss of PhenTrackFig. 2.

5. Are there environmental conditions under which tracking won't work as a strategy? (This is the section where we return to R_0 and ϵ, which we just mentioned earlier.

   (a) Thinking about environmental correlations (e.g., spring gets earlier and drier or such), are there some where tracking will not be favored?

   (b) Answer: Yes, probably whenever you shift the environment in another way (in addition to earlier τ_P) that does not impact the competitive dominant but does negatively impact the competitve inferior/tracker (See also Figure 1 below).

   (c) So, for example if τ_P gets earlier *and* R_0 gets smaller then the trackers may decline.

[1] Megan may have better notes on this section

Figures

1. Real-world data showing stat/non-stationarity in environment (ideally τ_P)
2. Real-world data showing tracking (and less tracking)
3. τ_P vs. R* trade-off and histogram of persisting τ_i under stat/nonstat τ_P environment
4. alpha vs.τ_i trade-off and histogram of persisting alpha under stat/nonstat τ_P environment
5. alpha vs. R* trade-off and histogram of persisting alpha under stat/nonstat τ_P environment
6. time-series of one run showing years where τ_i of one species is close to τ_P and other years where τ_i of other species is close to τ_P (and show this shift under nonstat)
7. non-stationarity in $R0$ and τ_P