Climatic drivers and intrisic biological processes shape masting dynamics...

Victor Van der Meersch, Mike Betancourt, & EM Wolkovich

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1. Intro (all forests → stand sync → ind. trees)

   The acceleration of climate change is predicted to have abrupt ecological effects worldwide [1]. Rapid shifts to novel climate conditions with more extreme events could disrupt key ecological processes – and potentially drive ecosystems toward critical transitions [2]. In particular, many forest ecosystems are showing sign of increased sensitivity to biotic and abiotic disturbances [3, 4]. Forests have the potential to adapt only if they can rely on their regeneration capacity, which promotes post-disturbance recolonization with individuals better adapted to new conditions [5, 6].

   Regeneration in many temperate and tropical forests depends on tree species that have a high reproductive variability across years, and where most individuals of a population reproduce synchrounously. These two characterisics—variability and synchronicity—define masting. Masting is hypothesized to have strong fitness benefits, mostly because high seed production could overwhelm seed predators—i.e. a higher proportion of seeds and seedlings could escape predation and establish. Masting could also favor greater pollen exchange and genetic outcrossing across individuals, favoring the production of seedlings that may be better adapted to new climatic conditions.

   Disruption of this reproductive timing by climate change could trigger cascading effects on forest resilience. Masting is a population-level characteristic that require individual trees to respond similarly to environmental cues in order to reproduce together within a certain distance—which should match with predator foraging range. Tree species that mast have likely evolved under colder climates, and warmer conditions could modify the reproductive cues that allowed for both variability and synchrony within the population.

   Understanding the reproductive behavior that arises at the population level requires to study individual trees' responses to cues. Reproductive success requires that an individual tree experienced good environmental conditions—and in particular no late spring frosts and sufficiently warm temperatures during the growing season.

2. Results and discussion

   - We built a model that matches conceptual figure
     - alternate states (latent)

- states encode constraints
- tree level estimates lead to stand estimates!
- and we added climate

- Model identifies 2 states (here, figure with the two distributions)
  - masting is real! Mirror the intro
  - some level of synchrony within stands
  - say how often they transition in average conditions...
- Climate impacts on masting (figure of climate effects)
  - warm summer increase transition
  - frost decrease number of seeds
  - no efect of spring (supp mat)
- Our projections vs current studies
  - current studies: ACC leads to more seeds via more masting
  - but even if you drive warming way upp you still get a plateau
  - this even happens with summer temp effect on M to M (figure proj)
  - To actually ahve a breakdown, we would nee the parameter valeu on M to M to be at least as important as NM to M
- How constraints prevent breakdown!
  - ...
- But synchrony does appear to go down
  - Review previous results and overall figure
  - these years look less synchrone. . .
  - but here, it could be driven both by within and between asynchrony
  - (what level of between-stand synchrony predict..?)
  - evolutionary benefits of mating depends on scale of synchrony *rightarrow* which scale depends on which evolutionnary model you consider, but for seed predators... should be quite small (foraging distance = X km)
- Asynchrony indeed driven by multiple factors
  - within between
  - discuss results... maybe figure with %?
- What drives synchrony?
  - bad years could act as precise cue, and with biol. constraints it would explain the following synchrony
  - how ACC could change those dynamics, and on which scale?
  - (Unclear how breakdown at tree and then at stand level?)
  - basically, we need to figure out the biology useful for predictions with ACC

References

[1] Christopher H. Trisos, Cory Merow, and Alex L. Pigot. The projected timing of abrupt ecological disruption from climate change. *Nature*, 580(7804):496–501, April 2020. ISSN 1476-4687. doi: 10.1038/s41586-020-2189-9.

[2] Thomas Wernberg, Scott Bennett, Russell C. Babcock, Thibaut de Bettignies, Katherine Cure, Martial Depczynski, Francois Dufois, Jane Fromont, Christopher J. Fulton, Renae K. Hovey, Euan S. Harvey, Thomas H. Holmes, Gary A. Kendrick, Ben Radford, Julia Santana-Garcon, Benjamin J. Saunders, Dan A. Smale, Mads S. Thomsen, Chenae A. Tuckett, Fernando Tuya, Mathew A. Vanderklift, and Shaun Wilson. Climate-driven regime shift of a temperate marine ecosystem. *Science*, 353(6295):169–172, July 2016. ISSN 1095-9203. doi: 10.1126/science.aad8745.

[3] Katharina Albrich, Werner Rammer, and Rupert Seidl. Climate change causes critical transitions and irreversible alterations of mountain forests. *Global Change Biology*, 26(7):4013–4027, May 2020. ISSN 1365-2486. doi: 10.1111/gcb.15118.

[4] Giovanni Forzieri, Vasilis Dakos, Nate G. McDowell, Alkama Ramdane, and Alessandro Cescatti. Emerging signals of declining forest resilience under climate change. *Nature*, 608 (7923):534–539, July 2022. ISSN 1476-4687. doi: 10.1038/s41586-022-04959-9.

[5] Camille S. Stevens-Rumann, Kerry B. Kemp, Philip E. Higuera, Brian J. Harvey, Monica T. Rother, Daniel C. Donato, Penelope Morgan, and Thomas T. Veblen. Evidence for declining forest resilience to wildfires under climate change. *Ecology Letters*, 21(2):243–252, December 2017. ISSN 1461-0248. doi: 10.1111/ele.12889.

[6] Monica G. Turner and Rupert Seidl. Novel disturbance regimes and ecological responses. *Annual Review of Ecology, Evolution, and Systematics*, 54(1):63–83, November 2023. ISSN 1545-2069. doi: 10.1146/annurev-ecolsys-110421-101120.