

Problem 6.10: Reading – Transitions

Part III of Scheffer's book [9] is titled Dealing with Critical Transitions, five chapters examining the existence and nearness of catastrophic transitions in a system.

Select one of the chapters4 in Part III. What are the challenges that we face in dealing with such systems, and what suggestions does Scheffer have to offer?

I chose to read the "Early-warning signals for critical transitions" article published in Nature by Martin Scheffer et al. Scheffer discussed how many complex real-world systems have critical thresholds or tipping points. The examples of tipping points he provided included asthma attacks, epileptic seizures, financial market crashes, abrupt changes in climate, and changes in wildlife populations. Unfortunately, the models that exist for these complex systems are not usually accurate enough to predict such tipping points. Scheffer proposes three temporal warning signs for systems approaching tipping points: slower recovery from perturbation, increased autocorrelation, and increased variance. There are also spatial warning signs which arise in some systems.

These tipping points are most commonly caused by fold bifurcations that occur when the dominant eigenvalue which characterizes the slope around the equilibrium point approaches zero. As the dominant eigenvalue approaches zero, it becomes increasingly slow at recovering from small perturbations to the system. It is possible to test the recovery rate of small simple systems by perturbing them and measuring the recovery rate experimentally. However experimentally measuring the recovery rate is not always possible for large complex natural systems so the recovery rate from natural perturbations should be studied instead. As a system approaches critical points, an increase in autocorrelation arises. This increase in autocorrelation is caused because as systems become slower at recovering from small perturbations, the state of the system starts to resemble its past state more and more. Finally an increase in variance arises near tipping points because as systems become slower at recovering from small perturbations, the amplitude of the fluctuations in state increases.

In addition to temporal warning signs, Scheffer also spatial warning signs which are present in coupled systems. Scheffer mentioned that desert vegetation resembles a regular pattern before a transition to a barren state and the spin of atoms in ferromagnetic materials takes a pattern before a transition. Unfortunately these spatial warning signs are specific to each system and there is no "one size fits all" spatial early warning sign.

Scheffer introduced four warning signs of imminent tipping points in complex systems: slower recovery from perturbations, increased autocorrelation, increased variance, and specific spatial patterns arising.