WATER

A NATURAL HISTORY

ALICE OUTWATER

WATER

A NATURAL HISTORY

ALICE OUTWATER

ILLUSTRATIONS BY BILLY BRAUER

A Member of the Perseus Books Group

Published by Basic Books,
A Member of the Perseus Books Group

Designed by Elliott Beard

Library of Congress Cataloging-in-Publication Data

Outwater, Alice B.
Water : a natural history / Alice Outwater ; illustrations by Billy Brauer. — 1st ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-465-03779-8 (cloth)
ISBN-10: 0-465-03780-1 ISBN-13: 978-0-465-03780-3 (paper)
1. Hydrology—United States. 2. Hydraulic engineering—United States. I. Title.
GB701.O88 1996
551.48—dc20 96-24182
CIP

ONE

THE FUR TRADE

This story about American water begins, surprisingly, back in Europe during the Middle Ages, when peasants living in cramped quarters close to their animals were probably warmer than the rich in their drafty great halls. Fireplaces, the medieval equivalent of modern space heating, were so inefficient that to keep the winter's chill at bay the well-to-do slept under fur covers, put on fur-lined robes or tunics upon rising, and donned fur-lined cloaks before venturing outside. More furs were worn in the Middle Ages than at any time before or since.

By the end of the thirteenth century, furs had become so much a part of the wardrobe of the times that rich and poor alike wore them in all seasons. Kings and dukes owned as many as twenty or thirty garments lined in fine furs, and would dress

in two and even three layers of fur-lined clothing. Records of royal wardrobe purchases by French and English kings list enormous numbers of skins for royal households; from 1285 to 1288, for example, King Edward I bought a hundred and twenty thousand squirrel pelts a year. But the market would have been quite small if only royalty wore furs. Even relatively humble citizens owned one or two robes lined in lambskin or cat which could be bought for a few shillings, or a few weeks' work. In 1363, an English statute stipulated the furs that might be worn by each social class: hoi polloi were restricted to local skins—lamb, rabbit, cat, or fox—while the nobility, clerics, and richer citizens could wear ermine, lynx, sable, beaver, and fine Baltic squirrel.

Not surprisingly, trade in fine furs began early and became quite robust. Beginning in the ninth century A.D., Viking traders collected beaver, sable, and squirrel as tribute from the Finns and exchanged them in England for wheat, honey, wine, and cloth. Skins collected from southern Europe and North Africa appeared regularly at the Marseilles fur markets; those from Scandinavia and Russia were sold at Bruges; Spanish beaver was sold in London. So great was the demand for luxury furs that furriers—called skinners in medieval England—became politically powerful, socially prestigious merchants: the historian Elspeth Veale reports that their mercantile guild was powerful enough to set the length of time for an apprenticeship at fourteen years compared to the usual seven—an arrangement that made skinners among the most exclusive guilds of the merchant class. By the end of the 1300s, the fur business had become so successful and the market so insatiable that most of the wild European furbearing species were gone.

Initially, trappers simply moved deeper into the Russian interior. Complete records for pelts collected from northern and western Russia and shipped from Novgorod to England survive for two periods in the late 1300s: from July to September 1384, a total of 382,982 skins were imported from the Baltics,

accounting for 97 percent of England's total fur imports; from March through November 1390, 323,624 furs were imported, of which 96 percent were Russian. In the next two centuries, millions of Russian squirrel, beaver, marten, ermine, and sable pelts were bought by European skinners.

The beaver was in particularly high demand, for a number of reasons. First, its fur is uniquely suited to felting. The undercoat is much finer and denser than lambswool or rabbit hair, and the shaft of each slim hair is covered with tiny barbs that lock together to make the beaver waterproof. When this undercoat was shaved off the skin, pounded, stiffened, and rolled into felt for a hat, the tiny barbs on each individual hair linked the whole so securely that the hat kept its shape far longer than hats made from other furs. Second, the beaver could be used in its entirety. Castoreum, a glandular secretion that oils the beaver's hair and is used to mark its domain, was highly sought after, both as a medicine and for use as a perfume base. Beaver flesh was preferred to that of game birds, and beaver tail was considered a great delicacy; moreover, because of the scales on its tail, beaver flesh could be eaten in lieu of fish during the Lenten season. And finally, since beavers build dams, stay by their pond, and take time to raise their kits, they are easily caught.

Beavers once lived throughout the European wilderness and the British Isles. As people pushed back the forests, and as furriers paid good money for beaver hides, the beavers began to disappear. Scotland's beaver trade dried up by 1350, by which time a beaver pelt could cost up to a hundred and twenty times as much as a lambskin. By then, the Continental beaver was scarce: of 377,200 furs delivered to England from the Baltics in 1384, only 3,926 were beaver. The wardrobe records of France's kings further reflect the devastation of the European beaver population. In eighteen months of 1387 and 1388, King Philippe and his brother were able to order 450 beaver hats for their personal use; the next year the King bought only 144 beaver hats for himself and his son; in 1390, his purchases of

beaver hats fell to 62, and he filled out his wardrobe with felt hats made from black lambswool, marten, and rabbit. Year by year, the King of France was able to buy fewer and fewer beaver hats. After 1415, of an annual purchase of hundreds of hats, rarely more than a dozen were of beaver. All the evidence suggests that beaver hats were still prized and that the King's diminishing purchases were not of his choosing. Indeed, beaver hats were so precious that they were often willed to heirs.

Such sixteenth-century innovations as glass windows, better chimneys, and the use of coal as fuel had made it warmer indoors, and fashion changed along with the interior temperature. Sumptuous fabrics and jewels supplanted many of the furs as prized possessions, and the trade in pelts declined. While the reprieve allowed relict European populations of many furbearing species to rebuild, the beaver was simply gone from most of the Continent. By the mid–1500s, only the remote reaches of Siberia and Scandinavia had ponds still abundant in beavers.

But the desire for beaver hats had become an imperative of fashion that scarcity could not destroy. Now, however, there was only one place on earth where millions upon millions of beavers still existed. All that remained was for the last stronghold of the beaver to be discovered.

When the Europeans landed in the New World, the Indians who greeted them were using flint knives, bone awls, and stone or skin kettles. European iron tools were so vastly superior to these Stone Age implements that as soon as the Indians became aware of their existence, they wanted them. Indian women especially welcomed the European technology: iron kettles, knives, awls, and hoes were clearly superior to their own tools, and the woven goods—blankets and coarse cloth—were pleasing alternatives to animal skins. Axes, guns, powder and shot, traps, and access to a market economy would soon change the lives of the men as well. The only product the Indians could

exchange for the European goods they coveted were the coats of the animals that crowded the wilderness. And so, in a Faustian bargain of enormous reach—one that would eventually leave them without the means to earn a living and no way to return to the lives they had led before the arrival of the Europeans—the Indians turned wholeheartedly to the task of trapping the North American furbearers.

Beavers were the first to go. By the mid–1600s, beaver hats were once again plentiful in Europe and were being worn by both sexes. A gentleman's attire included a black beaver hat adorned with an ostrich plume; men swept such hats from their heads when they bowed, with an elegant, practiced gesture. In 1638, Charles I of England decreed that "Nothing but beaver stuff or beaver wool shall be used in the making of hats." Samuel Pepys noted in his diary in 1660 that his beaver hat cost £4 5s. (more than a wig and less than a cloak), while a 1719 treatise by the Countess of Wilton describes a fashionable lady's annual wardrobe as including "a beaver and feather for the forest," at a cost of £3—the same price as a set of stays or English shoes. The high-crowned Spanish beaver hat was followed by the conical beaver of the Puritans, which was itself superseded by the broad-brimmed slouch hat of the Restoration, the plumed "shovel" hat of the French Revolution, and the flat-crowned clerical and three-cornered cocked hat that became standard headgear for men throughout the eighteenth century. Everyone wore hats, and the best of these were made from New World beaver.

The effects in Europe of the beaver trade were apparent, but the effects in the New World were far less obvious. In one sense, Europe's insatiable demand for beaver hats did make a noticeable change, allowing the Native American to pass from the Stone Age to the Iron Age in a single bound. The Indians embraced the new tools and goods so quickly that only the earliest white visitors saw Indians in their original state. In 1620, the Pilgrims noted that the Indian villages of Cape Cod were

stocked with European kettles and hatchets—presumably bought with beaver skins. "Nor could it be imagined," wrote the colonial historian Edward Johnson in 1653, "that this Wilderness should turn a mart for Merchants in so short a space, Holland, France, Spain and Portugal coming hither for trade." But in fact this is precisely what happened. Stretching over three hundred years, the North American fur trade would alter the physical landscape of the New World as no other trade has done before or since.

At the onset of the fur trade, ten good beavers—adult, winter-prime northern hides that were stretched and cured—bought the Indians one gun. One good beaver bought, variously, half a pound of powder, four pounds of shot, a hatchet, eight jack-knives, half a pound of beads, a good coat, or a pound of tobacco. "The beaver does everything perfectly well," an Indian trapper told a Jesuit priest in 1657. "It makes kettles, hatchets, swords, knives, bread. In short, it makes everything. The English have no sense—they give us two knives for one beaver skin."

Neither side understood that another exchange, far more deadly in nature, was simultaneously occurring. It is thought by many that Columbus brought syphilis—endemic in the Americas—back to Spain. What is known is that within a year of his return the disease had entered France. When the young French King Charles VIII led his army of thirty thousand men against Naples in 1494, the ranks were filled with soldiers hired from across Europe. In 1495, the unsuccessful campaign was over, and Charles's mercenaries returned to their homelands with contagious genital lesions. A victim could be dead in two weeks of a pustular rash that ulcerated down to the bone, or survive for decades while the neurological ravages of the disease progressed from blindness to madness and death. Millions of Europeans died from syphilis in the 1500s, and the pandemic taught people of another time the hard-earned lesson that casual sex carried the threat of deadly disease. Syphilis eventually helped to transform the licentious Old World libertines into Puritans and Pilgrims.

Across the Atlantic, an even more devastating calamity was unfolding, as European diseases emptied out Indian villages. Smallpox, measles, tuberculosis, influenza, and typhus entered the Americas and struck the immunologically unprepared Indians with terrible ferocity in wave upon wave of epidemics. Mortality rates in the initial onslaughts were rarely less than 80 or 90 percent of a village's population. Traditional healing practices were useless against the biological assault, and the Indians quickly learned that the only way to escape the new diseases was to abandon their villages and cast aside family and community ties.

The settled, populous agricultural tribes fared the worst: the people of villages attacked by a new pathogen often missed key stages in their annual subsistence cycle—corn planting, say, or the fall hunt—and were consequently weakened when the next infection arrived. Those who survived, wrote Robert Cushman, a contemporary chronicler, "have their courage much abated, and their countenance dejected, and they seem as a people affrighted." To the Puritans, the epidemics were manifestly a sign of God's providence, a way of making room for them in the new land. More than fifty of the earliest European settlements were sited near abandoned Indian villages, with the settlers appropriating Indian fields. "God hath hereby cleared our title to this place," wrote Governor John Winthrop of the Massachusetts Bay Colony in a letter to his friend, Sir Simond D'Ewes.

Left without any response to these plagues but flight, the Indians concluded that fur trading was their best hope for survival, a decision of great benefit to the Europeans. With the Indians doing the trapping, beaver skins became the coin with which the colonists paid off the debts incurred in establishing a colony, bought additional necessities from Europe, and ultimately acquired modest fortunes. Beaver skins bankrolled most of the early colonists, including the Pilgrims. Captain John Smith had arrived off New England in 1614 "to take Whales

and make tryalls of a Myne of Gold and Copper. If those failed, Fish and Furres was then our refuge." He found no gold and caught no whales, so devoted himself to fishing and trading for furs. As his men fished, he ranged up the coast with a small boat and crew and "got for trifles neer 1100 Bever skins, 100 Martins and neer as many Otters; and the most of them within a distance of 20 leagues." It was Smith's assessment of the likelihood of quick returns from the fish and fur trade that convinced a consortium of English merchants to finance a Pilgrim colony in the New World.

When these Pilgrims landed on the tip of Cape Cod in early November of 1620, they spent a month searching for the best spot to build a settlement. Previous voyages had described thriving Indian agricultural villages on Cape Cod and northward, with neat wigwams and well-kept fields of corn, squash, and beans. Instead, the Pilgrims found villages that were deserted but often held evidence of recent human occupation: fields of plant stubble, empty wigwams, caches, burial sites, and European tools. In some villages, skulls and bones were strewn about the ground, suggesting a plague so deadly that no one had survived to bury the corpses. Fields that the Indians no longer had the heart or the numbers to plant were lying fallow, and the Pilgrims happily moved in.

By the time Squanto wandered into their midst the next spring, over half of the Pilgrims themselves had died—not of plague but of malnutrition and too many bad colds. Squanto claimed to be the sole survivor of the Pawtuxet tribe, whose fields the Pilgrims had appropriated. He gave them corn and showed them how to plant it, and when the fields were tilled, the Pilgrims cast about for furs to send back to England to pay off their debt. Volunteering his services, Squanto guided the Pilgrims up to the present site of Boston harbor, on a "voyage to the Massachusetts." They left their boat where Charlestown is now and walked in the direction of Medford, where they met some Indians decked in beaver skins. One member of the expe-

dition reported that Squanto was impatient to "rifle the savage women" of their beaver coats, but the Pilgrims wisely insisted on fair trade. The women "sold their coats from their backs, and tied boughs about them, but with great shamefacedness (for indeed they are more modest than some of our English women are)."

The coats the Pilgrims bought were made of beaver taken in the winter, when the fur was prime. To make such coats, women would scrape the inner side of the pelts and rub them with marrow; each pelt would be trimmed into a rectangle, and from five to eight skins would be sewn together with moose sinews into robes that were worn with the fur side in. After fifteen to eighteen months of wear, the skins became well greased, pliable, and yellow, the fur downy, or *cotonné*, and ready for felting. In the early years of the beaver trade, the courtiers of Europe wore hats that were made from the used coats of North American Indians.

The Pilgrims filled their boat with a "good quantity of beaver" and promised to return later. True to their word, they returned the following March with Captain Miles Standish, and again they had a "good store of trade." Plymouth Colony, with no large navigable rivers nearby, was poorly situated for extensive fur trade into the interior of New England, so the Pilgrims sailed up the coast to trade for furs and extended their fur-trading venture to Maine as early as 1625, bringing home, according to Plymouth Governor William Bradford, "seven hundred pounds of beaver besides some other furs."

The first two shiploads of beaver skins sent to England were captured by pirates, but in 1628 a cargo worth £659 arrived safely, and the Plymouth fur trade grew rapidly. During the period 1631–1636, Governor Bradford estimated that the sales of beaver came to £10,000, a "great sume of money" for such a small colony as Plymouth.

The Plymouth traders were never without competitors in their quest for Maine beaver. In 1620, six or seven ships were

trading for Maine furs, and four years later some forty ships from the west of England plied the Maine waters and stopped on shore, where local Indians brought the furs they had gathered during the winter. Many of the towns in Maine, including Augusta, Brunswick, and Portland, were founded as trading posts for beaver skins.

In the Connecticut River Valley, the English entrepreneur William Pynchon was granted a monopoly on the fur trade. By the mid 1670s, nearly a quarter of a million beaver had been shipped to London from the Connecticut River Valley alone, and there were no more beaver to be found in the area.

The Dutch monopolized much of the fur trade south of Cape Cod. In 1624, the Dutch West India Company sent four hundred beaver skins from New Amsterdam. Hudson beaver was plentiful, and tens of thousands of beaver skins were shipped out each year. In 1664 the British colonies captured the city, renamed it New York, and took over the beaver trade. Two decades later, the British complained that "this year . . . the revenue is much diminished, for in other years we used to ship off for England 35 or 40,000 beavers, besides peltry; this year only 9,000." Beaver skins were the principal export of New York until 1700, when the trade ended abruptly. By that time, London had imported nearly two million beaver skins from New York. Since France, Holland, Spain, and Portugal were also trading for American beaver, the total number harvested must have been enormous. Beaver populations that had been stable for thousands of years were effectively exterminated along the American east coast by 1700.

In contrast to the free-for-all in what became the United States, the Canadian fur trade was managed as a sustainable enterprise. Chartered in 1682, the Hudson's Bay Company sought to preserve the furbearing populations. An interval of several years was required between seasonal hunts in a single area, so that populations could reestablish themselves after an area had been trapped out. With exclusive jurisdiction over an

immense tract of wilderness, the Hudson's Bay Company enjoyed a monopoly that lasted for nearly two centuries and effectively preserved the Canadian beaver populations. The colonists to the south were not so prudent.

Across the entire sweep of North America, the fur trade was the cutting edge of the frontier, the driving force behind the exploration of the country, and for a time the traders were able to coexist with the Indians. Fur traders generally worked within the existing Indian system, and laid no claim to Indian lands. They took Indian women as wives from the start, and these unions created alliances and cultural bridges between the Indians and the traders. As long as Indians did the trapping, the overhead costs of the fur trade were low, and most tribes welcomed the trade goods as payment. The trader managed the production system, and the Indian provided the labor: white men made fortunes, Indians acquired metal implements, and the fur trade was widely seen as a civilizing agent that introduced the Indians to the concepts of private property and regular work.

The problem with this arrangement was that although the demand for beaver skins was virtually limitless, the supply of beavers was finite. Once tribes had become dependent on trade goods, they were caught in a bind: iron tools break, guns need continuing purchases of powder and shot, cloth and beads would always need replacement. Before the traders came, the Indians had hunted beaver with spears, taking only a few for food and clothing. Now they were killing every beaver they found; whole colonies were destroyed in a season. When the beaver was eradicated from one area, the traders would move on. In 1634, a Jesuit missionary at an outpost on the Great Lakes wrote, "These animals are more prolific than our sheep, the females bearing as many as five or six a year. But when the savages find a lodge of them they will kill all, great and small,

male and female. There is danger that they will finally exterminate the species in this region as has happened among the Hurons who have not a single beaver, going elsewhere to buy their skins." His pessimism was prophetic.

In the 1700s, the British colonies occupied a thin slice of coastland from Maine to Florida, barely 400 miles wide. The rest of the continent was Indian country, claimed by Spain, France, and England, but populated with dozens of tribes, which were no longer so welcoming to the white man. Scalping and murder were regular occurrences. In some tribes, torture was a highly refined art and victims would be flayed alive, painstakingly dismembered, or burned by inches over a period of days. Treaty by treaty, tribe by tribe, the French, Spanish, and English created alliances that allowed them to establish posts farther and farther inland to trade for beaver. The Western fur grab began in earnest.

Beaver from the interior was shipped out of Montreal, a collection point for skins from the entire Canadian wilderness and from the upper Mississippi and the Missouri Rivers as well. There was also serious penetration of white men into the Plains country of the Sioux. The sons and grandsons of the original explorers—traders who spoke Indian languages and understood Indian customs—told the Indians tales of great warehouses stuffed full of goods. Guided by these white traders, Indians paddled loaded canoes from the beaver fields of the upper Mississippi and the Missouri through the Great Lakes to Montreal, a round trip of over 4,000 miles. Ever lengthening strings of canoes made this trip, the paddlers sweating, singing, cursing against the power of the rapids and the bite of the portage straps.

After the exploration of the Mississippi and Missouri by La Salle and other French adventurers, dozens of expeditions ranged up and down the banks of these rivers, armed to the hilt and carrying caches of trade goods. Instead of paddling laden canoes from the midcontinental prairies to Montreal, the Sioux

could now trade closer to home. In early 1748, thirty-three Frenchmen were trading with the Comanches, the Wichitas, and the Assiniboins up the Missouri and into the South Platte; the Spanish were trading with the Osages and the Panis-Noirs, the Niobrara and the Arikara; and French treaties with the Comanches and the Jumanos allowed traders into New Mexico. St. Louis, founded in 1763, quickly became the fur-trading capital of the world. Pirogues laden with trade goods would work their way up from New Orleans and return with high piles of furs and robes, often towing great rafts, like high floating islands, carrying still more furs. A single expedition could bring as many as thirty thousand beavers to market.

By the close of the eighteenth century, the beaver was nearly gone, with the last beaver colonies keeping to rough, less accessible country. Moreover, the Indians, pauperized and debilitated by disease, had turned to onshore pirating, and traders traveling through the now fur-impoverished Great Lakes region would be set upon for whatever goods they were carrying. Trappers spent months struggling up the sullen Missouri, then on over buffalo country, where streams were few and far between, through badlands, and into the foothills of the Rockies, where on many of the rocky highland streams they found no scrap of fur in sight. The beaver had been all but eliminated by the colonists in the East, the Hudson's Bay men in the North, and the French and the Spanish in the South and West.

When Meriwether Lewis and William Clark set off to explore the country in 1804, a great part of their mission was to find an artery for the fur trade of the trans-Missouri West. President Jefferson had instructed Lewis to make note of the numbers and species of furbearing animals, to ascertain the attitudes of the Indians to the fur trade, and to establish "the most direct and practicable water communication across the continent for the purposes of commerce." The explorers were heroes, and their travel reports of the northern Great Plains and the Rocky Mountains were widely published in newspapers.

Lewis and Clark wrote of Blackfoot country that was "richer in beaver and otter than any on earth," and of the land of the Crow, where beaver were so plentiful that they could be taken from streams with a club. The river systems that flowed where the Great Plains butt up against the Rocky Mountains were the last great beaver fields found in the United States. When Lewis and Clark returned in 1806, fur-trading expeditions were already saddling up.

After five hundred years of development, the fur trade was poised to take maximum advantage of the last of the beaver stocks. Pack trains of eighty horses would scale the mountains carrying goods, and each company set up its own rendezvous points, where as many as two thousand Indian trappers spent a fortnight camping, drinking, gaming, and bartering their pelts to exchange for tools, cloth, and tobacco.

By the 1820s, the Indians of the Rockies had seen that trapping for trade goods led to cultural disintegration, and they were no longer willing to gather furs for the traders. Without native labor to trap the beaver and transport the skins to posts, the fur companies sponsored white trappers to harvest the furs. For almost two decades, no fewer than a thousand mountain men were working the waterways of the Rockies at any given time. About a dozen large fur companies traded for beaver, and hundreds of smaller, independent enterprises were established, flourished, and faded. (One notable fortune made at that time was John Jacob Astor's, whose American Fur Company shipped beaver skins from the Columbia River Basin . . . so you might say that the beaver built the New York Public Library.) Altogether, the mountain men did their level best, in the face of hostile conditions, to clear out the country's remaining beavers.

By the time the first wagon train made its way West on the Oregon Trail in 1843, the beaver was gone. The mountain men had retired from trapping and were hiring themselves out as guides, and the beaver felt used for the tall top hats had been replaced by silk brought from China. The change in fashion

from the dull black beaver hat to the shiny silk topper signaled the end of an era.

With the incentive of European trade and the aid of European tools, the Native Americans had done a thorough job of exterminating the beaver. The tribes got their trade goods, the traders got rich, and the Europeans got their hats. Society has always followed fashion, and to this whim much of the New World lost an animal that shapes the waterways. The beavers had created and maintained an ecological system that enriched the land, but by the time the hat of beaver felt gave way to the silk top hat of the 1840s, the beaver was nearly extinct—so thoroughly trapped in the continental United States that its numbers are still sparse in much of the arid West.

Today, there are between 7 million and 12 million beavers in the United States, most of them around the Great Lakes and along what remains of the Mississippi floodplains. Entire ecosystems based on the beaver's compulsion to spend its nights building dams were slowly but steadily undermined. It would be centuries before the nation figured out exactly what it had lost.

TWO

NATURE'S HYDROLOGISTS

The beaver is utterly familiar. Forty inches long and over a foot upright, a beaver seems like a little person with a fondness for engineering. Good-natured, gentle, and clean, it makes a friendly pet that follows its owner around much like a dog, scrambling up onto a lap to be rubbed on the belly whenever it's invited. Beavers were commonly

kept as pets around Indian encampments, but they do have a fatal flaw in a modern household: they never stop building. When kept indoors, they will cut down the legs of tables and chairs and build little dams between pieces of furniture. Left on their own, they will rearrange waterways.

Beavers do more to shape their landscape than any other mammal except for human beings, and their ancestors were building dams ten million years ago. These Miocene beavers were 7 feet long, felling trees ages before the mammoths roamed. Their underground spiral burrows can be found from western Europe to central Asia and North America; after their extinction, some of these burrows filled with debris that fossilized, creating twisted masses of stone that geologists call devil's corkscrews. Legends of these prehistoric giants were once widespread. The Indians of Nova Scotia claimed to know of an ancient beaver dam so vast that it flooded the Annapolis Valley; farther west, tales circulated of tribal ancestors using immense beaver teeth to hollow out their canoes.

In tribes across North America, legend had it that the beaver helped the Great Spirit build the land, make the seas, and fill both well with animals and people: Long, long ago when the Great Waters surged in a blind and shoreless world, the gigantic beaver swam and dove and spoke with the Great Spirit. The two of them brought up all the mud they could carry, digging out the caves and canyons and shaping the mud into hills and dales, making mountains where cataracts plunged and sang. Some tribes believed that thunder was caused by the great beaver slapping his tail.

Until European colonization of the New World, *Castor canadensis*, the North American beaver, was one of the most successful mammals on the continent, living almost everywhere there was water, from the Arctic tundra to the deserts of northern Mexico. It was scarce only in the swamps of Florida and Louisiana, where its dams and lodges were no match for vora-

cious alligators. Everywhere else, along thousands of streams, lived colony after colony, dam after dam of beavers in close succession, as many as three hundred dams per square mile, each with its own ring of wetlands.

It is estimated that as many as two hundred million beavers once lived in the continental United States, their dams making meadows out of forests, their wetlands slowly capturing silt. The result of the beaver's engineering was a remarkably uniform buildup of organic material in the valleys, a checkerboard of meadows through the woodlands, and a great deal of edge, that fruitful zone where natural communities meet. Beavers are a keystone species, for where beavers build dams the wetlands spread out behind them, providing home and food for dozens of species, from migrating ducks to moose, from fish to frogs to great blue herons.

A total vegetarian, the beaver eats roots, tubers, and the inner bark of trees. As a consequence, its own meat is sweet and tender, and to avoid becoming everyone's favorite prey it took to the water long ago and is well adapted to aquatic life. Its dense coat conserves heat, and its multipurpose scaly tail functions as a rudder, as a place to store fat for lean times, as an internal temperature regulator, and as an early warning system to other beavers thanks to the noise it makes when slapped against the water.

Served at medieval banquets as "bear's paws," the tail of the beaver covers an even more singular feature. Beavers have neither external testicles nor penis, hence their name—*castor*, from the Latin *castratum*. (Some Victorian references claim that *castor* is derived from *gaster*—belly, in Greek—but that was a shyer era.) The beaver's sexual organs are modestly tucked up inside its body, while a pair of glands in the anal area of both sexes secrete castoreum, the musky oil the beaver uses to grease its coat and mark scent mounds to delineate its territory. Castoreum was a popular medicine in the Middle Ages, said to cure

ailments ranging from headaches to impotence; it is high in salicylic acid—the basic ingredient of aspirin—which the beaver ingests by dining on willow bark. Long used as a base for perfume, its scent is described as a pungent, waxy, burnt-orange odor, with smoky notes of Irish peat fires and good pipe tobacco and undertones of cardamom and tea.

Castor's teeth never stop growing; the pair on the upper and lower jaws form curved blades that chisel through wood as hard as rock maple and are perfectly designed for felling trees. Beavers are the largest rodent in North America: at close to sixty pounds, the adult females slightly outweigh the males. The beaver's rotund belly is filled with an enormous gut packed with vegetative matter and the bacteria that convert vegetation into calories. To extract the most calories from its high-fiber diet, the beaver eats everything twice when food supplies are low, a practice called coecotrophy. Ruminants manage this by burping up their ingested food and chewing the cud, but the beaver actually passes food through its entire digestive tract twice, by eating the gelatinous, porridgelike substance that comes out its anus the first time through. Double-digested beaver stool looks almost like pure sawdust.

When they are about three years old, beaver kits leave home to find a companion, with whom they mate for life. During this quest for new territory, they are at their most vulnerable to predators (and today to cars), but they are remarkably safe once they've built their living quarters. When the new couple finds a suitable stream, they mark the area with scent mounds and dig out a den in the stream bank. Beavers are burrowers, and they have powerful, curved claws on all four feet. They're also equipped with a number of features that aid underwater construction: valves close off their nose and ears; thin membranes over their eyes serve as goggles; and skin flaps behind their front teeth allow them to tow tree branches in their teeth without swallowing half the pond. With these adaptations, beavers are

able to dig their burrow's entrance well below the surface of the water. Slanting the tunnel upward to above the high-water line, they clear out a room three feet wide and line it well with shredded wood and grass. The underwater entrance keeps them safe from lynx and wolverines, and to ensure that the water stays high enough to hide their burrow's mouth during the low summer flow, they build a dam.

Choosing a dam site where the stream is not too deep and the bottom muck is firm, they fell saplings first and then larger trees. Working by night—sometimes on separate trees, sometimes together on a single trunk—they sit with their paws around the tree, their tails either folded beneath them like a seat or extending behind as a prop. Tilting their heads from side to side, they make deep bites in the tree, driving their long yellow teeth into the wood to wedge, pry, or pull out a chip, chiseling the trunk until the tree topples. After cutting the tree into manageable lengths, they push and pull the logs into position on the dam, pointing the butt ends upstream, and hold them fast with piled mud and stones. As the dam grows higher, the water slows, and the beavers weave in more branches and pat on more mortar until a substantial barrier is completed.

Dams must be continuously maintained, and beavers do so every night, replacing shifted sticks and poles and patting on more mud. They build dams throughout their territory: some for water control; some, it seems, just for fun. A family of beavers can build a 35-foot-long dam in a week.

Where the streams have clearly cut banks and a channel with a uniform current, beavers build a solid bank dam with the poles underneath and earth on top; water discharges through an opening in the dam's crest. If the stream is wide, they bow the dam into the flow of the water, increasing the structure's stability. When the young trees nearby are all consumed and the edge of the forest is too far away for the beavers to drag their branches easily, they dig canals about 2 feet wide and 1 foot

deep in which to float the branches back to home base, sometimes extending these canals for hundreds of feet to reach new trees. If a riverbank is steep, they build slides down to the water. Dams more than 4,000 feet long have been found, built by generations of beavers, and nineteenth-century reports describe dams encrusted with lime and half petrified, attesting to hundreds of years of continuous repair.

The beaver is a clever engineer, but its brain is embarrassingly small—smooth and unconvoluted except for the well-developed olfactory lobe. The beaver's ratio of brain size to body weight is the lowest found among mammals: like that of the primitive marsupials, the beaver's brain is about a third the size of the average mammal's; a beaver-size human would have a brain fifteen times as large as a beaver's. Beavers don't have much gray matter, and they don't see well. Nevertheless, there is abundant evidence—noted in Enos Mills's 1913 study *In Beaver World* and confirmed by the contemporary naturalist Hope Ryden, who studied a colony of beavers in New York State—that much of their building technique appears to be learned during their long childhood. Oddly, although the European beaver (*Castor fiber*) is nearly identical in appearance to the American beaver, it has no interest in dam construction; in most regions, European beavers confine their efforts to digging burrows in the stream bank. It seems likely that the fine points of dam construction were lost to *Castor fiber* during the centuries when only a few survived in parks.

Virtually every *Castor canadensis* builds dams, however, and behind each dam the water slowly backs up and covers the land. A rush of insects, animals, and plants transforms that thin sheet of water into a place where every level, every nook and cranny, is teeming with life. Ecologically, wetlands are an example of an ecotone—a transition between two diverse communities. Uniquely, an ecotone contains organisms native to each overlapping community as well as organisms characteristic

solely of the ecotone itself. The so-called edge effect—the increased variety and density at community junctions—is what makes wetlands so productive of life, and the beaver's role in this system is to build the dams that make wetlands, increasing the edge between waterways and dry land.

In a wetland, the food web is dense and the niches are varied. Frogs twang in the evening, warning of a raccoon wading out to dig up grubs and insects. Herons stalk the frogs, and migrating ducks settle out of the sky to rest and feast before traveling on. Meadowlarks and magpies alight upon the stumps, and muskrats, voles, and otters make their homes along the shore. Sometimes a moose or a deer wades into the water to eat the greens along the shore, while minnows hide among the stalks.

The crush of insects, animals, and plants in the still water is directly attributable to the lowly algae, the primary producers at the base of the food web. Every tablespoon of wetlands water is crowded with millions of organisms that make up a highly diverse planktonic community, and also with planktonic secretions and excretions, feces, and corpses, along with the debris that washes into suspension from the surrounding land. The plankton include—besides the algae, or phytoplankton—zooplankton and bacteria; these are respectively the plants, animals, and scavengers of this small kingdom.

The tiniest plankton are the scavenger planktonic bacteria, which live freely suspended as single cells or form colonies around a nucleus of dead organic material. They, along with aquatic fungi (the hyphomycetes), clean up the corpses and wastes and other organic debris in the water. About three hundred species of aquatic fungi have been identified: most are tiny structures with four arms; some are curving threads. The fungi and the bacteria are saprophytes—eaters of the dead. The algae, by contrast, transform sunshine and inorganic nutrients in the water into food in order to reproduce. If the largest planktonic

ECOLOGY/HISTORY

Nominated for the Winship/PEN New England Award

In *Water: A Natural History*, environmental engineer Alice Outwater takes us on a journey that begins five hundred years ago, back to the wardrobe records of the kings of France and the diaries of the first Western explorers, to recover a lost knowledge—how the land cleans its own water. *Water* moves from the reservoir to the toilet, from the grasslands of the Midwest to the Everglades of Florida, through the guts of a wastewater treatment plant and out to the waterways again. Step by step we come to learn what should have been obvious from the beginning: a complex ecological system long kept American water remarkably clean but as we have randomly removed necessary components from it, we have simplified the system to the point where it can no longer do its job. While engineering can depollute water, only these ecologically interacting systems can create healthy waterways. *Water* is the unforgettable story of the symbiosis that existed between the country's water, the land from which it springs, and the life the two support together. It is a story that none of us who hope to live on this planet can afford to miss.

ALICE OUTWATER is an environmental engineer, a consultant in sludge management, and the coauthor, with Larry Gonick, of *The Cartoon Guide to the Environment*. She lives on a farm in Waitsfield, Vermont.

"This book's great virtue is the ease with which it explains how water works its way through North America. [Outwater's] tone is attractively specific: stylish in its own directness, and realistic in its proposals." —*THE NEW YORKER*

"Far from being a dry, pedantic text, this book is readable. In fact, it's fun. It's interesting, and it doesn't take a degree in environmental engineering from MIT—which the author has—to understand what she saying." —*BOSTON HERALD*

"This thought-provoking books belongs in all environmental collections, academic and public." —*LIBRARY JOURNAL*, chosen as one of the "Best Science and Technology Books of 1996"

BASIC BOOKS
A Member of the Perseus Books Group

http://www.basicbooks.com
Cover design by Roberto de Vicq de Cumptich
Cover photograph © Pat O'Hara/Tony Stone Images

US $16.50/$20.00 CAN
ISBN-13: 978-0-465-03780-3
ISBN-10: 0-465-03780-1
51650
9 780465 037803
1097