1. Background
   1. Brief overview of the history and theory behind regime change/non-linear dynamics in ecology
      1. Stemming from catastrophe theory, original debates of ecological regime shifts was largely focused around stability and linear dynamics. Then the stability debate roared for a while.
   2. Definitions of regime shifts
      1. Key papers defining some of these terms include:
         1. Some studies suggest to use regime or attractor instead of state (or alterative stable state), since regime implies dyanmics, and a state implies a static set of conditions (Scheffer and Carpenter 2003, Möllmann et al. 2015). The terms **regime** or **attractor—**using the term [alternative] stable state (or equilibria) loses the dynamics of the system.
            1. Carpenter (2003) defined regime shifts as: ‘a rapid modification of ecosystem organization and dynamics with prolonged consequences’.
            2. The 2015 special feature (led by (Möllmann et al. 2015) refers to regime shifts as an abrupt and persistent change in the system that manifests across trophic levels.
         2. Andersen et al. (2009) categorize regime shifts into three types:
            1. Driver threshold

Smooth pressure-status relationships

Driver changes linearly but system responds at a threshold

* + - * 1. State threshold

Threshold-like responses (discontinuous response)

RS occurs after driver exceeds some threshold

* + - * 1. Driver-state hysteresis

Bistability with hysteresis

* + 1. Are there consequences to these varying definitions in application/operationalization?

1. Major Point I: What exactly is a [regime shift]?
   1. Subpoint I: Various definitions of regime shift
   2. Subpoint 0: Should regime shifts be used in a theoretical or empirical sense? Should we ever attempt to “identify” or forecast a regime shift, or should we focus merely on identifying “EWSs” or critical transition points, feedbacks, etc.?
   3. Conceptual diagram of regime shift which encompasses, e.g., critical transitions, other ‘types’ of regime shifts (there is a review paper somewhere that has a venn diagram of the applications and gaps in applications – JLB to find in zotero)
   4. Subpoint IV: How can we define a regime shift such that is useful in empirical studies? (see Thrush et al. 2009)
2. Major Point II: Major assumptions of terms and analyses
   1. I.e., what assumptions must we make about a system, generally, to use each ‘term’ (and the associated set of indicators/analyses)?
3. Other stuff
   1. False negatives and false positives when detecting regime shifts
      1. What does this mean?
      2. What are the consequences of these errors for management?
      3. Using multiple lines of evidence
   2. Defining alternative stable states and ‘abrupt transitions’ based on observation
      1. The definition of what systems gradually change (e.g., forests in succession states) are based on our reality and observations – what happens if we assume an abrupt transititon when really what we are observing is a gradual transition (e.g., these are like false negatives, right?)
         1. Thoughts on Regime v. Alternative State from Co-authors and others

**Regime shift detection methods appropriate for noisy and sparse ecological data**

1. Motivation
   1. Numerous RSDMs exist in the literature, and some may serve as early warning signals of impending shifts. Thesemethods have been applied, primarily, to toy data or simplesystems, or have been applied to highly controllable sytems of which we know a lot (e.g., SCheffer/carpenter lakes).
   2. Despite these successful applicatiosn of RSDMs to some empirical data, these methods are not transferrable to ecological systems data from large, open systems. Numerous conceptual and data issues arise when attempting to detect RS in empirical community- or ecosystems-level data.
      1. Observation error and process error
         1. It is difficult to separate these sources of error when we are mining data for ecological regime shifts – if we do not know if and where a regime shift occurred, how will we be able to detect it?
         2. If we do not know where (in what vars and at what scales) the RS is expected to appear in the data, how do we collect the observations that pick it up?
         3. Does the definition of a regime shift influence our detection of the regime shift?
            1. Say two experts, one an “ecosystems ecologist” and the other an avian ecologist, were to advise m eon the matter of analyzing avian community time series data for a single location.
            2. So I am going to blindly analyze some data set. Say, this is a tract of land that has not been severely disturbed, yet some suite of ecological functions have changed (no changes in the vegetative structure are yet obvious). Let’s say that they have seen a rapid decline in some indicator species, but they are not sure if this is just due to environmental stochasticity,or if this is part of a larger issue. The same bird population(s) in the surroudnign area seem to be doing OK, relative to their location.
            3. They give me bird community surveys, with perfect observation. I see a drop in indicator specie(s) over time which is alarming. What is the motivation for moving forward with RSDM on the entire community?
            4. Is there a point in analyzing the entire data for community level reigme shift? Do we know enough about what these RSDMs do and do not detect to make inference regrading the results? What if I go back to the ecologists and say there was a regime shift at time X; this is the point where the species declined. Should I analyze the data without this species to see if the rest of the community is responding?If I remove that species and see other species decline, e.g., are they dependent upon that species, or resources similar to that species? DO they operate on the same temporal and/or spatialscales? What do I do next?
2. Questions
   1. How do we know there was a regime shift given some data?
   2. What are the issues with sparse and/or noisy data in detecting regime shifts?
   3. Do methods currently exist which are appropriate for detecting ecological regime shifts in noisy ecological and,multivariate data?
3. Methods/Approach
   1. A review of the ecological literature for RSDMs
   2. For each method I will synthesize the following information
      1. Assumptions required to apply each method
         1. Statistical
            1. Parametric
            2. Shape of the regime shift (e.g., discontinuous, monotonic)
         2. Theoretical
            1. *A priori* assumptions of regime shift location/timing
            2. Do the variables have to encompass the driver of the regime shift?
      2. Data requirements
         1. Minimum N; minimum # years
         2. Transformations
      3. Data output
      4. Does the method use statistical tests to confirm the location of a shift?
      5. Does the method detect, predict, or identify correlates of abrupt changes?
   3. Which, if any, of these methods
      1. Can be used on ecological monitoring data?
      2. Which can handle noise
      3. Where have these been successfully applied?
4. Comparative Analysis
   1. Use one or a few ecological data to compare the RSDMs identified in the literature review
   2. Potentially incorporate scales of functioning within the community (e.g., what happens to the qualitative results when we analyze a system across, or within functional scales?)
5. Discussion Points
   1. False negatives and false positives using RSDMs
      1. What does this mean?
      2. What are the consequences of these errors for management?
      3. Using multiple lines of evidence
      4. Supplementing RSDMs with attribution studies in ecosystems – this is beyond the scope of this paper, but is something to consider
6. Table of Definitions:
   1. Variants of abrupt changes:
      1. Critical transition
      2. Regime shift
      3. Regime change
   2. Early warning signal
   3. Characteristics of shift
      1. Transcritical bifurcation
   4. Other terms
      1. Eigenvector
         1. Dominant eigenvector
      2. System
      3. Multivariable