Ecological complexity and the biosphere: The next 30 years

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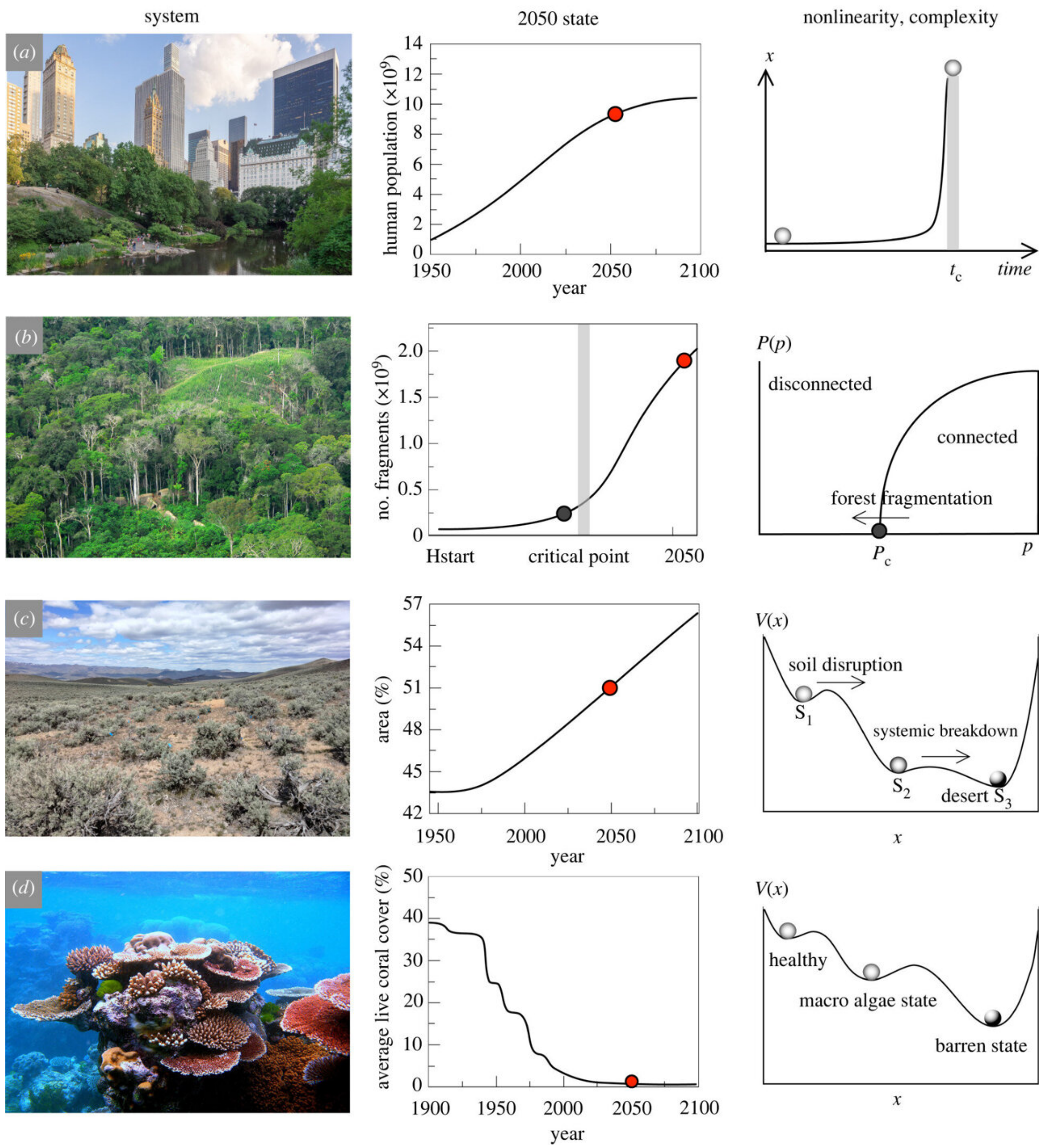

Ecological complexity challenges for 2050. With the rise of global temperatures, population growth and the resulting pressure on resources and habitats, biodiversity will face major threats. One crucial role of science is to develop reliable predictions of future trends. Here, four examples are chosen (left) along with current forecasts (central column, estimated 2050 states indicated with a red circle) and examples of the complex systems approaches used (right). (a) Urban centers (image of Central Park, New York, by Ajay Suresh, Creative Commons) are rapidly expanding as massive migrations occur towards cities. Human population growth (center) is slowly decelerating, but two extra billion humans will be added to the current numbers, reaching 9.7 billion by 2050. The current trend is a consequence of the nonlinearities associated with hyperbolic dynamics, which predicts a singularity at a given finite time tc (right). (b) Rainforests (left image by Gleilson Miranda, Creative Commons) are experiencing rapid loss and fragmentation of their habitats, with predicted critical points (center plot, gray bar, see [2]) to be reached in a few decades. These critical points correspond to percolation thresholds (right panel). (c) Drylands (image courtesy of David Huber) are expanding and will grow from the current 40% to more than 50% in just three decades. Models of drylands involving vegetation cover as a key variable predict sharp transitions between alternative states, connected through three different shifts [3]. Here two of them are indicated. (d) Marine ecosystems, and coral reefs (left image by Toby Hudson, Creative Commmons) in particular, are being affected by warming ocean temperatures, eutrophication, pathogens and overfishing. Reef cover is rapidly shrinking and might experience massive decays in the next decades. Here, the previous and predicted time series of coral reef cover in Hawaii is shown (center, data from https://19january2017snapshot.epa.gov/cira/climate-action-benefits-coral-reefs_.html). Multiple alternative states have been identified (right) with different sources of stress causing jumps from one state to another. Credit: *Philosophical Transactions of the Royal Society B: Biological Sciences* (2022). DOI: 10.1098/rstb.2021.0376

In 1972, the report Limits to Growth showed that business as usual on a planet with limited resources and a rapidly expanding human population can only end up in unsustainable growth and collapse. The report was inspired by systems science, a precursor to today's complexity science.

Now it's time to update that work using the tools developed over the last half-century, as SFI External Professor Ricard Solé (Universitat Pompeu Fabra) and Science Board member Simon Levin (Princeton University) write in the introduction to a special issue of *Philosophical Transactions* *of the Royal Society B*. The themed issue explores the role that complex-systems science will play in our understanding of the crucial changes facing Earth's biosphere in the next three decades.

We can now develop far more granular models, incorporating geographical variation, with scales ranging from soil-microbiome networks to plant-water interactions to coupled human–environment systems. And the development of complex-systems science allows us to better model tipping points, a key feature of climate change and environmental collapse, as well as potential intervention scenarios.

More information: Ricard Solé et al, Ecological complexity and the biosphere: the next 30 years, *Philosophical Transactions of the Royal Society B: Biological Sciences* (2022). DOI: 10.1098/rstb.2021.0376

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