The Watershed Wisdom of the Beaver

You know what a stream looks like. It has a pair of steep banks that have been scoured by shifting currents, exposing streaks and lenses of rock and old sediment. At the bottom of this gully—ten to fifty feet down—the water rushes past and you can hear the click of tumbling rocks as they are jostled downstream. The swift waters etch soil from first one bank, then the other as the stream twists restlessly in its bed. In flood season, the water runs fast and brown with a burden of soil carried ceaselessly from headwaters to the sea. At flood, instead of the soft click of rocks, you can hear the crack and thump of great boulders being hauled oceanward. In the dryness of late summer, however, a stream is an algae-choked trickle, skirted by a few tepid puddles among the exposed cobbles and sand of its bed. These are the sights and sounds of a contemporary stream.

You don't know what a stream looks like. A natural North American stream is not a single, deeply eroded gully, but a series of broad pools, as many as fifteen per mile, stitched together by short stretches of shallow, braided channels. The banks drop no more than a foot or two to water, and often there are no true banks, only a soft gradation from lush meadow to marsh to slow open water. If soil washes down from the steep headwaters in flood season, it is stopped and gathered in the chain of ponds, where it spreads a fertile layer over the earth. In spring the marshes edging the ponds enlarge to hold floodwaters. In late summer they shrink slightly, leaving at their margins a meadow that offers tender browse to wildlife. An untouched river valley usually holds more water than land, spanned by a series of large ponds that step downhill in a shimmering chain. The ponds are ringed by broad expanses of wetland and meadow that swarm with wildlife.

Until the arrival of Europeans in North America, this second vision was, almost without exception, what streams looked like. They were transformed into the gullied channels we mistake for the natural state of streams soon after the killing of millions of beaver. Most European settlers never saw the original condition of our watersheds, because the trappers came before them, a deadly colonial avant-garde that swept relentlessly from Atlantic to Pacific coast and hunted the beaver to near extinction. Deeply gullied ravines had been the norm in an anciently beaver-cleared Europe, and they quickly became the norm here too. Removing the beaver drastically altered and simplified the landscape.

Before Europeans arrived, there were an estimated 100 to 400 million beaver in North America. Today there are roughly 9 million, with their numbers having rebounded from an even lower nadir at about 1900. Early records show that beaver lived in nearly every body of water in New England.

The first white settlement in New England began with the arrival of the Mayflower in 1620, and in the decade following, 100,000 beaver were skinned in Massachusetts and Connecticut. Having quickly depleted the coastal stocks, trappers moved west into New York and killed another 800,000 beaver from 1630 to 1640. In 1638 England's Charles II declared beaver fur to be mandatory in the manufacture of hats, to the animal's further misfortune.

As the slaughter spread westward, the numbers increased: The French port of Rochelle received 127,080 beaver pelts in 1743 alone (beaver were not the sole target—1267 wolves and a staggering 16,512 bears were also shipped to Rochelle that year). By 1850, beaver were nearly extinct from the Atlantic to the Oregon Territory. Entire deciduous riparian forests disappeared from the west coast. Without the beaver's omnipresent influence, streams in every watershed eroded into the deep channels we know today, and soil washed to the sea.

Keystone of the Watershed

As Bill Mollison has observed, everything gardens. The beaver, however, goes far beyond simple gardening to feats of complex ecosystem transformation. Beaver don't merely build dams that create ponds. They control the flow of vast amounts of energy and material. With tough incisors and instinct, beavers create a shifting mosaic of moist and dry meadows, wet forests, marshes, bogs, streams, and open water that change the climate, nutrient flow, vegetation, wildlife, hydrology, and even geology of entire watersheds.

One of permaculture's core principles advises that we intervene at the point of maximum effectiveness—achieve the greatest result with the least effort—and beaver epitomize that axiom. The beaver understood how to hold water and soil on the land long before Keyline originator P.A. Yeomans, and the stunning increases in diversity and sheer biomass achieved by the beaver serves to confirm the wisdom of Yeomans's vision. We can learn much that is useful to permaculturists from a closer look at how the beaver works, and how their actions reach deep into the heart of ecosystem health and function.

When a beaver fells an aspen—their favorite food and building stock—the tree sends up suckers. The new shoots respond to the cutting of their parent tree by producing bitter alkaloids that beaver don't like. This promotes a dynamic balance between aspen growth and beaver felling. However, the young suckers are just right for moose and elk, and these large mammals prosper in the tasty browse where inedible treetrunks once grew.

Tree-cutting by beaver changes the course of ecological succession by opening the canopy and removing certain plant species. Light-loving plants, such as alders, hazels, and spruces, thrive and multiply. The chips and abandoned brush from the felled trees offer shelter and food to insects, small mammals, and birds. Most of the tree, though, is used by the beaver for dams and lodges.

Beaver choose the gently sloping lower reaches of valleys for their work. A small dam on flat land impounds more water behind it than one on a steep slope, doing the least work to create a large pond. The water that backs up behind the dam saturates the soil beneath it, creating a blend of anaerobic and aerobic pockets, varying with water depth, vegetation, soil type, and distance from the pond edge. Decomposition at the anaerobic sites is slow, preserving organic matter. Dead trees and snags left by the beaver or killed by flooding become home to a wide array of animals and microbes. The structural, biological, and chemical complexity of the region increases.

Vegetation drowned by the pond rots, releasing vast flows of nutrients into the water. The pond bubbles methane into the atmosphere. Erosion caused by the lapping of the expanding upstream shoreline pulls more nutrients into the water. In the pond and downstream from the dam, biomass now surges because of the water's increased fertility. The growing plants and animals trap these nutrients and begin to cycle them.

Ecosystems that retain nutrients recover more easily from disturbance than nutrient-losing ones. This means the pond communities and those around it are likely to persist for a long time.

Because the pond has slowed the once-rushing water, it can't carry as much sediment. The released burden settles onto the pond bottom. The small dam's ability to collect sediment is enormous: An average beaver dam, containing four to eighteen cubic meters of wood, will eventually retain 2000 to 6500 cubic meters of sediment behind it. That's tremendous leverage, and very effective use of resources! Paleoecological evidence shows that entire valley floors have been raised many meters by beaver pond sediments.

These sediments contain carbon, potassium, phosphate, and other nutrients, which are slowly released into the pond, or provide food for burrowers and other burgeoning denizens of the soft bottom. The burrowing worms and other creatures alter nutrient flows as well. They stir up the sediment, releasing soluble chemicals into the water, but they also trap and retain nutrients, storing them as bodies and food, and coating their burrows with organic matter.

Huge numbers of tubeworms and clams are nurtured by the slow water-speeds and the sediments that result, as well as abundant dragonflies and other predatory insects. Because of these predators, fewer blackflies and mosquitoes infest beaver ponds than man-made ponds.

Sediments in beaver ponds and wet meadows at their margins are warmer than those in dry meadows and forests, which means faster growth of plants and soil organisms. In many cases, beaver ponds also raise the water table, making moisture more available to roots and soil life. Shrews, voles, and other small mammals thrive in the warm, verdant growth.

More fish species are found in and near beaver ponds than in open streams. Overall, the diversity and biomass of plants and animals in beaver ponds is two to five times that of riffling streams.

The ponds themselves can vary hugely, creating many different habitats. Some ponds are squeezed into deep, narrow uplands, and others spread across broad, low valleys. Downstream ponds are closer to permanent aquatic habitats at river mouths, and thus trade species with them. Dams regularly collapse, and some are not repaired, so ponds are often in various stages of conversion to dryer habitats.

But just as significant are the varied habitats that ring beaver ponds. Upstream and down are open stretches of flowing water, home to stream species. At the pond edges the beaver have created bogs, marshes, wet meadows, and riparian forests. The new wetlands and meadows contain more nutrients than the older uplands, and so support more types and numbers of living beings. Edging the wetlands are dry meadows and woodlands. And beaver meadows are very persistent, because their previous flooding has acidified the soil, helping them resist invasion by shrubs and trees.

All these habitats are flooded in a very complex pattern that varies with both the flow of water over the seasons and the beaver’s activity. This means the conditions in all these communities vary widely over time, allowing yet more biodiversity.

Beaver create a stunningly diverse mosaic of habitats that shift over both space and time. Scientists in Minnesota found that returning beaver transformed a section of uniform deciduous forest into 32 different aquatic, emergent, shrub, and forested wetland communities at various successional stages.

On the left is a stream before beaver damming; the right side shows the same stream after beavers built 3 dams. Edge area of stream and water table margin was significantly increased, and habitat types (shown by numbers) rose from one to four. *Redrawn from R.J. Naiman et al. (1988), BioScience 38: 753-762.]*

A beaverless watershed will most likely contain a deeply gullied stream with a dry edge. A watershed with beaver will have open, shallow streams, many ponds both active and abandoned, wet and dry meadows, drowned, riparian, and dry forests, and different wetlands of all sizes, types, and successional phases. This whole network and the many species living there will shift and repattern as beaver move out of ponds or return to abandoned dams. These animals and the work they do are the key to biodiversity in the watershed.

Busy Little Engineers

The importance of the beaver hasn’t gone unnoticed by ecologists, and these creatures also offer both conceptual tools and affirmation to permaculturists as well. Recently, ecologists have coined a phrase to describe animals like the beaver: Ecosystem engineers. These are organisms that directly affect and regulate the availability of resources to other species, by causing physical changes in biotic and abiotic materials. In doing this they create and/or modify habitats.

I’m not wild about calling animals “engineers,” as my personal view of engineering is that it is not as creative, inspiring, or appropriate as what nature does—I’d rather call engineers “retarded beavers”—but the term is well established and will have to do here.

Ecosystem engineers fall into two camps. In the first are creatures like the beaver and earthworm, which work their magic by manipulating living and non-living materials (they are called allogenic engineers, for those who like fancy terms).

The second group are those which alter the environment by changes in their own bodies (autogenic engineers).

Trees are the consummate example of autogenic engineers, and Mollison has written brilliantly of the way trees interact with and affect their environment. However, he focuses mainly on the effects of trees on the non-living world: how they affect rainfall, hydrology, soil, clouds, and wind. One could deepen his essays by describing how trees regulate the other species around them. They create habitat for many species amidst their trunks, branches, water-filled crotches, leaves, and roots. The roots provide cavities and aeration, and change soil texture and infiltration rates, which affect both underground and surface dwellers. Leaf litter changes the drainage, moisture level, and gas and moisture exchange rates in soil habitats, and creates barriers to or protection for microbes, seeds, seedlings, and animals. Trunks, branches, and leaves drop into streams, altering flow and otherwise providing new habitat. This list could go on: The ways that trees "engineer" habitat are multifold.

The principal point to grasp about ecological engineers is that they act at points of maximum leverage to change the flow, availability, and pattern of energy, nutrients, and other resources that are used by other species. They often are not part of these flows themselves, thus their interactions are on a very different level from the predator/prey relations (trophic level) upon which so many of ecology's precepts are based.

Ecosystem engineers "design" their own habitats and those of others, and exert a great deal of control over them. This means they create stable, predictable conditions for themselves and for the ever-increasing numbers of creatures who become dependent on them, and for ecosystem processes. They damp the wild flows passing through their homes. They usually enhance biodiversity and make environments more complex.

Sound familiar? The whole idea of ecosystem engineers drops neatly into the permaculture toolbox. These species, like good designers, create and improve habitat for many species as a by-product of enhancing their own environment. They cooperate with ecosystem processes and energy and matter flows, directing them with minimal, efficient intervention, and they benefit themselves and others by doing so.

By understanding ecosystem engineers like the beaver, we can shine a bright, critical light on many of the practices and principles of permaculture. The effects of beaver on a watershed sound to me like nature's application of P.A. Yeomans' Keyline concepts, and support permaculture's belief that earthworks and ponds are critical for restoring ecosystem health. In sites where beaver have returned after a century or more of absence, we have natural models that demonstrate the hugely beneficial effect of holding water on the land.

Trees, as Mollison understood, are another ecosystem engineer to learn from. Others that could be integrated into the permaculture corpus of knowledge are:

- Reef-building corals
- Earthworms and other burrowers (the whole class are called bioturbators for their churning of sediments)
- Certain key fungi and other microbes, which mobilize nutrients
- Algae, which change how light and nutrients are distributed in water
- Elephants, which uproot, trample, and eat whole forests and then deposit huge manure loads elsewhere, stimulating new growth
- Woodpeckers, which alter insect abundance and create nest sites and shelter in trees for many species
- Alligators, which dig wallows that create new habitats

The final and most drastic ecosystem engineer is, of course, *Homo sapiens*. We're not very good at it. Usually the effect of our ecosystem engineering is to reduce the possibilities for every other species, rather than to enhance them. But by looking more carefully at the many ways in which nature's ecosystem engineers improve their own homesites while boosting the productivity and diversity of the larger environment, we can become wiser in our own manipulations.

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