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Excerpt
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Introduction: Balance and flux

> Apart from the hostile influence of man, the organic and the inorganic world are . . . bound together by such mutual relations and adaptations as secure, if not the absolute permanence and equilibrium of both, a long continuance of the established conditions of each at any given time and place, or at least, a very slow and gradual succession of changes in those conditions. But man is everywhere a disturbing agent. Wherever he plants his foot, the harmonies of nature are turned to discords. The proportions and accommodations which insured the stability of existing arrangements are overthrown.
>
> (Marsh 1874:34)

This statement, by George Perkins Marsh – a nineteenth-century American diplomat, conservationist, and writer – expresses a concept that can be traced in western thought as far back as ancient Greece: the idea that nature in the absence of human intervention is in a state of balance which changes little over long periods of time. In the nineteenth century, this view became a credo for the young science of ecology.

The concept of balance figures so prominently in discussions about natural resource management that it is worth looking at in more detail. In scientific formulations, balance – or equilibrium – is defined as a state in which there is no net change in a system. For example, in a chemical reaction, substances A and B might join to form compound AB, but AB also breaks down to form A and B. This is denoted by arrows going in two directions:

$$A + B \rightleftharpoons AB$$

The amounts of reagents on the two sides of the equation do not have to be equal, they just have to be stable. In the example above, equilibrium occurs when most of the system consists of compounds A and B. This is indicated by a longer arrow going to the left, and we say the equilibrium is to the left. If equilibrium occurs when most of the system is in the form of compound AB, we say the equilibrium is to the right; this is indicated by a long arrow pointing to the right. Either system is in equilibrium. Notice that change continues (A and B combine to form AB, and AB breaks down to form A and B). The important point is that there is no *net* change in the composition of the system; at equilibrium the ratios of AB to A and B do not change.

A similar type of equilibrium can occur in natural communities, if the composition of a system is stable. For example, suppose that 55% of a forest is old growth. From time to time, fires burn some patches of the old-growth forest, converting them to open fields. At the same time, however, young forests are getting older. Eventually they become old growth. If the rate at which old-growth forest is created equals the rate at which it is destroyed, the amount of old-growth forest will remain constant, like compound AB in the chemical equation, and the forest as a whole can be said to be in a state of equilibrium.

The idea of equilibrium is closely connected with the idea of self-regulation. This is an important concept for resource managers, because many ecological processes are considered self-regulating. If a self-regulated system is truly at equilibrium and something happens to cause it to deviate from that equilibrium, then we would expect to see a compensatory change that moves the system back to its equilibrium state. A thermostat is a familiar example. If a room's temperature is regulated by a thermostat set at 20 °C, then the thermostat should cause the heater to shut off when the room becomes warmer than 20 °C. When the heater is shut off and heat production ceases, heat loss exceeds production and the room's temperature falls, restoring the temperature after a while to 20 °C. With the heater off, the room continues to cool, until its temperature drops so far below 20 °C that the thermostat causes the heater to turn on again, thereby initiating a compensatory production of heat designed to return the room's temperature to 20 °C (Figure I.1). (Thermostats vary in the precision with which they do this. A very sensitive thermostat will turn off the heater when room temperature rises just slightly above 20 °C; a less sensitive thermostat will not respond until the temperature rises several degrees. But regardless of whether temperature fluctuates a lot or a little, the thermostat maintains temperature near a set level.) This type of regulation, in which change in a variable in one direction sets in motion a compensatory change that causes the value of the variable to change in the opposite direction, thereby tending to return it to its original level, is termed negative feedback.

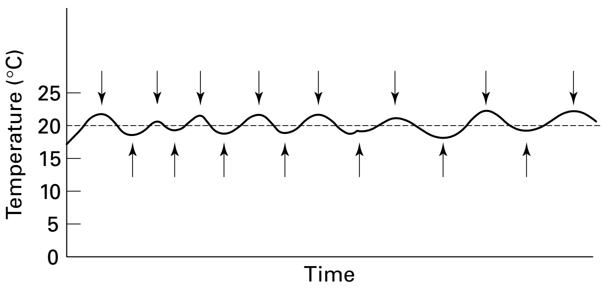

Figure I.1. A thermostat is a device that regulates temperature at a set point. In this example, the set point is 20 °C. Arrows pointing down indicate points at which the thermostat turns the heater off. Arrows pointing up indicate points at which the thermostat switches the heater back on.

It is easy to conceive of a population that is regulated at a set level, or carrying capacity, in this way. If such a population increases above carrying capacity, then there will be a decrease in reproduction and/or an increase in mortality until the population declines. If it drops below carrying capacity, then reproduction will increase or mortality will decrease, or both, allowing the population to grow until it reaches carrying capacity. If there is not a long time-lag between the changes in population size and compensatory adjustments, then this hypothetical population will remain fairly stable.

Until very recently, the prevailing scientific theories about populations and communities hinged on the idea of balance or equilibrium. George Perkins Marsh's idea of a harmoniously balanced natural world that people perturb permeates much scientific and popular writing about the nonhuman world. In this view, the nonhuman world is like a pendulum, characterized by a tendency to return predictably to its starting-point. Ecologists grounded in equilibrium theories focus their attention on populations that are in equilibrium with their resource base (Chapter 2), plant communities that return to an equilibrium or climax state after they are disturbed (Chapter 3), and species assemblages in which rates of extinction and colonization are in balance (Chapter 8). From this perspective, the activities of people are outside of and disturbing to the balanced natural world. We will see in Chapter 12, however, that scientists are now questioning the idea that most of the natural world is in a state of equilibrium most of the time. The idea that people should consider themselves outside of nature has also been called into question, for a variety of reasons.

The idea that the natural world without people is in a balanced state can lead to two quite different strategies for management. Either we can leave it alone and protect it (a preservationist approach), or we can take a utilitarian approach, manipulating it. In the words of ecologist Daniel Botkin, if nature is like a watch, we can "appreciate the beauty of the watch" or we can "attempt to take the watch apart and improve it" (Botkin 1990:156). The examples below, from North America and Africa, illustrate these two approaches.

Historically, American resource managers have tended to fall into one of two groups: utilitarian managers, who strive to maximize the amount of economically valuable products obtained from the natural world, and preservationist managers, who seek to preserve a substantial fraction of the natural world by protecting it from human use. In reality, these are two extremes on a continuum; most people's views fall somewhere in the middle, but some managers are much closer to the use end, while others are closer to the preservation end.

In North America, the roots of this controversy go back over 100 years. The controversy over the building of Hetch Hetchy dam in the scenic Yosemite Valley was one of the first of many conflicts in North America between those who want to preserve resources and those who want to use them for the benefit of people. The Yosemite Valley was set aside for public use by President Lincoln in 1864. Until 1890, when it became a national park, it was administered by the state of California. In 1901, San Francisco city officials proposed damming the Tuolumne River in the park to provide power and water for the residents of San Francisco. A bitter and emotional controversy ensued.

John Muir, champion of wilderness and founder of the Sierra Club, argued that the sublimely beautiful canyon should be left in its natural state for people to appreciate. He described the falls as "harmonious and self-controlled," "without a trace of disorder" (Muir 1912:251–252), and compared the inundation of the canyon to the destruction of the garden of Eden:

> Our magnificent National parks . . . Nature's sublime wonderlands . . . have always been subject to attack by despoiling gainseekers and mischief-makers of every degree from Satan to Senators. . . . Thus long ago a few enterprising merchants utilized the Jerusalem temple as a place of business instead of a place of prayer . . .; and earlier still the first forest reservation, including only one tree, was likewise despoiled.
>
> Their arguments are curiously like those of the devil, devised for the destruction of the first garden – so much of the very best Eden fruit going to waste; so much of the best Tuolumne water and Tuolumne scenery going to waste. (Muir 1912:256,257,260)

The dam's proponents believed the energy of the water going over the falls was wasted and should be harnessed for the benefit of people. They argued that controlling the machinery of nature would enhance, not degrade, the value of the canyon. This viewpoint was summed up by Representative Ferris of Oklahoma, Chair of the House Public Lands Committee:

> These patriotic earnest men believe it is a crime to clip a twig, turn over a rock or in any way interfere with Nature's task. I should be grieved if I thought practicality should completely drive out of me my love of nature in its crude form, but when it comes to weighing the highest conservation, on the one hand, of water for domestic use against the preservation of a rocky, craggy canyon, allowing 200,000 gallons of water daily to run idly to the sea, doing no one any good, there is nothing that will appeal to the thoughtful brain of a commonsense, practical man. (Quoted in Ise 1961:92)

The argument that people are entitled to use nature's resources was put even more emphatically by Representative Martin Dies of Texas, who stated "God Almighty has located the resources of this country in such a form as that His children will not use them in disproportion," and implied that to utilize them was to follow "the laws of God Almighty" (quoted in Ise 1961:92).

In 1913 Congress passed a bill authorizing the project, and the valley was dammed.

These two views of our relationship to nature might seem to be light years apart, but they have a lot in common. They are grounded in the same world view – the idea that people are separate from a natural world that tends toward a stable equilibrium. In one case people are superior to nature and entitled to manipulate it, dominate it, control it, use it, and improve upon it; in the other the natural world is pure and good, while people are morally tainted but long to be reunited with nature. In either case, we are outside of that which is in balance without us; humanity is either better than or worse than the non-human world. The primary difference between the two viewpoints is that utilitarian managers see themselves as manipulators of nature, while preservationists see themselves as nature's protectors.

The dam's proponents were utilitarian in their approach to resource management; they advocated the utilization of economically valuable natural resources. The dam's opponents took a preservationist stance; they argued that conservation should involve the protection of natural places from exploitation by people. These two positions exemplify two approaches to the management of resources.

It might at first seem odd that those who wished to dominate nature accepted the view that nature is in balance and people are outside of that balanced world. Yet if we return to the writings of George Perkins Marsh, who so clearly articulated the idea that nature is in balance, it becomes evident that this perspective is quite compatible with the idea that people are separate from nature and entitled to manipulate it. In Marsh's view, humanity was "of more exalted parentage" than "physical nature" and belonged "to a higher order of existence" (Marsh 1874:34). Consequently,

> man [and domesticated animals and plants] . . . cannot subsist and rise to the full development of their higher properties, unless brute and unconscious nature be effectually combated, and, in a great degree, vanquished by human art. Hence, a certain measure of transformation of terrestrial surface, of suppression of natural, and stimulation of artificially modified productivity becomes necessary. (Marsh 1874:37)

Marsh felt that by changing nature, people had "effected . . . changes which . . . resemble the exercise of a creative power" (Marsh 1874:10,37). Although Marsh argued that civilization had gone too far in transforming the natural world, he saw no contradiction between the idea that nature is harmonious and the idea that people should manipulate nature's harmonies.

If we turn our attention outside North America, we can again find examples of utilitarian and preservationist management plans that are rooted in the balance-of-nature perspective. Kenya's Tsavo National Park was set aside as a preserve by colonial authorities in 1948. At the time of its creation, most of the park was densely vegetated with trees, and the premier attraction was its elephant and rhinoceros populations (Sheldrick 1973). When the park was formed, people who had lived in the area were evicted and prevented from using the land for hunting or grazing. Wildlife viewing became the only permitted land use.

Throughout most of the park's history, managers took a hands-off, let-nature-take-its-course approach, with the expectation that the park would continue to support trees, elephants, and rhinos. By the late 1950s, however, it had become clear that elephants were destroying the trees and preventing their regeneration, and widespread elephant mortality seemed imminent because of this habitat degradation. Wildlife researcher Ian Parker reported that "many visitors who saw the ravaged woodlands were appalled. The acres of dead and battered wood were likened repeatedly to the Somme battlefields of the First World War" (Parker and Amin 1983:71).

The park's management argued that such die-offs were part of a natural cycle, and they continued to follow a strategy of minimum intervention. Things got worse instead of better, however. The effects of habitat alteration were compounded by severe droughts in the 1960s and early 1970s, and as a result thousands of rhinos and elephants died (Sheldrick 1973). By 1973, grassy areas had replaced woody vegetation throughout the park. Elephants, rhinoceroses, and other wildlife species associated with trees had declined, whereas populations of grazing species such as zebras and gazelles had increased markedly. Ironically, the policy of eliminating people and letting nature take its course led to a dramatic alteration in the landscape and its wildlife, instead of perpetuating a stable community as managers had envisioned (Botkin 1990; Rogers 1999).

In South Africa's Krueger National Park, managers pursued a different strategy of preserve management. In a decidedly hands-on program, they intervened to control the balance of nature by culling lions, elephants, and ungulates; constructing deep wells and dams; burning vegetation; and controlling diseases. These actions were designed to maintain the habitats and species that were prevalent at the time the park was created. In other words, a highly manipulative management style was used to keep a "natural" area in a particular state. The connection between equilibrium thinking and this type of management is less obvious than in the Tsavo example, but it is equally strong. In fact, the balance-of-nature viewpoint was explicitly accepted in the proclamation setting aside the area in 1898 (Rogers 1999).

Tsavo and Krueger were managed in strikingly different ways, yet both these strategies are grounded in the idea that nature tends toward balance and stability. If both hands-on and hands-off management are rooted in the equilibrium viewpoint, one might ask if any other alternative is possible. But if we stop assuming that nature tends to be in balance, new possibilities emerge.

As a result of several high-profile controversies about resource management, most people are aware of the tension between preservationist and utilitarian approaches to resource management, even if they do not use those terms to describe the situation. Unfortunately, the popular media have presented the debate as if these were the only two alternatives, posing questions like: Do we want owls or jobs? In reality, this is not a helpful dichotomy. There is a third approach.

The third approach, which I call the sustainable-ecosystem approach, seeks to integrate resource preservation and use. Instead of focusing on products or preserves, this approach focuses on conserving the processes that sustain healthy ecosystems. It is grounded in a different view of nature, which is sometimes termed the flux-of-nature viewpoint. From this perspective, natural systems are often in a state of flux and people are an integral part of that flux.

In Chapter 1, we will see how unregulated exploitation set the stage for the development of utilitarian management of natural resources. First, however, let us consider how we use information to manage living natural resources.

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Methodology: Getting the information we need to manage living natural resources

The scientific method

Resource managers need scientific information on which to base their decisions about conservation. The scientific method is a mode of inquiry in which testable propositions, termed hypotheses, are formulated and information is gathered to test them. The investigator makes predictions about what will happen under certain circumstances if a particular hypothesis is true and then determines whether or not those predictions are fulfilled. If the predictions are not fulfilled, the hypothesis is falsified.

Controlled experiments

There are many ways to test hypotheses. One is through a controlled experiment, in which a scientist compares a test group with a control group. Controlled experiments are not the only way to do science, however. The real world is more complex than the laboratory. It does not always lend itself to and sometimes it cannot tolerate experimental manipulation. I will return to this point below, but first, let us consider how controlled experiments can be used to provide the sorts of information resource managers need.

The process of hypothesis testing must begin, obviously, with the formulation of a hypothesis. The more we know about our subject, the more likely we are to come up with a plausible hypothesis. Reading what others have reported can help, but there is no substitute for the insight which comes from having observed the experimental system and becoming thoroughly familiar with it. This is one place where intuition plays an important role in scientific inquiry. Barbara McClintock, who made the revolutionary discovery of transposable genetic elements – or "jumping genes" – in maize, says that it is essential to have "a feeling for the organism," to understand "how it grows, understand its parts, understand when something is going wrong with it" (Keller 1983:198).

Suppose you are conducting research on the nutritional requirements of white-tailed deer, and you want to find out whether the amount of weight the deer gain depends upon dietary protein. You might begin by reading the accounts of some early naturalists. If you found a description written by a nineteenth-century rancher stating that mule deer at a particular site with "high-quality forage" (food plants) were in good physical condition, would that prove that protein is what controls weight gain in white-tailed deer? Not really, for several reasons. First, the rancher's observations pertain to mule deer, not white-tailed deer. Second, the observer presented no data on either weight gains among deer or what exactly was meant by "high-quality forage." Third, you have no way of checking the accuracy of this reported observation. Fourth, there is no indication of the sample size represented by this observation, so even if events were recorded accurately, the weight difference might just be a fluke stemming from something unusual about those particular individuals, or the difference might be so slight that it really is not meaningful. Fifth, you have only this one "study" on which to base your conclusions.

Although this type of anecdotal account cannot provide conclusive evidence, it can nevertheless suggest areas of fruitful inquiry. The hypothetical description referred to above would suggest that there *might* be a relationship between food quality (and, perhaps, protein content) and weight gain in mule deer (and, perhaps, in white-tailed deer as well). So you decide to design a controlled experiment to find out if this is the case.

You should begin by stating a hypothesis. In order to facilitate statistical analyses of your results (see below), your hypothesis should be framed as a statement of no difference, which is termed a null hypothesis. This is the proper procedure even if you think there will be a difference. If your intuition is correct and there is a difference, then the hypothesis of no difference will be falsified. This could be stated as the following hypothesis: *The amount of protein in the diet of white-tailed deer has no effect on weight gain.*

To do a controlled experiment, you compare one or more groups that receive a particular treatment to a control, a group that does not receive the treatment. If you have two similar groups of deer, you could weigh the deer in each group and then feed a high-protein diet (Diet A) to one group (Group A) and a diet with normal levels of protein (Diet B) to the other (Group B)