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Thresholds and Environmental Change

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A *threshold* is usually defined by dictionaries as a beginning, or the plate of a door opening. An environmental threshold is often described as a *tipping point*. One of the most enduring metaphors describing a tipping point is "the straw that broke the camel's back": the camel was fine until one more, small unit of burden was added, and then the situation changed dramatically.

Think of bringing water to a boil. If we observe water in a vessel over heat, it just sits there still and calm until it suddenly changes to a boil— the threshold or "tipping point" where the water temperature exceeds the barometric pressure of the atmosphere that holds molecular activity of the water in check, and the water begins to change from a liquid to steam, or its gaseous state. Most of us know the temperature threshold of water boiling is 212 degrees Fahrenheit. Many people also know this temperature threshold changes with altitude. At higher elevations, the atmospheric (barometric) pressure is less, and water boils at a slightly lower temperature. Thus, environmental thresholds vary with the setting, and even small variations such as the boiling point of water can have big effects. (e.g., the "high elevation" directions we see on many packaged food products and baking recipes). Ignorance or failure to respond to thresholds may just result in pancakes better suited to throwing as frisbies, but it could also lead to fatal botulism if home-canned food is not boiled longer during processing at high elevations. Understanding natural thresholds and environmental consequences can be incidental or profound.

In the forest, and other natural environments, countless thresholds are involved in simple to complex relationships. Some of these have been studied and documented; the temperature thresholds of ignition for various fuel types on the forest floor, or the angle of repose and moisture content thresholds for landslides and avalanches. More complex thresholds are described with less precision for predator/prey complexes such as wolves and elk, or bark beetles and conifers. Some benign thresholds are called the "point of marginal returns" by economists, in that inputs have an effect up to a point, then adding more has no additional effect. This might be illustrated by some fertilizers, although an additional threshold of toxicity might operate at very high levels.

Discussions and dialogue about thresholds for carbon monoxide, ozone, temperature and other climatic factors related to climate change or "global warming" can be contentious. Often, people are confused when measurements of real change are very small. yet both scientists and non-scientists cite them as evidence of environmental change we are experiencing now or will be soon. Many people understandably scoff at the notion that a one or two degree change in average annual global temperature could melt polar icecaps, raise oceans, and flood coastal cities. A lot of the confusion may result from poor communication about how thresholds operate and which limits are being reached or exceeded and how they relate to both natural processes and human impacts. There is also confusion and continuing research about the reliability of these estimated and predicted changes.

Carbon dioxide, for instance, provides many threshold complexities. Just about everyone knows that we breathe in air including oxygen and breath out air containing an increased amount of carbon dioxide. Many people think plants actually breathe in carbon dioxide and breathe out oxygen. This is simply not true; plants respire just as we do. They do use carbon dioxide in photosynthesis, releasing off oxygen from the water they use in the process. By removing more carbon dioxide from the atmosphere than they release through respiration, plants

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can be a net carbon "sink" or storage mechanism. Thus, oxygen is limiting and has a threshold for respiration, and carbon dioxide is limiting and has a threshold for plant growth. There are many similar processes for respiration, also called oxidation, and these are the major factors in human-caused increases in the total carbon dioxide on our planet. Burning (fire), rusting, and decomposition are all oxidation processes that humans have a great impact on. The biggest culprit in increasing carbon dioxide concentrations (and contributing to global warming), is burning oil, gasoline, coal and other fossil fuels. The biggest counter to increased carbon dioxide is "sinking" carbon through plant growth which captures and stores carbon in plant material, releasing oxygen from the molecule, as described earlier.

The threshold of concern is the point where carbon (dioxide) increases faster than it is captured in plant growth. Rusting is the same process as burning, but contributes little to the global equation, but decomposition has the potential to contribute enormously if the highly-organic permafrost zones continue to warm, melt and decompose.

Most people know and accept that increased global carbon dioxide holds more of the earth's heat in and increases temperature. The argument seems to be whether carbon dioxide is really increasing, how much human activity contributes, and whether reducing carbon emissions can have a significant impact. Understanding the concept of thresholds can help us understand and accept substantial changes predicted based on small environmental changes.

Multiple thresholds of concern are being approached by real and potential/predicted climate change. Some of these have already been documented, such as melting glaciers and icecaps, thawing permafrost, ocean plankton die-off, etc. One current, dramatic event clearly associated with a climatic threshold is the vast outbreak of mountain pine beetle killing lodgepole pine in British Columbia, covering millions of acres with nearly all of these pines dead or expected to die within the next few years. Historically, the average winter low temperatures were below the threshold for beetle survival, otherwise many of these, otherwise susceptible monoculture, old and over-dense forests would have succumbed to beetles long ago. The entire forest management regime in these areas must change in response to this new threat, including dramatic changes in deciding which tree species to favor, and in the wildlife habitat and economic systems that depended on the traditional forest. This is just one example of how many things we know about forest management (and food and other agricultural crops) can be dramatically challenged by climate change, whether it be increasing global warming as forecast, or just in dealing with changes in climate thresholds that are already soundly documented.

Other climatic threshold effects may be predicted by using our knowledge of habitat or other environmental thresholds for various species. For example, should current climatic trends continue, polar bears will approach extinction, and western larch and Engelmann spruce may disappear from our western landscape. Some of the many predictions being made will unfold as projected and some will not. Two problems hinder our ability to make a sensible scientific approach predicting climate change and its effects, and providing an informative, effective public education effort, especially through the media. We either lack scientific information on the thresholds for many relationships (and I have seen many cause-effect relationships that operate on a threshold versus a gradual basis) or we know the thresholds (e.g.: minimum annual precipitation on south slopes for ponderosa pine), but don't know how much change there will be.

In the case of public information, the impacts and challenges of dealing with the social, political, and economic impacts of climate change are so enormous and challenging. The subjects of the oceans rising, and agricultural zones shifting into desert, for example, are so interesting and subject to sensationalism, that it will take a long time, and the reality of a few disasters, I fear, for any large-scale policy to take effect. But as forest scientists, educators, managers and owners we are particularly challenged NOW to make as much sense as we can of the data available, seeking to understand and plan for change, because the decisions we make today will be with us for decades, or perhaps centuries.

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