Thresholds, cascades, and wicked problems

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Virginia Water cascades cc-by-sa/2.0 - © Peter S - geograph.org.uk/p/2330011

This article was first published on 26 October 2020 for Greenpeace International

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I remember thinking, in the 1970s, that once people became aware of the ecological crisis — disappearing species, polluted rivers, poisoned air — that the necessary changes would be simple to achieve. Humanity only had to curb industrial waste and destruction, preserve wilderness for other species, put limits on our consumption, stabilize human population, and just be smart about how to live on Earth without destroying it.

Of course, I was naive to think any of that would be easy. Since that time, human population has doubled, consumption of material resources has quadrupled, biodiversity collapse has accelerated, and after 34 international climate meetings, we are emitting more carbon than ever before. Meanwhile, we have not exactly ended war, vanquished racism, nor achieved gender or economic parity. Even worse, giant corporate interests actively work to halt and reverse any ecological regulation on industrial activity.

Our emotional responses to crisis evolved over millennia, primarily to meet immediate needs, perhaps to benefit our tribe or community, not necessarily to solve complex, multi-dimensional, long-term dilemmas. Our ideas about "solutions" tend to be linear, short-term, and linked to a perception of simple cause and effect. Our educational institutions encourage this linear thinking about problems and solutions. Meanwhile, our social and ecological challenges are systemic, multidimensional, and complex.

Living ecosystems are dynamic, always changing, and possess qualities such as thresholds, cascades, feedback loops, tipping points, lags, and generally unintended consequences to input. Maybe we need to learn more about how change actually occurs in nature, not just in our imaginations or in our engineering dissertations.

Complexity, chaos, and order

In a 1931 paper on the language of mathematics and physics, Polish linguist Alfred Korzybski wrote the now famous line, "A map is not the territory", acknowledging that all models, maps, and perceptions of the world are "reductions" of natural complexity. When we presume to design projects to "solve" ecological problems, we should keep in mind that living systems possess characteristics that may not feel intuitive to us.

Fifty years before Korzybski, French physicist Henri Poincaré noticed that multiple orbiting bodies travelled paths that were neither random nor entirely predictable. This appeared at the time as a paradox. In the 1920s, German physicist Werner Heisenberg demonstrated that the more precisely one determines the velocity of a particle, the less one knows about its position, a realization that came to be known as the "**uncertainty principle**."

Meanwhile, many naturalists observed that living systems — biomes, herds, flocks, organisms, societies — are never in fixed states, but always in process, what science historian James Gleick described as "becoming rather than being." Thus, arose what we now call "**chaos theory**."

Living systems exhibit both patterns and chaos, simultaneously, always changing, but change is neither continuous nor purely chaotic. Rather, change in **complex systems** appears to fluctuate among long periods of relative stability, punctuated by bursts of rapid change. These systems have no central control, and abrupt shifts can be triggered by a random input, such as an asteroid hitting Earth, or by an accumulation of small changes that reach a tipping point.

Complex systems respond to input, and those responses can become new inputs into the system. Cause and effect in this case are neither simple nor linear. When forests first grew on Earth, they sequestered carbon from the atmosphere, cooling the Earth, limiting forest growth, and altering the species of trees that flourished. As human carbon emissions heat Earth, we trigger feedbacks that both heat and cool the Earth. Some **feedbacks** self-regulate, some self-amplify. Events in such systems can stabilize or run out of control.

Nevertheless, not all effects are immediately observable; some are delayed by centuries. Long **lags** in the Earth system are difficult for human observers to notice in a single lifetime. Meanwhile, some effects build up slowly over time and eventually reach a biological or physical threshold, a **tipping point** at which point tiny changes can yield a large and sudden response.

In a society, in an ecosystem, and even in one's own body, the members or parts rely on each other. This **interdependence** may render diverse systems more stable than simple systems.

In addition to all of this, even **random** events can disrupt complex systems. The asteroid that hit Earth 65 million years ago was a random incident that had a huge influence on who perished (many large reptiles), who survived (our ancestor mammals), and who changed (small raptor reptiles became birds). Complex systems are vulnerable to random events.

Sometimes random events or tipping points will trigger other tipping points in a **cascade** of effects similar to a nuclear chain reaction. A cascade can cause a complete, irreversible state shift in a complex system and actually cause key **information** held within the system to be lost. Complex bio-physical systems collect and store information about their own patterns. Genetic codes, habits, instincts, and cook books are examples. If not protected, this information can be lost.

Human design and planning models are only beginning to glimpse how we might interact with these dynamic features of ecosystems and social systems, with, for example, flexibility and adaptive preparedness.

It's about the context

In response to some human/ecological dilemma, perhaps you've heard someone say, "If everyone would just _________ " (fill in the blank). Yes, we could solve so many problems if everyone would just … be nice to each other, be reasonable, rely on solar power, lose their ego, consume less stuff, and so forth.

Or perhaps you've read an engineering report about how we could — technically — scrub all the carbon from industrial exhaust, or build enough windmills to power the world, or solve the problem of human consumption by adopting vegan diets. Each one of these alleged solutions may contain some truth, but none of them tells the whole story. The natural world is not so simple. Corporate apologists also like to simplify our ecological dilemma, claiming ecological progress, while actively working against real solutions.

Urban design offers countless examples of engineering solutions gone wrong. During the last century, transportation designers responded to traffic congestion by building more roads, bigger roads, smoother roads, freeways, roundabouts, and so forth. This approach led to cities designed for cars and produced greater congestion. The engineering mindset failed to consider the deeper, systemic context.

Cars were a dubious idea in the first place, and the car culture was promoted by profiteers, not by a wise assessment of transportation options. In the 1930s, Standard Oil, General Motors, and Firestone Tire created a U.S. company, National City Lines, that bought public transportation systems and sabotaged them. They literally tore out light rail tracks and lobbied and bribed government officials around the world to build roads at public expense. Much of the world adopted a private car culture because that system benefited a few business elites, who wanted to increase profits. The engineering may have been brilliant, but the fundamental assumptions were wrong, or at least incomplete.

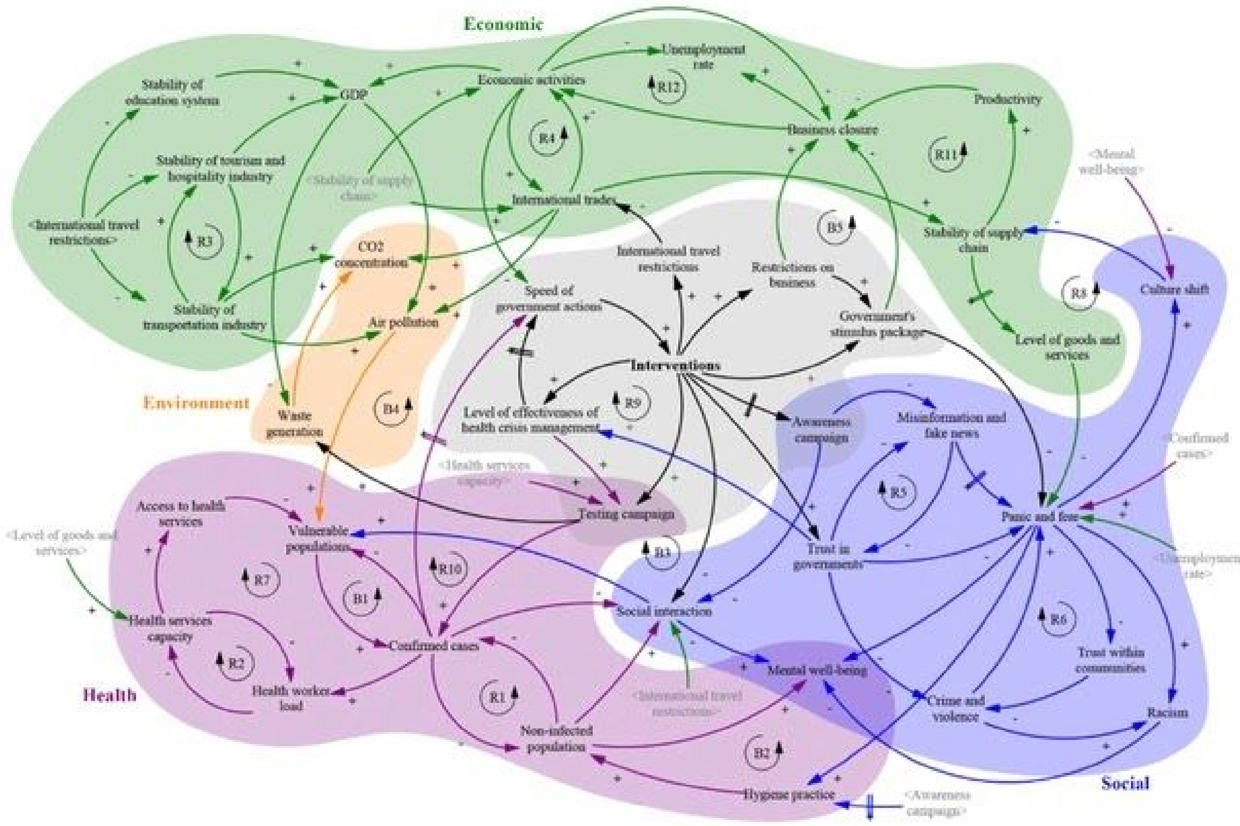
Our industrial food boom spawned similar failures of systemic context. Our inventive, so-called green revolution of food solutions produced a lot of food and made profits for large corporations, but depleted soil nutrients, spread toxins, severed mycelial networks, and disrupted nutrient cycles, creating eutrophic lakes and dead zones in our oceans. Oops! Maybe we should have thought that through better.

Thousands of years ago, ancient Taoists and Indigenous cultures appear to have understood the interacting, co-evolving qualities of living systems. Poets have long felt that reciprocity with wild nature. By the 1950s, certain researchers in western academic cultures began to grasp the challenges of human interaction with these large, complex living systems, giving rise to systems theory and ecology.

Wicked problems

In the 1970s, architectural design professor Horst Rittle, at the University of Stuttgart, described “wicked problems” that defied linear solutions, contained contradictions, and implied solutions that may create or aggravate other problems.

Today, we face many wicked problems, including social injustice, the Covid-19 pandemic, and the climate emergency. Each of these influences the others, making them all even more wicked. Earlier this year, engineer Oz Sahim, ecologist Shannon Rutherford and their colleagues at Griffith University in Australia created a “Causal Loop Diagram” to describe the “wicked complexity” of the Covid pandemic. The graphic representation provides a good impression of what a wicked problem looks like:



The wicked problem of Covid-19: The pandemic's complexity transcends health, environment, economy, and social boundaries. Any intervention triggers responses in those various fields. From Oz Sahin, Hengky Salim, Emiliya Suprun, Shannon Rutherford , et al., "Developing a Preliminary Causal Loop Diagram for Understanding the Wicked Complexity of the COVID-19 Pandemic," Griffith University, Australia Systems , May 2020.

The climate crisis presents another wicked problem, beset with social, political, ecological, economic, thermodynamic, and chemical complexity, involving lags, thresholds, and feedbacks. Here are just the most urgent tipping points that could cascade into a runaway state shift for the entire Earth:

Amazon rainforest dieback: Evaporation and transpiration move water between soil and atmosphere, creating clouds and generating about half of the Amazon's rainfall. Industrial logging and agriculture as well as global heating disrupt this process and shift the climate into a drier state that may not be able to support a rainforest.

Atlantic Ocean Circulation brings warm water north from the tropics. Ice melt from global heating dilutes salty seawater with freshwater, slowing the current, which could stop or reverse, and dramatically change the climate throughout Europe, Scandinavia, the Arctic, and elsewhere.

Monsoons in Africa and India bring essential rainfall to semi-arid regions. Warmer ocean temperatures have reduced the land-ocean temperature gradient, reinforced by slower vegetation growth, causing less evapo-transpiration of water to the atmosphere, and thus less rainfall, resulting in more drought, famine, and thousands of deaths.

Boreal forest shift: The conifer forests of Canada, Europe, and Asia, which sequester carbon, are already depleted by industrial logging. Studies in 2012 and 2014 reveal that warmer temperatures have increased fires and disease and allowed bud worms to move north, reducing these forests. Some declining boreal forests are now net carbon emission sources, rather than sequestering sinks, adding to the warming.

Melting Permafrost releases methane, a greenhouse gas. A total melt would triple Earth's atmospheric carbon content. A 2019 NOAA Report concluded that thawing permafrost may already be releasing "300-600m tonnes of carbon/year to the atmosphere."

Coral reef die-off: Warmer, more acidic oceans cause coral reefs to expel the algae that provide them with energy. Dying reefs eliminate habitat for a quarter of all marine fish species, which has a direct impact on over 500 million people worldwide, who rely on those fish for sustenance.

Melting Ice sheets in Antarctica, the Arctic, and Greenland are changing ocean currents and raising sea levels. A total melt of the most vulnerable ice sheets — West Antarctica and Greenland — would raise sea levels over ten meters, devastating every coastal city on Earth.

Albedo shift: Melting ice increases Earth's heat absorption (decreases reflectivity, or albedo), thus adding to the warming.

The Jet Stream, influenced by global temperature gradients, appears to be slowing, which can lead to extreme weather events, heatwaves, floods, and droughts.

All these effects influence each other, reduce biodiversity, and increase human health and economic impacts. This is the nature of multiple wicked problems among complex, interacting systems. We desperately need a social tipping point, a political tipping point, to help us overcome our outdated awareness of and response to these crises.

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