Anticipating sudden transitions in biological populations

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Natural populations can shift suddenly in response to small changes in environmental conditions. Examples of such sudden transitions include the collapse of fisheries in response to over-fishing and disease outbreaks in response to falling vaccination rates. Given that these population transitions can have substantial economic and health implications, it would be valuable to obtain advance warning that such a "tipping point" is approaching. Theory from nonlinear dynamics argues that these tipping points should be associated with potentially universal changes in the dynamics of the system resulting from an increase in the time to recover from perturbations. We have used laboratory microbial ecosystems to study these proposed early warning signals of impending population collapse. Yeast cooperatively breakdown the sugar sucrose, meaning that below a critical size the population cannot sustain itself. We have demonstrated experimentally that changes in the fluctuations of the population size can serve as an early warning signal that the population is close to collapse [1]. In particular, we find that the population fluctuations become both larger and slower near a tipping point leading to collapse. In addition, we have demonstrated that in spatially extended populations it may be possible to use the emergence of spatial patterns to anticipate an impending collapse [2]. The cooperative nature of yeast growth on sucrose suggests that the population may be susceptible to cheater cells, which do not contribute to the public good and instead merely take advantage of the cooperative cells. We have confirmed this possibility experimentally and found that such social parasitism reduces the resilience of the population [3,4]. Finally, advance warning of collapse of this cooperator/cheater population must be obtained by measuring the coupled dynamics of the two sub-populations [5].

[1] Dai, Vorselen, Korolev, and Gore, *Science* (2012).
[2] Dai, Korolev, and Gore, *Nature* (2013).
[3] Gore, Youk, and van Oudenaarden, *Nature* (2009).
[4] Sanchez and Gore, *PLOS Biology* (2013).
[5] Chen, Sanchez, Dai, and Gore, *Nature Communications* (2014)