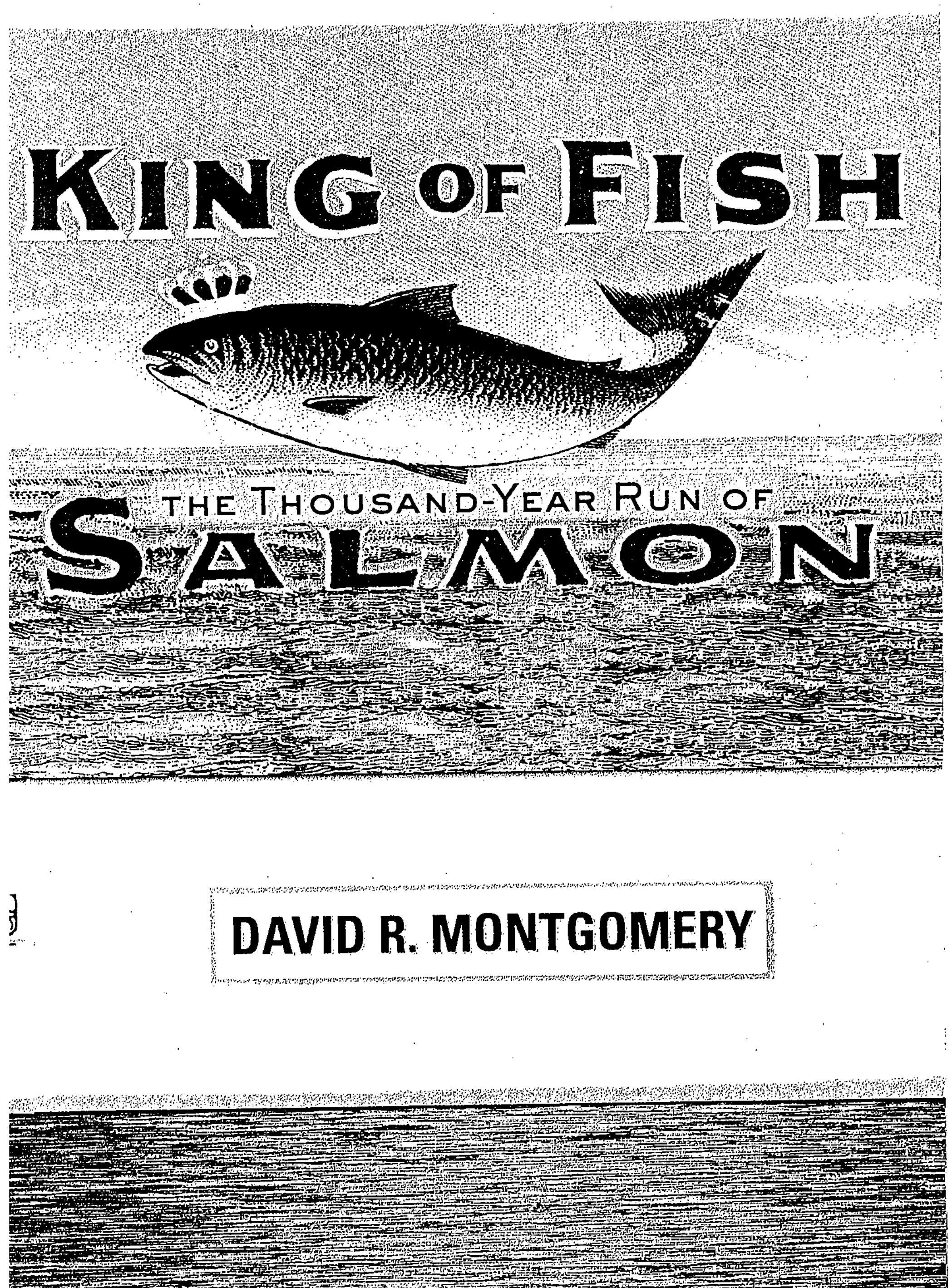
"his is a fascinating and important book. It should be read by us all."
—*The Economist*



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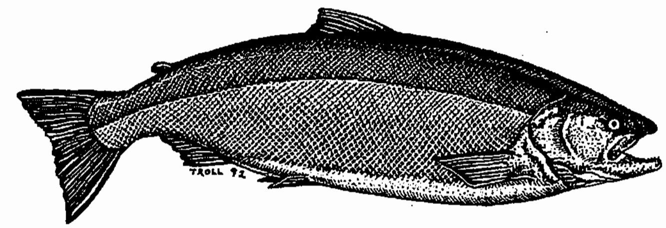
In the summer of 2001 there was a series of power outtages in California, and water intended to supplement flows to help downstream salmon migration was instead spilled during peak demand periods to sell power to California at astronomical prices. Yet this was a low-water year when the extra flows were critically needed by the salmon. Even after Endangered Species Act listings, the downstream migration of juvenile salmon remains a lower priority with those running the Columbia River power grid than does cashing in on power deregulation.

Columbia River salmon were sold down the river for the promise of cheap electricity. Fulfilling this promise, the BPA dams on the Columbia River system transformed the economy of the Pacific Northwest, helped win the Second World War, and turned the dry interior of the region into some of the most productive farmland on the planet. Yet today the region has skyrocketing power rates, and both salmon and power are expensive. To be sure, the taming of the mighty Columbia River catalyzed regional development, albeit at the price of now legendary salmon runs. Similarly, twentieth-century forest clearing, rural development, and urbanization led to equally deadly changes to many other salmon rivers throughout the Pacific Northwest.

CHAPTER
10

RIVERS OF CHANGE



The maintenance of conditions favorable to fish life in our mountain streams is largely dependent upon the preservation of the forests.

S. B. Locke, *U.S. Bureau of Fisheries Document* 1062, 1929

THERE IS SOMETHING TIMELESS ABOUT A RIVER. UNLESS the view includes something really strange like burning water or a big dam, it is easy to imagine that a river has always been pretty much like what we see today. The seductive allure of flowing water fosters an assumption that rivers maintain their character over time as they carry away water, sediment eroded from hillsides, fields, and mountains, and whatever else we dump into them. But rivers are dynamic systems. Depending on what enters its channel, a river may serve as a sewer or a life-giving artery.

As rivers adjust to changes in their load of water, sediment, and wood, the resulting changes in habitat type, abundance, or quality can dramatically alter the health, number, and kinds of river-dwelling organisms. A legacy of prehistoric change characterizes the environmental history of Puget Sound rivers, but these natural disturbances since the last glaciation were either small, relatively short-lived, or confined to only some river basins. With generations of reserves at sea in any given year, salmon thrived in the dynamic, ever-changing landscape even as local populations occasionally crashed or temporarily disappeared.

Pacific Northwest rivers today bear little resemblance to those that sustained salmon-based economies and cultures of native peoples centuries ago. After several generations both individual and collective memories of the land get pretty murky, and the memory of the landscape among those still alive extends back little more than half a century. We think we know the world we see today, vaguely remember the world of our childhood, and can sort of imagine our grandparents' world. But few people are aware of the extent of historical changes to the Pacific Northwest's rivers. Fewer still have any real sense for what rivers were like before the signing of the treaties that unleashed the changes still sweeping across the region.

It is quite difficult to find places to go to get a feeling for what the rivers of the Pacific Northwest were like before European settlement. Even rivers that have benefited from restoration efforts remain tamed and sanitized versions of their former selves. A canoe trip on the lower Nisqually River, which flows into southern Puget Sound just north of Olympia and which serves as the border between the Nisqually Indian Reservation and the U.S. Army's Fort Lewis, is as close to a trip down the rivers of Lewis and Clark's day as can be found around Puget Sound.

The 1854 Treaty of Medicine Creek reserved the lower reaches of the river for the Nisqually Tribe. Consequently, while streamside forests on other Puget Sound rivers were cleared by the early 1900s, the valley bottom along this stretch of the Nisqually remained relatively undisturbed. The U.S. Army annexed the north side of the valley in 1917, and still uses it as a buffer for its artillery practice range. The lower Nisqually River remains virtually bypassed by history, left close to its natural state except for occasional heart-stopping artillery barrages.

In the summer of 1998, Brian Collins, Tim Abbe, and I canoed the lower Nisqually to study the influence of logjams on the river. Floating down this river is a real treat for us logjam connoisseurs. Grand old cottonwoods growing on the floodplain are big enough to remain stable when, once undermined by bank erosion, they fall into the river. The way logs stack against each other reveals that wood moving through the channel racks up on stable logs as though woven into a natural tapestry.

Logjams capture more logs and further obstruct flow, feeding a runaway process that leads to the immense piles of wood that greet a canoe around almost every bend. On our way down the river we found huge jams plugging the entrance to side channels that once served as the main channel. We even found a curious place where aerial photographs show that for a while the river flowed backward for a few hundred yards upstream of where it was completely blocked by a logjam. We counted two thousand logs per mile of channel, more than 90 percent of them racked up in gigantic jams.

Our trip showed us that, much like that of the Queets River in Olympic National Park, the valley bottom along the lower Nisqually River hosts a complex web of channels. In the main channel as well as the side channels, the deepest pools lie under and around the biggest logjams. Although potentially dangerous to an unlucky boater, the logjams on the Nisqually create ideal salmon habitat with lots of deep pools in the main channel, a network of tranquil side channels that flow year round, and an abundance of overhanging and submerged logs to provide cover from predators. As we left the river at the end of the day, fishermen standing shoulder to shoulder along the banks testified to the quality of the river as salmon habitat.

Early accounts of Pacific Northwest rivers paint a portrait unfamiliar to most people, but recognizable by anyone who has floated down the Nisqually or tried to march up wood-choked rivers into the heart of Olympic National Park. In his journal of a Hudson's Bay Company trapping expedition on the central Oregon coast in the summer of 1826, Alexander McLeod, the expedition's chief trader, described logjams on Oregon's Siuslaw River:

> Jeaudoin and his companion went in Course of the Afternoon some distance up the North Branch of the River but finding the Navigation much impeded by fallen trees they returned at dusk conceiving the Obstacles insurmountable. . . .
>
> [L]ate last night the four men sent up the South Branch returned not being able to proceed owing to the quantity of fallen Trees which obstructs its navigation. (Davies 1961, 167, 171)

Fur trappers like McLeod pursued beaver all over North America, yet coastal Oregon's logjam-filled rivers stymied them. The region's huge trees simply were too big for streams to move. Vast numbers of snags and logjams clogged rivers throughout the Pacific Northwest. Charles Wilkes, commander of the 1838–42 U.S. Exploring Expedition to the Pacific, reported that even on the mighty Columbia, "channels in this river will be always more or less subject to change, from the impediments the large trees drifting down cause, when they ground on the shoals" (1844, 152). To those who take modern wood-poor rivers as a frame of reference, the amount of wood in the prehistoric rivers of the Pacific Northwest is almost unimaginable.

Brian Collins investigates the extent and style of historical changes to Puget Sound rivers in order to re-create as accurate a picture as possible of their original condition. Acting as an environmental forensic detective, he pieces together fragments of information to reconstruct a picture of pre-European contact river conditions. His work takes him to library archives and on canoe trips to survey modern rivers flowing through mature forest, agricultural valleys, and rapidly urbanizing lands.

In the course of his work, Brian scoured archival records of the Army Corps of Engineers to tally the number of logs pulled from Puget Sound rivers in the early days of Euro-American settlement. The Army engineers started clearing Puget Sound rivers in 1880. Though these efforts continue to this day, they peaked between 1890 and 1910, when an average of

three thousand snags were cleared every year from the lower Skagit River. Many of these were massive trees; the largest snags pulled annually from Puget Sound rivers were 12 to more than 15 feet in diameter. Over the course of a century 150,000 snags were cleared from just five rivers.

Puget Sound rivers were not unique in their prehistoric load of large wood. Jim Sedell, a researcher with the U.S. Forest Service, pioneered the use of historical records in reconstructing changes in river conditions on the Willamette River, Oregon's second largest river. Sedell found that over 5,000 trees 5 to 9 feet in diameter were cleared from a single 50-mile-long reach in the first decade of the Army Engineers' program to improve the river, 1870–80. All together, more than 65,000 snags and streamside trees were removed from the Willamette from 1870 to 1950—an average of 880 per mile of river. That's about one every six feet.

The 1875 annual report of the Secretary of War (U.S. House of Representatives 1875) described the Willamette as littered with logs "too numerous to count" and described how "[e]ach year new channels are opened, old ones closed; new chutes cut, old ones obstructed by masses of drift [logs]; sloughs become the main bed, while the latter assume the characteristics of the former; extensive rafts are piled up by one freshet [high flow] only to be displaced by a succeeding one; the formation of islands and bars is in constant progress" (766). The Army Engineers noted how logjams not only split the river into four or five main channels but also blocked navigation.

Before the clearing of old-growth forests made possible convenient overland transportation, rivers served as transportation corridors along which communities were organized and lives were oriented. But travel was slow. Snags and logjams made most rivers nearly impassable. Native settlements were located along navigable waterways, including the lower reaches of major rivers. Few people lived inland or up the river valleys. As the regional population exploded, settlers wanted rivers opened to navigation to develop the agricultural potential and forest resources of the fertile valleys and rugged uplands. Spreading inland along river corridors, settlers cleared valley bottoms first as they built a regional economy.

Assigned the task of pulling snags from Puget Sound rivers, the Army Engineers recorded their progress in annual reports to Congress.

In their report for 1875, Major Nathaniel Micheler described the Snohomish River as "very shallow and filled with snags." Similarly, Assistant Engineer Robert Habersham reported that in August 1879 the Stillaguamish River was "much obstructed by snags and trees embedded in the bottom, and at six points completely closed by rafts [of logs] which have diverted the current so as to cut out minor channels, forming small islands" (U.S. House of Representatives 1881a, 2610).

The Army Engineers' objective was an unobstructed, single-channel river open to commerce. The biggest logjams formed great rafts of wood that could block even the Skagit River, the largest river draining into Puget Sound. At the site of the modern town of Mount Vernon, a stable raft of logs blocked the Skagit for more than a century before settlers cleared it in the 1870s. The jam wasn't just a bunch of logs stuck together in the river. Tier upon tier of logs up to eight feet in diameter, and packed solidly enough to be crossed almost anywhere, formed a stable obstacle that supported a forest of 2-to-3-foot-diameter trees growing on its surface. The forested log raft forced the main channel of the river to flow beneath a natural wooden bridge.

Beneath the raft, dangerous rapids raced between deep sheltered pools described by settlers as full of fish. Spanning the main channel, the Mount Vernon logjam obstructed high flows and created a backwater that annually flooded about 150 square miles of the upstream valley. Perennially submerged wetlands and sloughs provided ideal summer rearing habitat and slow-water refuges for salmon during winter floods.

Valley bottoms began to change as settlers and special "snag boats" designed for the task cleaned logs and logjams from rivers. In 1877, after failing to obtain an appropriation from Congress to remove it, settlers started to dismantle the massive Skagit River jam themselves by cutting up the huge logs holding it together. Within a few years the obstruction unraveled and the extensive network of freshwater wetlands along the Skagit River began to dry up.

Settlers soon began to ditch and drain floodplain marshes to create rich farmlands. By the 1930s only scattered wetlands remained along Puget Sound rivers. Today few signs other than subtle depressions across plowed fields indicate the former extent of sloughs and marshes

that historically provided immense areas of rearing habitat for juvenile salmon. Removing the snags, logjams, and streamside trees that created navigation problems and blocked development eliminated some of the most productive salmon habitat on earth.

The program of clearing wood from rivers did not originate in the Pacific Northwest. Snags and logjams also presented treacherous navigation hazards to steamboats in the midwestern and southern states. In the two decades after the end of the Civil War, Army Engineers pulled 46,858 snags and 651 large drift piles from the Mississippi, Missouri, and Arkansas rivers. During this same period Army Engineers cut down an astounding 180,268 streamside trees along these rivers to prevent future snags. Eventually, close to a million snags were pulled from the lower Mississippi, reshaping the river into a fluvial freeway for moving goods through America's heartland.

In 1886 Captain E. H. Ruffner of the Army Engineering Corps wrote a book to promote clearing logs from rivers in order to improve transportation and commerce. In it Ruffner described the dramatic effects of wood on rivers in regions where such effects are barely acknowledged as possible today. Before engineers cleaned up the South's rivers, snags and logjams obstructed rivers from North Carolina to Arkansas. Although little recognized even in academic circles, the effects of wood in these rivers were similar to those documented a century later in studies of Pacific Northwest rivers.

The most famous logjam, called the Red River raft in Louisiana, was a complex of log dams that filled in 140 miles of river and affected almost 300 miles of channel. The jam probably started forming in the late 1400s and built upstream at an average rate of about a mile per year. By the late 1800s it had advanced from near Alexandria, Louisiana, to within 3 miles of the Arkansas border. The immense jam filled mile after mile of channel and prevented passage of all but the smallest craft.

The water impounded behind the massive jam inundated vast areas of the floodplain, and created huge lakes where tributaries entered the main valley. Captain Ruffner described how bank erosion dropped massive trees into the river, which when anchored into the riverbed would split the flow into numerous side channels. Deposition of sediment around these massive trees formed elevated surfaces that filled in to form the valley bottom.

Late in the spring of 1873 Army Engineers finally opened a passage through the massive river-blocking jam after years of effort and failed attempts. That same day a boat laden with cotton steamed up the river and through the opening to inaugurate a new era in river-borne commerce. But success was short-lived. Six years later a flood deposited a huge amount of wood that once again blocked five miles of the river. Rising to the challenge, Army Engineers reopened the river the following year. This time they permanently stationed a snag boat on the river. Learning that rivers remained at risk of obstruction from new logjams wherever large trees could form new snags led the Army Engineers to not only remove logs from rivers but to start cutting down trees standing along their banks.

Removal of the Red River raft triggered extensive changes in the character of the river and valley bottoms. Clearing the log raft drained lakes and vast wetlands, which by 1900 covered just 3 percent of the area that they had inundated before the river was cleared. Within a few decades the farmland created by draining the natural lakes sank beneath the water again, this time under reservoirs created for flood control and recreation.

The consequences of removing logjams in Pacific Northwest rivers were equally dramatic. In 1982 Jim Sedell evaluated the potential for loss of salmon habitat from historical draining of valley-bottom wetlands and side channels throughout the Pacific Northwest by studying pristine rivers in Olympic National Park. His investigation of the distribution of juvenile coho salmon in floodplain channels along the Hoh and Queets rivers showed that almost all of the young fish were in the small side channels that crisscrossed the valley floor. Salmon used the main channel mainly for spawning and migration. Side channels formed by logjams not only provided much of the coho habitat, they held almost ten times more fish. Recently, a similar study in the urbanizing Snohomish River basin just north and east of Seattle found that streams still connected to valley-bottom wetlands host two to three times more adult coho salmon than streams without wetlands.

Streams flowing through forests support three to four times more coho than rural, urban, or agricultural streams. Thus the clearing of valley bottom forests, urbanization, and agricultural development further reduced the capacity of rivers and streams to support salmon throughout the Puget lowland. Even though valley bottom clearing and agricultural practices on floodplains greatly reduced historical salmon abundance around Puget Sound, regulatory attention to the effects of land use on salmon focuses almost exclusively on upland forestry.

Clearing of small streams and upland tributaries for transporting logs followed a few decades after clearing of major rivers. Getting logs to mills was a major problem for early timber merchants. Railroads were expensive, hard to build, and worth constructing only in relatively flat terrain. Rivers, on the other hand, only needed to be cleared of obstructions in order to be used to move logs downstream. On big rivers, logs floated down to riverside mills or piled up at the limit of tidal influence. On small streams, floods released from temporary dams could sweep logs downstream. This practice, called "splash damming," was imported from Maine, where it originated in the 1700s and continued in use until the last log drive down the Penobscot River in August 1971.

In principle splash damming was easy. One simply blocked the river with a temporary dam, filled the lake behind the dam with logs, and then breached the dam to create a wall of water that swept the logs downstream. The resulting flood would do all the work. In practice, however, splash damming was hard, dangerous work.

Logjams were the enemy on a log drive. Woodsmen armed with peaveys—stout poles with a hook on one end—followed the flood to dismantle any jams that formed. Sometimes these guys actually rode the flood wave, perched in nail-studded boots on top of bobbing logs, knowing that to slip could prove fatal in the churning, log-strewn waters.

For logs to be sluiced downstream by a splash-dam release, the channel needed to be free of large debris, boulders, or bedrock outcrops that could hang up logs shooting down the river. Initially, logjams were dismantled one log at a time, starting with the key logs that anchored the jams. Eventually, companies specializing in log driving decided this really was a job for guys with dynamite. Lots of dynamite.

Scores of rivers were simplified by blasting out inconveniently located logjams, boulders, or outcrops that might impede passage of a log-filled flood.

Thousands of splash dams were constructed throughout the Pacific Northwest. Many rivers hosted a whole series of dams. In coastal Oregon, fourteen dams operated on the Millicoma River between 1884 and the 1920s; fifteen splash dams operated on the Coquille River in the first half of the twentieth century. In coastal Washington, splash dams blocked the entire length of some major tributaries: The Willapa River had seventeen splash dams; the Humptulips River had at least eighteen; and the Chehalis River system had over forty-eight. Repeated splash damming must have been a nonstop catastrophe for migrating, spawning, and juvenile salmon, as repeated filling and breaching of these dams sent flood after flood down scores of rivers and streams. Sustained for decades, such intensive, regionwide disturbance was unlike anything salmon or their streams had ever experienced.

Conflicts between timber and fishing interests started almost as soon as commercial forestry began in the Pacific Northwest. Sawmills needed proximity to markets, a way to get logs there, and flowing water to run saws. The mouths of salmon-bearing rivers and streams naturally provided ideal sites. Sawmills began appearing along Oregon's rivers in the 1830s, and by the 1850s Indians were complaining about mills scaring away salmon. Clatsop Indians living along the lower Columbia River insisted that a sawmill near their village be relocated as a condition for signing their 1851 treaty with the United States. They maintained that the sawmill had ruined their salmon fishing.

The tribes were not the only people to notice the effects of logging on salmon. In coastal Washington, salmon hatcheries were constructed in the early 1900s to mitigate the effects of splash dams on commercial salmon fisheries. In Oregon, concern over destruction of docks, land lost to bank erosion, and effects on salmon fisheries led to the Log Boom Act of 1917, which empowered the Public Utilities Commission to regulate splash damming.

Dow Beckham was a logger who when he retired wrote a memoir, *Swift Flows the River*, about a life spent in the Oregon timber industry.

Beckham relates how a 1940 hearing of the Oregon Public Utility Commission over a splash dam franchise on the Coos River captured the essence of the debate between forestry and fishing interests. The Coos River Boom Company argued that a splash dam was the only way for the company to transport timber from the virgin forest on the South Fork of the Coos River to the sawmills on Coos Bay. Their competitors, the Coos Bay Logging Company, owned the only road along which logs could be transported overland. Coos River Boom argued that the splash dam was needed to promote low-cost log transportation and support the local economy. The Oregon State Fish Commission opposed licensing new splash dams, which they believed would decimate economically important salmon runs and imperil the operation of their salmon hatchery. After a series of acrimonious hearings that spanned several years, the Public Utility Commission ruled that the splash dams would provide the greatest public benefit.

Beckham described how log-driving companies, even when subject to restrictions, simply ignored regulations and were "in almost constant violation of the rules. . . . We could not have handled the volume of logs otherwise. If they had enforced the rules, splash dam logging would have terminated" (1990, 113).

The removal of logs that formerly trapped and held gravel, together with repeated scouring to bedrock during splash dam releases, turned many once-productive salmon streams into bedrock chutes with little value as salmon habitat. A 1950 Oregon Fish Commission report written by J. T. Gharrett and J. I. Hodges on the condition of coastal Oregon streams observed,

> Splash dams. . . built for the purpose of sluicing logs down the rivers, have blocked the salmon runs and eliminated the productivity of the streams above them. This practice has also resulted in the sluicing of the gravel and destruction of the spawning areas below the splash dams. Many impoundments for log ponds, power production, and irrigation have been created without providing the proper facilities for fish passage. These have eliminated the salmon runs in many river sections. (20)

A story in Dow Beckham's memoir conveys how splash damming illustrates two recurring phenomena in the history of salmon. At a public meeting in the 1950s between fishery interests and representatives of the Oregon State Fish and Game commissions and the Menasha Corporation, which maintained a splash dam, everyone in attendance except the company officials agreed that Menasha's two splash dams provided inadequate fish passage. Even so, representatives of the state wildlife agencies maintained that no rules or regulations were being violated. Positions staked out at this meeting illustrate how industries contributing to the decline of salmon steadfastly deny even obvious impacts. At the same time, regulatory agencies charged with translating the intent of laws into rule and regulations in fact accommodate powerful economic interests when they shape the rules and their enforcement.

The splash dam era in Oregon spanned eight decades, starting in the 1880s, when timber harvesting began to spread from river valleys into upland areas. Within a decade, a local newspaper, *The West Shore*, reported that in Columbia County, Oregon, every "stream of any size has been cleared of obstructions, so that logs can be run down them in the high water season" (Sedell et al. 1991, 326).

By the turn of the century, the same could be said for counties throughout Puget Sound, the lower Columbia River, and coastal Oregon and Washington. Over three hundred major splash dams operated year-round. Many more operated seasonally on small streams and tributaries. In some upland streams, splash dams operated for just a few decades before the practice began to wane as logging roads and trucks replaced streams and railroads as the logger's transportation network. In the mid-1950s, once river transport of logs was no longer essential to the powerful timber industry, the Oregon state legislature banned the practice, in 1956. In 1966 Potlatch Timber conducted the last log drive in the Pacific Northwest, down Idaho's Clearwater River.

That any salmon at all remain in streams with a legacy of splash damming testifies to their resilience in the face of disturbance. In a pamphlet written for the Washington State Department of Fisheries, *Logging Dams on Coastal Washington Streams*, H. O. Wendler and

G. Deschamps described the effects on salmon of the splash dams operating on coastal streams:

> If fish were spawning, the sluiced logs and tremendously increased flows would drive them off their nests. . . . After splashing, no fish were seen, nor were any seen the following day.
>
> Besides harming the fish, physically, the stream environment was often adversely affected by splashing. Moving logs gouged furrows in the gravel and in many instances the suddenly increased flows scoured or moved the gravel bars, leaving only barren bedrock or heavy boulders. . . . If the sudden influx of logs into the stream below the dam caused a log jam, as was frequently the case, dynamite or black powder was used to clear the obstruction. The policy followed in those days was that if examination showed that two boxes of powder would suffice, four were used. . . . Great numbers of salmon and steelhead trout were reportedly killed by these blasts. (Wendler and Deschamps 1955, 31–32)

The effects of industrial logging on salmon runs were also noted in British Columbia. In *Fishery Problems in British Columbia*, John Laws Hart of the Pacific Biological Station in Nanaimo, Vancouver Island, concluded,

> [H]arvesting of the timber resources in British Columbia has threatened the prosperity of the fisheries for the great anadromous species. . . . [T]he effects of stream deterioration are so great that it is questionable whether it is possible now to state what part of the decline in abundance of salmon is due to interference with spawning grounds and what part of the decline is the result of the fishery itself. (1950, 422)

By midcentury it was clear that habitat degradation due to logging operations was a major factor contributing to depletion of salmon runs on the Pacific Coast.

The pace of landscape change accelerated in the second half of the twentieth century. In short order the newly invented chainsaw and bulldozer reshaped the practices of the U.S. Forest Service and the timber industry, and the land itself. Trees could be felled much faster than before, and roads could be punched in almost anywhere. After the Second World War, the U.S. Forest Service and the timber industry constructed in the nations forestlands the most extensive road network ever built. Almost half a million miles of logging roads form a system almost ten times more extensive than the interstate highway system—long enough to circle the globe more than fifteen times. The length of the road system rivals or exceeds the total length of streams and rivers in many areas across the forestlands of the Pacific Northwest.

Once, when I asked a timber industry colleague about access to a potential study site, he jokingly assured me that we didn't need to worry. His company had roads to within 100 yards of anywhere on their vast holdings. His jest isn't far from the truth. The pace of timber cutting increased astronomically as logging roads carved the landscape into forest patches about the size of city blocks.

Almost immediately, fisheries biologists noticed an effect on salmon runs. Gharrett and Hodges's 1950 report, in which they summarized the effects of logging on coastal Oregon streams, concluded that such effects were obvious. Specifically, they found that logging operations resulted in loss of gravel from streambeds, silting in of spawning gravels, and higher stream temperatures. Their report also noted how branches and unmarketable wood dumped into streams by logging operations resulted in logjams thought to be impassable to fish, and they were careful to discriminate between most natural logjams and those that were impenetrable fish barriers.

Concern over the effects of logging slash in streams and the blocking of fish passages led biologists to call for stream-cleaning programs to keep logging debris out of streams. Fisheries biologists made it a priority to remove such jams to open up access to hundreds of miles of spawning areas. Growing perception of logging-generated logjams as barriers to salmon migration set the stage for new forest-practice rules prohibiting the dumping of logging debris in streams.

Soon, however, the idea of keeping logging debris out of streams mutated into a paradigm of keeping rivers and streams free of wood altogether. From the 1950s to 1970s natural resource agencies worked diligently to clear wood from streams. The landmark 1972 Oregon Forest Practices Act actually required removal of wood from streams. Washington adopted similar rules. California too. All along the West Coast a clean stream not only looked like a good idea, it was the law. Ironically, recognition of the cumulative effects of many small man-made dams in the decline of Atlantic salmon provided a (misguided) rationale to strip natural logjams from Pacific Northwest streams. Over the next several decades, increased understanding of Pacific Northwest streams and rivers revealed that this notion was tragically misguided.

Not everyone advocated stripping all wood from rivers. Henry Froehlich, a professor of forest engineering at Oregon State University, cautioned, "Overcleaning channels may not be in the best interest of stream protection. We must recognize what the stream systems are like in their natural condition and also to understand the role of the organic debris in these channels" (Froehlich 1973, 84).

At first Froehlich's advice fell on deaf ears. Without the ability, training, or inclination to determine which wood was natural and which was logging debris, most stream-cleaning crews simply removed everything they could lift or hoist from channels. Soon it became difficult to find streams that had not been stripped of logs and logjams.

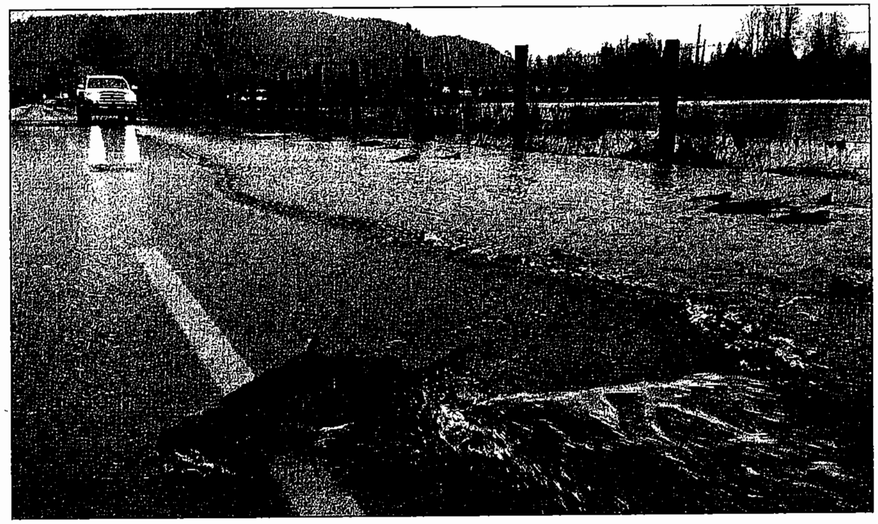
Following Froehlich's call to base stream management on an understanding of natural stream processes, scientists learned that large woody debris is a major influence on stream ecosystems and salmon habitat in the Pacific Northwest. Current understanding of Northwest salmon streams holds that formation of logjams, channel movement during floods, and catastrophic disturbances create and maintain some of the best salmon habitat. Sloughs and side channels that harbor juvenile salmon are created when rivers jump around their valley bottoms as a result of floods or logjams. Big logs that fall into rivers and streams help form deep pools and provide structure to salmon habitat. Curiously, destructive landslides and floods that knock big trees into streams and rivers help provide an environment in which salmon thrive in the times between such disturbances.

Changes in land use and forest cover can alter how sediment and water move across and through the landscape and thereby change the structure and dynamics of salmon habitat. The Skokomish River, which flows into Puget Sound east of Olympia, is a poster child for the impacts of misguided forest practices, river management, and land use in the Pacific Northwest. Normal rivers spill over their banks about once a year or two. That's normal. In most years along most rivers, the annual flood is not much higher than the banks and causes little inconvenience even to those living on the floodplain. Yet the Skokomish River now floods many times in most winters, leaving no doubt that it is one seriously disturbed river.

Year after year Seattle's TV newscasters diligently report that the Skokomish is once again flooding at the first sight of rain without questioning or investigating why this is happening. In the winter of 1998–99 the Skokomish River flooded twelve times. Mason County emergency management officials complain that it seems the county has to respond to the threat of flooding almost every time it rains. Rivers simply are not supposed to flood several times a month all winter long. Bill Hunter, a seventy-two-year old farmer who had lived along the river most of his life, complained that the river now floods so frequently that it limits what he can grow. He recalls when the river had deep pools, in striking contrast to the present shallow, featureless channel.

So what caused the mess on the Skokomish? In 1929 the city of Tacoma's Cushman Dam was built on the North Fork of the Skokomish River, which reduced the flow in the river downstream of the confluence of the North and South Forks. This also reduced its ability to carry sediment. Intensive timber cutting destabilized steep slopes in the basin headwaters, and gravity carried hill-slope soils down to the river. The level of the riverbed started to rise as the slug of sand and gravel moving down the South Fork arrived at the confluence with the de-watered North Fork. The supply of sediment moving downstream simply overloaded the river, which filled in 6 feet between 1950 and 1990. The rain hasn't stopped, the runoff still has to go somewhere, and the channel can't hold it anymore. So now the river frequently spills out over its banks and across the floodplain.

The Skokomish River is a classic example of "living downstream." Yet in all the TV time dedicated each year to covering flooding on the



In November 2001 a chum salmon tries to get across a flooded road to reenter the Skokomish River.

Skokomish, nobody talks about how upstream land use affects folks living downstream. The people living on the floodplain of the Skokomish River did not build the dam. They don't receive power from the dam. They did not profit from cutting the trees down in the basin's headwaters. They just got stuck with the bill: houses, farms, and roads that get flooded all the time.

The effects on salmon populations of changing stream environments became increasingly obvious to fisheries managers in the second half of the twentieth century, even though the basics were understood fifty years ago. In 1951, even as their annual reports continued to blame Indian fishing for declining salmon runs, the Washington State Department of Fisheries published *The Salmon Crisis,* a pamphlet which stated frankly, "The main causes of salmon depletion can be traced directly to the environmental changes that have taken place since the advent of civilization in the Pacific Northwest" (1951, 5).

Although changes in habitat structure due to loss of large trees transformed the physical structure of Pacific Northwest rivers, other environmental and land-use changes played an important role. Agriculture spread rapidly across floodplains, further simplifying channels. Within a few decades after rivers were cleared of snags and logjams, the floodplain sloughs were ditched, valley-bottom wetlands were drained, and side channels were plugged. Increased human occupation and use of floodplains made the natural occurrence of flooding a problem, so extensive networks of dams and levees were built to control floodwaters. Many rivers were straightened to reduce flooding and speed water on down the river. After a twentieth-century orgy of dam building, the continental United States now has 75,000 dams that together can store an average year's runoff. An estimated 25,000 miles of levees enclose more than 30,000 square miles of floodplain in the United States, an area larger the combined area of Massachusetts, Vermont, and New Hampshire.

Extensive construction of levees and dikes diminishes floodplain storage of water during floods, for confining the water within a walled-in channel just pushes flooding farther down the river. So once levees are built along part of a river, pressure mounts to extend the system downstream until eventually levees line the whole river. The result is a straight-jacketed river that can no longer move across its floodplain. Once locked in place, a river no longer supports natural processes of channel migration that create the side channels and off-channel water bodies that shelter young salmon.

Flood-control efforts can also exacerbate flood hazards by encouraging human occupation of flood-prone areas. Flooding is a problem created by people living in or building on areas that become part of the river during high flows. Settlers knew that rivers periodically spilled over their banks, so they built on high ground in the valley bottoms, above the level of frequent inundation. Once levees along a river stop the annual high flows from reaching the floodplain, development typically spreads across the flat ground near the river—usually right up to the levee. Unfortunately, rare but inevitable heavier flooding puts floodplain development at risk when the water rises over the levees or they eventually fail. I doubt whether old-timers, if they had the chance, would buy houses in new developments sprawling indiscriminately across floodplains, especially those in drained wetlands lying at (or sometimes even below) river level.

New development, levees, and fields on the floodplain of a river near Seattle in the 1990s.

As a piece of the landscape, floodplains occupy a relatively small percentage of the mountainous Pacific Northwest. In the region around Puget Sound, direct and indirect subsidies maintain human occupation and uses that run headlong into the inevitable periodic inundation of floodplains. Such subsidies include public money spent on rebuilding dikes and levees in the same places over and over again after floods. Additional costs accrue for repairing bridges, houses, roads, and businesses on flood-prone land. Policy makers and agencies are starting to ask why society subsidizes, and thereby encourages, human occupation of floodplains. Still it remains rare for the loss of salmon to be included in assessments of the costs associated with floodplain development.

In a 1964 report, "King County, Washington, Comprehensive Plan for Flood Control," written for the Board of King County Commissioners on flood protection along Seattle's Cedar River, the engineer Bertram Thomas noted, "The stream historically has claimed the whole valley for its use. . . . As a matter of fact, the flood control funds disbursed on the Cedar River in recent years would have covered acquisition costs of all lands along the river several times over" (1964, 26–27). In other words, the cheapest long-term solution to flooding problems would be to simply buy the entire floodplain and relocate the people living there. Out of step with the times, this unconventional idea was ignored. Since then, development that spread across the floodplain greatly increased the cost of flood control, and the river was locked into place by levees. In recent years the county has spent more on restoration projects along the Cedar River than it would have cost to simply buy the entire floodplain in the early 1960s.

Around Puget Sound, urbanization changed the way water moves across and through the landscape. Pavement and buildings prevent water from sinking into the soil. This increases runoff in proportion to the area of impervious surfaces. In many developed areas, the increased runoff turned the annual high flow into an annual cataclysm for stream-dwelling organisms. Not surprisingly, fish with eggs in the gravel during the months when storms normally hit quickly disappeared. Adapted to digging nests in tune with smaller flows, the higher flows scoured out their incubating eggs. The typical pattern for urban streams was for fall-spawning salmon to be replaced by cutthroat trout, which spawn in the spring when their eggs are generally safe from high flows.

The Washington State Department of Fisheries recognized the threats posed by urbanization, stating in its 1965 annual report, "Real estate development continues to contribute an increasing number of hydraulic project proposals . . . but protection to the fishery is not always easily attained as fishway construction and alteration of plans may be costly to the developer" (Washington State Department of Fisheries 1965, 61). Project by project, development modified streams across the Puget Lowland. Powerless to stem land-use changes, the state Department of Fisheries lacked the authority and mechanisms to enforce meaningful salmon protection measures in the rapidly urbanizing Puget Lowland.

In the ten-year plan the Department of Fisheries prepared for the state legislature in 1967, it offered a stark prognosis.

> If no more stream losses were to occur, natural production of salmon would probably be maintained at a relatively high level. This, however, will not be the case, as evidenced by recent initiation of extensive channelization and flood-control work. . . . The future outlook for Puget Sound and Washington rivers and streams for salmon use appears rather bleak if we allow the present trend of hydraulic changes and encroachment to persist. (Washington State Department of Fisheries 1967, 25–26).

Although no directives from agency heads and elected officials privileged developer's interests over salmon, the system was set up so that the fish would lose—one project at a time.

In addition to paving over or changing the hydrology of streams, urbanization also drove demand for gravel, which is essential for construction and typically is mined from riverbeds. Surprisingly, the annual value of sand and gravel mining exceeds by far the value of gold mining in Washington State. As Washingtonians poured more and more concrete, gravel mining carved deeper into riverbeds and farther across floodplains along major rivers. Unfortunately, gravel is also essential to salmon, as the Department of Fisheries noted: "Gravel removal is a constant and increasing problem. Gravel is a basic element to natural salmon reproduction and excessive removal . . . can be extremely costly to the salmon resource. The impact in many cases can never completely be overcome. . . . Little change in this trend is envisioned in the near future" (Washington State Department of Fisheries 1965, 60).

Development also fueled demand for water. Projections of the water demand for industry and agriculture in the 1960s left "little doubt that many streams presently having adequate minimum flows for fishery purposes will be in serious trouble within the next decade" (Washington State Department of Fisheries 1966, 176). Thus, as urbanization proceeded across the Puget Lowland, it put people and salmon in direct competition for the two key things salmon need most: water and gravel.

Urban streams present a difficult challenge for salmon recovery efforts because of the fundamental changes in runoff and land cover that accompany development. Some measures to manage urban runoff, such as using porous concrete to allow rainfall to sink into the ground and thereby slow runoff, may be expensive at first but economical if considered over the long haul. Many other measures simply require not doing certain things that developers and homeowners like to do, such as paving over driveways with hardtop, clearing streamside trees and armoring streambanks, or building levees to keep channels from moving around. Simple measures for rehabilitating urban streams include managing stormwater to prevent excessive increases in peak runoff, protecting natural wetlands from development, moving levees back from the channel's banks, and prohibiting development in "channel migration zones" so that channel movement is possible across a portion of the river's floodplain.

In addition, we must decide which rivers and streams to protect, and which if any to write off in the urban environment. This point is controversial and is rejected by many committed environmentalists. But the Port of Seattle is not going away anytime soon. The habitat quality of the lower Duwamish River is improving, but it is simply not restorable in any reasonable time frame to its former glory as a salmon river. In contrast, the relatively rural Snoqualmie River and many of its tributaries still can be protected from urban encroachment and development. Given the projected doubling of the human population around Puget Sound in the next fifty years, choices need to be made, or they will be made by default and accident rather than by design. And it was the day-to-day accumulation of little decisions that over time transformed the freshwater world of salmon.

Recognition of the effect of forest clearing on Pacific Northwest rivers is leading to regional efforts to reintroduce wood to rivers. Controversy over allowing logs and logjams back into rivers currently focuses on the interests of recreational boaters who want to keep rivers clear of logjams, which can present a hazard to kayaks and canoes. Though boating organizations certainly are justified in seeking to minimize risks for boaters, a perfectly safe river free of wood is a river with few salmon.

The size of forest buffers to be left uncut along streams also is controversial in both commercial forestlands and urban and rural lands. Until recently the debate over the size of forest buffers neglected the key point that rivers move. But now channel migration zones are being prescribed to account for the propensity for channels to move around across a river's floodplain. Most regulators understand that wood is important to fish, but I suspect that few fully comprehend what will happen as big trees are reintroduced as a dynamic element in rivers. As big wood returns, rivers will start to once again behave as they used to, bouncing around their floodplains and eroding their banks and depositing bars of sediment. In a pristine river this is the norm. But now there are people living on floodplains. And there are roads and towns and other things in the way that people don't necessarily want to lose to a migrating channel. If we succeed in restoring rivers they will definitely behave differently from what we are used to, and will potentially cause the kind of trouble that salmon could use for a change.

A key question for salmon-recovery efforts in the Puget Sound region is where we want our rivers to fall on a continuum from a wood-rich, multichannel river to a controlled, wood-free canal. Should we target habitat conditions as they were in the 1850s at the time of the Indian treaties? Or should we strive for conditions in 1900 immediately after the clearing of valley bottom forests? It would be easier, and less effective, to set the bar a little lower and target conditions in the 1950s after rivers were canalized, levees blocked off of side channels, and valley bottom wetlands were drained. The easiest, and least effective, approach would be to hold the current line and guard against *further* degradation of salmon habitat.

Naturally, the optimal strategy depends on whom you ask. If you give top priority to navigation or development in the floodplain, the wood-free, levee-bound Snohomish River is the obvious model. If you give top priority to salmon production, then you are aiming for a river like the wood-filled, split-channel lower Nisqually River. But salmon-recovery goals should also take into account the innate capacity of the river to produce salmon. Unfortunately, land-use changes have caused rivers with historically very different channel patterns to lose their distinctive features and assume relatively similar, simplified patterns.

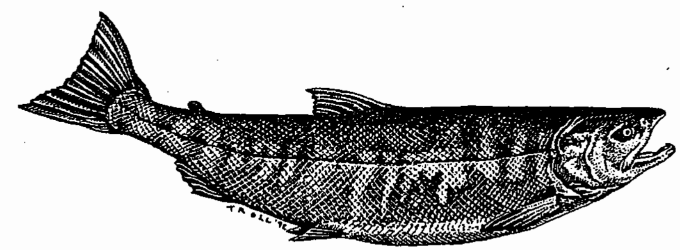
The impacts of freshwater habitat loss are not evenly distributed among salmon species. Chum salmon (*Oncorhynchus keta*) populations around Puget Sound are doing well in spite of the dramatic changes to river systems. More or less ignored by commercial fishermen, they've been increasing in recent years. Pink and sockeye runs are also doing reasonably well, more or less holding their own. It is the chinook and coho runs that are in the greatest danger, with populations continuing to decline below perilous levels.

Why the big difference? Chum salmon spend very little time in freshwater. Juveniles pretty much head straight to sea after hatching, minimizing their dependence on freshwater habitats. In contrast, coho and chinook spend one or more years in freshwater habitat before heading to sea. It is no coincidence that the salmon most dependent on freshwater habitat are in the deepest trouble. Conversely, it is no miracle that the Queets and Nisqually rivers, which remain much as they were before civilization transformed the region, still support relatively healthy runs.

Recovery of Puget Sound coho and chinook will only happen if we let rivers behave more as they did when they sustained large salmon runs. These fish not only need water, they need dynamic rivers to create and sustain suitable habitat. Without a doubt, the best way to allow a river to retain some natural character is to give it a little room to move around and, well, act like a river.

CHAPTER
11

The Sixth H



Our present problem is one of attitudes and implements. We are remodeling with a steam shovel, and we are proud of our yardage.

Aldo Leopold, *A Sand County Almanac*, 1949

THE THOUSAND-YEAR RUN OF SALMON ILLUSTRATES HOW technological advances and land-use change can magnify the effects of intensive fishing to eventually exhaust a public good. Details vary from region to region and from river to river. But recurring themes run through the strikingly similar stories of salmon declines throughout the animal's range.

Huge salmon runs initially provided an abundant food source that sustained subsistence economies in Europe, the American-Canadian Northeast, and the Pacific Northwest. In all three areas, native people relied on salmon fisheries, which they protected through cultural practices that restrained overexploitation. In the absence of technologies to