WATER AND ECOSYSTEM CHARACTER

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Contents

Summary

There is a reciprocal dependence between water quality and quantity in a given area, and the character of the local ecosystem. Water works as the elemental driver of an ecosystem function, influencing its character by means of antagonistic processes of landscape remodeling (morphogenesis) on the one hand, and soil formation (pedogenesis) on the other. These processes acting concurrently determine the intensity and direction of ecodynamics, the basic mechanism by which the character of ecosystems change, its tendency toward stabilization and increasing complexity, or its progressive erosion and degradation. The ecological succession of vegetation toward a climax mediate ecodynamics by providing soil cover and protection against morphogenesis, contributing to the ecosystems capability to accumulate water, and improve its quality. Through a series of examples of the interrelationship between ecosystems' character, as determined both by natural processes or by human management, and the quantity and quality of the waters produced within, the present text discusses the need for nature conservation and environmental management practices to warrant the sustainability of life support systems.

1. Introduction

Exceptional weather patterns were brought about on the Americas during the spring of 1998, driven by a particularly prevalent Pacific Ocean warm-up known as El Niño. While an ensuing drought caused the Amazon River level to lower and move away from the waterworks inlet near Manaus (Brazil), making it necessary to relocate the pump inward the riverbed; unusually copious precipitation caused the volcanic soil of the desert near Tucson (USA) to erupt in wildflowers, in the most dazzling blooms of the century. Such exceptional events are normally triggered by the combination of many environmental factors, and sure enough El Niño influences temperatures, wind direction and strength, and water availability in vast geographical areas. However, of all environmental factors involved in ecosystems' dynamics, water is the elemental driver, the linking substance that, on the one hand, dissipates excess energy, remodeling the landscape; and on the other, carries essential nutrients, replenishing the pools of growth factors for life development.

Water drives ecosystems' dynamics by means of two-way interactions: a) water quality and quantity determining the character of an ecosystem, that is, its diversity, richness, evenness, resilience and evolution toward the climax; and b) an ecosystem's structure and function determining the quality and quantity of the water produced within. The present text explores both these aspects, discussing how water permeates the interactions taking place during ecological succession, the consequent character imprinted on the ecosystems, and the environmental impacts brought about by human activities, especially the chemical contamination of water and the degradation of the global environment.

2. Water is the linking substance for all ecosystems on Earth

A classical long term ecological study designed to test the capacity of whole ecosystems to adjust to vegetation manipulation has been carried out since the 1970s at Hubbard Brook Experimental Forest in New Hampshire (USA). The locally replicated series of experiments were planned to determine the effects of changes in ecosystems' character on 1) the *quantity* of stream water flowing out of the watershed, and 2) fundamental chemical (i.e., water *quality* parameters) relationships within the ecosystem. The most drastic manipulation involved clearing of all vegetation in a watershed, and keeping it in check by herbicide treatment while monitoring water quality and quantity parameters.

A primary finding of the study is that one aspect of the homeostatic character of the ecosystem, i.e., maintenance of nutrient capital, is dependent upon the undisturbed functioning of the nutrient cycle, and that after destruction of the vegetation no mechanism acts to greatly delay loss of nutrients. Other principal results show that even though water flowing out of the watershed appeared as clear and potable as that from undisturbed watersheds, this was not the case. Regarding water quantity (1), annual runoff increased up to 39 percent after cutting of the vegetation, while summertime runoff increased up to 414 percent. This greater proportional summertime streamflow implies that removal of transpiring leaf surface removal must be accountable for most of the water retention capacity loss, but the increased annual runoff indicates that water retention and conservation mechanisms in the watershed were also impaired. Regarding water quality (2) nitrate concentration in stream water exceeded (at times almost doubled) the concentration recommended for drinking water (calcium, magnesium, potassium, and many other essential nutrients losses were also greatly increased). It may be concluded that unless the complex ecological interrelationships mediated by water in ecosystems are well understood, naive management practices can result in unexpected, and possibly widespread deleterious effects.

The role of water as the elemental driver for ecosystem's dynamics encompasses broad scales. In this section, case studies evidence the interdependence between water quality and quantity, and the character of ecosystems at the continental, regional, and local levels.

2.1 Water quality and quantity determining the character of ecosystems

2.1.1 Continental scale: Eurasia freeze down in the greenhouse

Global warming could shut down an ocean current that warms the higher latitudes of Europe, causing most of Scandinavia to plunge into a freeze while the Earth turns warmer. However cold by most standards, northern Eurasia climate can be considered surprisingly pleasant as regarded by geographical location. This is a result of the enormous amounts of heat swept into the North Atlantic by the warm waters originating in equatorial latitudes and pumped by the globe-girdling current dubbed Conveyor Belt. The conveyor is driven by the evaporation of surface warm water, that boosts its saltiness enough to result in a density gradient, causing it to sink. The saltier and cooler deep water flows southward, completing the conveyor belt loop. As the climate warms up due to atmospheric greenhouse gas accumulation, freshwater from melting Arctic glaciers may dilute the saltier superficial waters of the North Atlantic, eliminating the extra density that drives the conveyor, and consequently the heat pump to Northern Eurasia, causing it to freeze down.

This example shows how alteration of water characteristics resulting from large scale changes in the global environment can affect the overall character of ecosystems at a grand, continental scale. In the following example, choices of land management practices influence water quality and quantity at the regional scale represented by a large interior sea.

2.1.2 Regional scale: the Aral Sea demise

For decades, billions of liters of water from the Amu Darya and the Syr Darya – the two tributaries of the once fourth largest freshwater lake in the world, the Aral Sea – have been diverted toward cotton fields extending the surrounding deserts in central Asia. Over the last four decades the Aral Sea has lost 80 percent of its volume, exposing 36,000 square kilometers of seabed lined with toxic agrochemicals accumulated from cotton field runoff, clogging the irrigated soils with as much as 700 tons of salt per hectare, and tainting the groundwater supplies. Relentless winds sweep the area, blowing clouds of toxic dust onto the neighboring villages, imposing the world's highest rates of respiratory diseases. What is now left of the Aral Sea's water is saltier than the ocean, and none of the native fish species has survived. A decade or so will still elapse before the Aral Sea breaks up into three small lakes, and disappears as an ecosystem.

The diversion of large volumes of water, and its contamination through lavish management, exemplified above, can determine the ultimate alteration of an entire ecosystem’s character, from a freshwater lake teeming with endemic life, to a chain of dying salt water bodies enclosed by contaminated wastelands. There is no need for such profound alterations for an ecosystem to shift in character. Impoundment, for instance, preserves and regulates the volume of water flow, and causes only minor alterations in water quality (often for the better), but may as well result in significant environmental impacts, as shown below.

2.1.3 Local scale: tearing down Snake River dams to save salmon runs

Schools of now endangered Chinook salmon used to leave ocean and swim up Snake River to spawn, until a triad of dams barred the runs in exchange for hydroelectric energy for the booming American Pacific Northwest in the 1970s. Hoping to help escape extinction, hundreds of millions of dollars have been spent on capturing smolts and trucking or barging them downstream where the fish have an unfettered run to the Pacific. Less than one-half percent survive to return to their spawning grounds a few years later, and it seems that unless something in done soon, most of the remaining runs will go extinct, shutting down prospects for a growing business, the tourist rush – not to mention the blow to the Endangered Species Act. The solution of choice now being considered by government agencies is a drastic one indeed, to tear down the Snake River dams, and let the ecosystem recover its original character.

This example shows how resource choices at a local scale, and at a definite time (hydroelectric energy, for instance), can end up affecting other valuable resources (fisheries and biodiversity). Salmon and biodiversity may be more valuable to society as a whole, at the present time, than megawatts. Additionally, it shows that water is ultimately implicated in most human interventions on ecosystems, and that water conservation must be a priority in all environmental impact assessments of development projects.

2.2 Ecosystem character determining water quality and quantity

2.2.1 Continental scale: giant Antarctic ice sheet collapse and coastal lands flooding

The geologic history of the Earth is dotted with extraordinary events of a global reach, as a result of the interconnectedness of all ecosystems afforded by water. One such event, known to have occurred before, now shows clear prospects of rebounding, the accelerated collapse of the giant West Antarctic Ice Sheet (WAIS), and the ensuing flooding of all low-lying coastlands on earth. The kilometer thick WAIS is the world’s only ice sheet that is grounded well below sea level at its margins, making it susceptible to collapse. Sediment cores recently drawn from beneath the ice sheet (ice thickness about 1030 m, sediment about 600 m below sea level, some 700 km inland from the open sea) show the presence of diatom species and minerals (cosmogenic ^{10}Be) typically found only in open waters, unmistakably pointing out that sediment deposition occurred in the absence of ice cover. This happened during the penultimate interglacial period around 123,000 years ago, at a time not much warmer than today, but characterized by differently shaped continents, and higher sea levels. What worries glaciologists is that it seems that even a slight warm up of the Antarctic climate may prone the ice grounding line – where it begins to float off the bottom - to retreat toward thicker ice. The thicker the ice the faster it flows outward and therefore the faster it thins. The faster it thins, the sooner it floats and moves the grounding line farther inward, in a hastening process that may consume WAIS in a single century, and result in sea level rise of up to six meters worldwide.

This example indicates that a subtle shift in one attribute of an ecosystem, namely a few degrees rise in temperature in the Antarctic continent, may cause a cascade of changes that produce enormous increase in the quantity of liquid water, changing the character of all coastlands on a global scale. There are also examples, as the one described below, in which the character of regional ecosystems, as effected by human management practices, affect the quality of the runoff waters, threatening faraway unrelated ecosystems.

2.2.2 Regional scale: Great Plains agriculture suffocating the Gulf of Mexico

A huge swath of nearly lifeless ocean has been expanding from the Louisiana coast, spreading about 16,000 square kilometers into Texas waters in the Gulf of Mexico. One of some fifty large oxygen-deprived coastal regions in the world, this popularly called death zone is a creature of the Mississippi River, a consequence of millions of tons of fertilizers washed from farm fields across the Great Plains and spilled into the Gulf of Mexico. Nourished by this fertile broth massive algae blooms thrive near the surface, fueling the plankton food web. As all derived organic matter sinks to the bottom it is consumed by oxygen-absorbing bacteria, leading to hypoxia. When oxygen levels fall below 2 milligrams per liter most marine life succumbs, and anoxia ensues when the bacteria use up the remaining oxygen, suffocating even themselves.

Only by altering the agricultural practices across millions of hectares, thousands of kilometers upriver, could the water quality flowing downstream the Mississippi be improved, and the death zone be revived. The economic and social benefits that would be rendered to Louisiana coastal residents by such a revitalization would actually be just an additional gain – the real profit would be harnessed by Great Plains farmers themselves, as their agricultural operations would become more efficient. Bettering agricultural practices in general is mandatory to improve environmental conditions at the local scale as well, as pictured below.

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