A conversation with Peter Morin, May 5, 2015

Participants

- Peter Morin, PhD – Professor, Department of Ecology, Evolution, and Natural Resources, Rutgers University
- Nick Beckstead, PhD – Research Analyst, Open Philanthropy Project

Note: These notes were compiled by the Open Philanthropy Project and give an overview of the major points made by Professor Morin.

Summary

The Open Philanthropy Project spoke with Peter Morin of Rutgers University as part of an investigation of potential risks to ecological systems to inform its work on global catastrophic risks. Conversation topics included an overview of ecological regime shifts, and examples of their potential causes and consequences.

Overview - Ecological regime shifts

Description

An ecological regime shift is a persistent, hard-to-reverse change in the structure and function of an ecosystem. Regime shifts range in magnitude from lake eutrophication to the collapse of the cod fishery in the North Atlantic, to an "invasional meltdown," in which introducing one invasive species into an environment can facilitate the invasion of other non-native invasive species.

Once the degradation of a system results in a regime shift, it can be difficult or impossible for the system to return to its original state. For example, as a result of eutrophication, some lakes and shallow impoundments have been taken over by harmful surface vegetation. Even significant efforts (e.g. adjusting nutrient levels or harvesting the vegetation) might be insufficient to return the aquatic ecosystem to its original state.

Units of analysis

An analysis of the risks and consequences of ecological regime shifts can focus on ecosystems (e.g. oceans, rainforests), on populations of species, or on inputs such as resources. Excessive amounts of certain resources can pose serious risks for ecosystems (e.g. disruption of the carbon cycle due to greenhouse gases, eutrophication caused by excess nitrogen and phosphorous).

A note on the relative importance of species extinctions

In an ecosystem comprised of many species, a system-wide regime shift would have a greater impact than the extinction of some of its species. Though some species are the products of billions of years of evolution, the roles played by certain species can be redundant and/or interchangeable (e.g. the role played by soy, corn, wheat, and rice crops in the production of biomass for human consumption). The complex relationships that make up an ecosystem are resilient enough to absorb minor shocks. Not every extinction will cause the loss of an ecosystem's properties or lead to a regime shift.

The scale of extinctions currently taking place is very different to that of the Permian extinction event, which eliminated 95% of life on earth (most likely due to an period of intense volcanism). Species that become extinct due to human activity tend to be rare ones, though there are some counterexamples (e.g. passenger pigeons). It would be difficult to drive more common species, such as the main aquatic and terrestrial primary producers, to extinction.

Network theory

Network theory can be used to assess the interdependence of an ecosystem's components, as well as its resilience to the loss of these components. The more highly connected the component, the greater impact its loss will have on the system.

Potential causes of ecological regime shifts

Reduced biodiversity

Humans have domesticated certain animal species for farming (e.g. honeybees) and expanded the use of monoculture (e.g. cultivating only a small number of banana genotypes). Because more diverse systems tend to be more resilient, these practices have increased the susceptibility of farmed animals and crops to disease.

Eutrophication of bodies of water

Fertilizer run-off containing nitrates and phosphates has caused eutrophication in lakes and oceans. Eutrophication can reduce biodiversity and increase toxicity levels in aquatic animals and plants.

Ocean acidification

Ocean acidification decreases the amount of carbonate ions available to organisms that depend on them to form shells (e.g. mollusks, coral, and some phytoplankton).

A reduction in the populations of these organisms could cause major changes to the ocean food web, which could also impact the availability of fish for human consumption. Ocean acidification could also impact the ocean's ability to adequately perform its role in biogeochemical cycles (e.g. carbon absorption in the carbon cycle).

Deforestation

Rainforest biomes play an important role in biological processes such as carbon cycling. For example, plant life is responsible for over 90% of the carbon uptake in tropical rainforests (animal life uptakes less than 10%). There are concerns about the rate of deforestation in some rainforests in Brazil (e.g. Amazonia) and South East Asia (e.g. Indonesia).

A significant amount of the rainforest rainfall is generated from the forest's own plant life through the process of transpiration. Deforested regions may therefore experience a decline in rainfall, which could cause a transition to a drier climate. Desertification would be unlikely, but a transition to a more savannah-like system might be a possibility. This type of regime shift might render the land unsuitable for agricultural use, though this outcome is highly uncertain.

The economies of these areas often depend heavily on resource extraction. Full-scale deforestation could have a significant negative impact on economic and social structures.

Introduction of invasive species

The intentional or unintentional introduction of a non-native species can have a significant negative impact on the flora and/or fauna of the new environment. Examples of invasive species that have been particularly destructive include:

- Asian chestnut trees
- Dutch elm disease
- Asian long-horned beetle
- Emerald ash borer
- Cats in Australia
- Mosquitoes carrying avian malaria in Hawaii

In the eastern U.S., Asian chestnut trees infected with Asian chestnut blight fungus killed much of the dominant canopy species. Cats in Australia have caused the loss of several native species. Mosquitoes carrying avian malaria caused the extinction of several native Hawaiian bird species. In general, we do not have a strong understanding of the impact of introducing species to a non-native environment.

Overfishing

Overfishing can deplete fish stocks. In some cases, the stocks might not fully recover. For example, overfishing of North Atlantic cod reduced stocks to very low levels and led to the collapse of cod fisheries. Despite a subsequent moratorium on cod fishing, the stocks and fisheries have not fully recovered.

Introduction of new harmful pathogens

Humans and other animals are susceptible to new forms of pathogens and infectious diseases (e.g. the Ebola virus, human immunodeficiency virus [HIV]). Land use changes and other factors have led to more frequent interactions between species (e.g. humans, pigs, and fruit bats in South East Asia), creating new pathways for cross-species pathogen transmission.

Potential future causes of ecological regime shifts

Disruption of the carbon cycle

Anthropogenic activity has increased the atmospheric concentrations of carbon dioxide and other greenhouse gases. Currently, the earth's biomes draw excess greenhouse gases from the atmosphere through processes such as the carbon cycle. Degradation of these buffers (e.g. through deforestation and ocean acidification) could affect the carbon cycle. Apart from human activity (such as burning fossil fuels), the role of animals in the carbon cycle is small in comparison with plants.

Gene drives

Multiple examples of non-native species invasions show that it is often impossible to predict the consequences of introducing species into a new environment. The effects of introducing species that have been substantially genetically altered with advanced bioengineering techniques are similarly unknown.

Bioengineering organisms with a significant fitness advantage

Speaking very hypothetically, if a primary producer, such as cyanobacteria, were bioengineered with phage resistance, that would likely result in a large increase in its population. Alternatively, some scientists are using bioengineering to develop "super" photosynthetic cells in order to help produce biofuel. Organisms engineered in this way could also potentially have a large fitness advantage.

Either development (phage-resistance or "super" photosynthetic cells) could result in eutrophication and "dead zones," and potentially have significant impact on ocean ecosystems. It is unclear how large this impact might be (e.g., whether it would be comparable to an invasive species, a very destructive invasive species, or significantly worse). Previous mass extinction events in the ocean were primarily caused by changes in the climate, extrinsic factors like a meteor impact, or intrinsic factors like volcanism (which some scientists believed played a role in the Permian mass extinction), which involve different dynamics from this hypothetical scenario.

Damage to soil bacteria

Soil bacteria play a key role in nutrient cycling and agriculture. They are very complex communities of organisms and can use multiple biochemical pathways to generate energy (e.g. some species can survive by consuming rocks). Due to their complex make-up and diversity, soil microbes would likely be resilient to changes in their environment. If there were a superviral pathogen that could attack many types of soil bacteria at once, it could have devastating consequences. However, that possibility seems unlikely to Prof. Morin.

Other people to talk to:

Ecological regime shifts

- Marten Scheffer – Professor of Aquatic Ecology and Water Quality Management, Wageningen University
- Stephen Carpenter – Stephen Alfred Forbes Professor of Zoology and Director of the Center for Limnology, University of Wisconsin
- Michael Pace – Professor and Chair, Department of Environmental Sciences, University of Virginia

Microbial diversity and bacterial evolution

- Richard Lenski – Hannah Distinguished Professor of Ecology and Evolution, Michigan State University
- Brendan Bohannan – Professor of Environmental Studies and Biology, University of Oregon

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http://www.givewell.org/conversations