Summary of: The Value of Noise by Benjamin Blanz and Hermann Held

It is known that many ecosystems have the potential for catastrophic shifts[1] and will exhibit early warning signs before these critical transitions[2]. These early warning signs are the result of critical slowing down (CSD), which occurs as a bifurcation in the steady states of the system is approached[3]. The variance and first order auto regressive coefficient of time series, universally exhibiting known extreme behaviours near bifurcations, have successfully been used to identify CSD in natural and simulated systems[2,4–6]. However, all of these applications rely upon a large number of observations, relative to the characteristic time scale of the systems considered, which are typically not available in the context of marine ecosystems[7]. Furthermore, while generating early warning signals can be difficult, incorporating such information in management is no less challenging. Here we show how practically useful early warning information can be extracted from the noise component of realistically short time series and incorporated into existing management strategies aimed at preserving a sustainable amount of fish stock. For a setup realistic in the context of fisheries, we find that utilising the likelihood function of the autocorrelation coefficient combined with Bayesian updating can significantly reduce the degree of uncertainty about ecosystem growth. We further find that in combination with an existing precautionary probabilistic management strategy the additional information from early warning allows less strict harvesting quotas, while maintaining sustainable harvesting goals with regard to the expected time to a collapse event. Our results indicate that the common misconception that CSD early warning can only be used with long time series is due to an inefficient use of this information channel, not due to a deficiency of the information itself. Only when the existing decision making framework accounts for uncertainty, can the improvements in knowledge gained from CSD early warning be assimilated into management actions. Unfortunately, in many cases management does not account for the uncertain state of our knowledge about the ecosystem. Frequently, the non-linear dynamics of these systems, a prerequisite for the consideration of probabilities of catastrophic regime shifts, are not accounted for. This lack of consideration has led to management failure, resulting in collapsed fish stocks[8]. By explicitly incorporating non-linearity and uncertainty into model fitting it is possible to ensure that the likelihood of collapse remains below chosen safety levels. Hence, traditional model fitting fused with early warning information in the management cycle will improve management choices, either leading to higher economic gains or enhanced safety levels.

References

1. Scheffer, M., Carpenter, S., Foley, J. A., Folke, C. & Walker, B. Catastrophic shifts in ecosystems. *Nature* **413**, 591–596 (2001).
2. Drake, J. M. & Griffen, B. D. Early warning signals of extinction in deteriorating environments. *Nature* **467**, 456–459 (2010).
3. Scheffer, M. *Critical Transitions in Nature and Society*. (Princeton University Press, 2020).
4. Dakos, V. *et al.* Methods for Detecting Early Warnings of Critical Transitions in Time Series Illustrated Using Simulated Ecological Data. *PLOS ONE* **7**, e41010 (2012).
5. Lenton, T. M., Livina, V. N., Dakos, V., van Nes, E. H. & Scheffer, M. Early warning of climate tipping points from critical slowing down: comparing methods to improve robustness. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* **370**, 1185–1204 (2012).
6. Hennekam, R. *et al.* Early-Warning Signals for Marine Anoxic Events. *Geophysical Research Letters* **47**, e2020GL089183 (2020).
7. Lindegren, M. *et al.* Early Detection of Ecosystem Regime Shifts: A Multiple Method Evaluation for Management Application. *PLOS ONE* **7**, e38410 (2012).
8. Möllmann, C. *et al.* Tipping point realized in cod fishery. *Sci Rep* **11**, 14259 (2021).