Predicting system crashes in nature and society

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The world can deliver sudden and nasty shocks. Economies can crash, fisheries can collapse, and climates can pass tipping points. Providing early warning of such changes currently requires the collection of enormous and often prohibitive amounts of data. A new method developed by Steven Lade from the Max-Planck-Institute for the Physics of Complex Systems in Germany and Thilo Gross from the University of Bristol in the UK could change this. In a paper published in the open-access journal *PLoS Computational Biology* on February 2, the researchers present a mathematical methodology that uses easily obtainable information to greater effect and can therefore reduce the amount of additional data that needs to be collected.

The proposed method adds a new twist to an old idea. Predicting the behavior of simple systems is easy. However, systems at risk of severe transitions, such as fisheries and economies, are complex and intricate. To warn of critical transitions, scientists mostly use approaches that require close and continuous monitoring of the system under consideration. The present situation thus presents a fundamental dilemma: predicting transitions without a credible mathematical model requires large amounts of data, but building such a model entails gathering even larger amounts of information.

Len Fisher, author of Crashes, Crises, and Calamities explains the advantages to the new approach: "How can we improve our chances of seeing crashes coming? The number-crunching methods used by economists and others require massive amounts of data, and all too

frequently collapse under their own weight. In their new study, Thilo Gross and Steve Lade show how we can use traditional intuition and understanding in a surprising and mathematically rigorous new way to reduce the amount of data that we need, while actually enhancing our chances of 'seeing it coming'."

The key insight on which the new approach builds is that some bits of information are easier to obtain than others. For instance, in fisheries it is easier to find out which fish are eaten by a specific species of predator than to precisely quantify the relationship. The researchers have found a way to utilize this easily obtainable information without requiring information that is difficult to obtain.

In simulations of fisheries, Lade and Gross have demonstrated that their method can use available knowledge to reduce the need for stock monitoring data that is costly to collect. "Our approach combines the best of both worlds: we make use of specific knowledge that is available, while not requiring full knowledge of the system." says Dr Lade. "Our main contribution is how partial information is utilized," adds Dr Gross; "we don't try to build any single fully-fledged model. Instead, we use a mathematical trick to study all models in parallel that are not excluded by what we know."

Their model of fisheries is effective for predicting a simulated collapse, and the authors now plan to test the method with observational data, refine the approach and the ways in which expert knowledge is used, and develop the framework so that it can be applied to other systems.

More information: Lade SJ, Gross T (2012) Early Warning Signals for Critical Transitions: A Generalized Modeling Approach. *PLoS Comput Biol* 8(2): journal.pcbi.1002360. www.ploscompbiol.org/doi/pcbi1002360

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