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THE GREAT FAILURE: NINETEENTH-CENTURY DISPERSALS OF THE PACIFIC SALMON

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This paper is an account of the first attempts to naturalize Pacific salmon (*Oncorynchus spp.*) outside of their home range. The experiment spanned ten years in the late nineteenth century, a time when thousands of plant and animal species were successfully adapted to new homelands. In this context, dispersal of the salmon was a squib in the ecological explosion. The first facility for collection of salmon eggs was built on the McCloud River, a tributary of the Sacramento, in 1872.[1] Between 1873 and 1881, the United States Fish Commission took more than 50 million eggs at this station. These eggs accounted for 14 million young salmon planted in the Sacramento system, and 33 million fertilized eggs that were shipped to other parts of the United States. Only the Territories and the state of Florida made no attempt to naturalize the salmon during this period (Figure 1). Another 4.9 million eggs were distributed among Europe, eastern Canada, Hawaii, Australia, and New Zealand (Table 1). Hatchery technology and shipping methods were efficient enough so that, in spite of enormous distances traveled, about 75 percent of the eggs hatched; and somewhat more than 28 million young salmon were liberated in alien streams and lakes.

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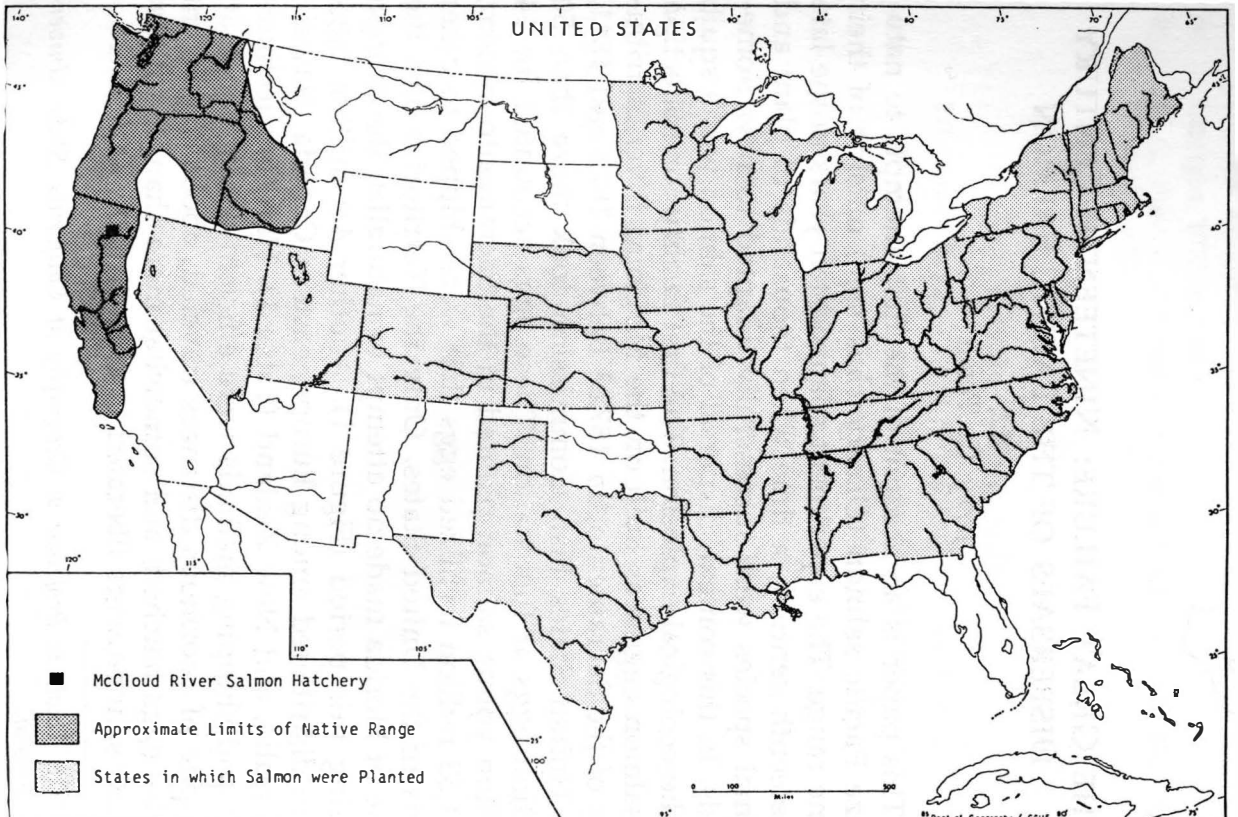

Figure 1. Dispersal of Chinook Salmon, 1873-1882.

Table 1: SALMON EGGS CONSIGNED TO FOREIGN COUNTRIES, 1874-1881

Country	Number
Canada	1,415,000
New Zealand	1,175,000
Germany	830,000
Netherlands	500,000
France	358,000
England	200,000
Australia	150,000
Hawaii	30,000

Source: United States Commission of Fish and Fisheries, *Report*, 1881.

The experiment ended in 1882, a total failure. Though young salmon appeared to thrive in some streams, and a very few adults were reportedly taken, no reproducing populations had been established. This effort, considering the difficulty of building and maintaining a hatchery on the remote McCloud River, the number of fish produced, and the breadth of the dispersal field, may have been the greatest failure of early fish culture. By contrast, a total of 435 juvenile striped bass (*Roccus saxatilis*), transported from New Jersey to the Sacramento River in 1879 and 1882, produced an enormous Pacific population, one that has since spread northward to the coastal rivers of Oregon. At about the same time a few hundred carp imported from Germany were to produce the entire North American subrace of this species.

The salmon was one of many creatures carried to alien lands during the nineteenth century. Immigrants to new homelands often deplored what seemed to them incomplete and unsatisfactory plant and animal assemblages. In older settled regions, deterioration of nature under the impact of human depredations led to similar dissatisfaction. Transportation improvements made practical the

importation of alien species to augment or rehabilitate nature. In retrospect, convinced as we are of the sanctity of ecosystems, the period was one of exuberant and haphazard tinkering with the natural order. Few laws governed importation of exotic plants and animals. Individuals and voluntary associations dedicated to naturalizing aliens were limited only by imagination and finances. Acclimatization societies proliferated, especially in New Zealand and Australia, where the need to reform nature was apparently most urgent.[2] Similar groups formed in North America; the Ornithological and Piscatorial Acclimatizing Society of California, for example, was organized for the purpose of importing and and naturalizing every species of bird, fish, and game animal native to Europe and the eastern United States.[3] Other such societies brought the starling and the English sparrow to North America.[4]

Improving the Fisheries

Large scale dispersal of fish species in the United States depended upon completion of transcontinental rail links. Although private and state initiatives started earlier, systematic nationwide efforts began with establishment of the United States Fish Commission in 1872. Congress charged the Commission with investigating

> . . . the cause of the decrease of the seacoast fishes and those of the rivers and lakes with suggestions as to the best methods of restoring the same; and active measures looking toward the propagation and multiplication of the useful food fishes, either by restocking depleted waters or by introducing desirable species into new waters.[5]

For a body dependent on congressional appropriations, introduction of useful species proved to be an excellent public relations program. Congressmen with little tolerance for pure research could, at least, point to some tangible improvements in their home states or districts to justify funding the Commission. Too, increasing the supply of fish was greatly preferable to restricting the harvest,

both because of popular appeal and enforcement costs. Early choice of species to be propagated and transported at government expense reflected a spartan sense of federalism. The Commission concentrated on anadromous fish, whose spawning migrations or oceanic life carried them beyond the jurisdiction of a single state, and food, rather than sport species.

Fish introductions, like the general movement of population, were mostly from east to west. Private, state, and federal efforts brought twenty-one exotic species to California between 1871 and 1900.[6] Only two Pacific slope species, the Chinook salmon (*O. tshawytscha*) and rainbow trout (*Salmo gairdneri*) merited transport out of their native range in the period. The salmon not only overcame the piscatorial chauvinism of the east, but also became the most prized and most widely dispersed of American fishes.

Early Appraisals

Enthusiasm for introducing the salmon sprang from a solid evaluation of its value as a food fish, and a wildly erroneous interpretation of its adaptive capacity. Early western travelers has testified to the edible quality of the salmon, and to their astonishing abundance in rivers during the spawning migrations. Commercial exploitation began early in the settlement of the west; salmon canneries had started operations on the Sacramento River by 1852. Markets for canned salmon extended as far afield as Australia; and frozen fish, at least occasionally, appeared in New York City. As a food fish, it seemed to be almost the equal of the scarce and expensive Atlantic salmon.[7] In contrast to purely oceanic species, the salmon were netted as they ascended their natal streams to spawn. Fishermen took large numbers in relatively short times with river drift nets, gill nets, and seines, a type of fishing generally more certain and economical than pursuing marine fish on the open sea.

Yet, the salmon was threatened in its native range, just as its qualities began to attain world-wide recognition. Observations on the deterioration of salmon runs in the Sacramento River appeared in California newspapers as early as the mid 1850's.[8] Hydraulic gold mining debris blanketed spawning gravels in the Sacramento system; by 1875 the Feather, Yuba, and American Rivers—all major salmon streams twenty years earlier—had no spawning runs at all.[9] The McCloud River was, in fact, chosen for the site of the first hatchery because it was one of the few streams in the state that still maintained a healthy salmon population.[10]

As spawning areas diminished, fishing pressure took its toll. In addition to the cannery fleets intercepting adult spawners, Chinese shrimp fishermen on San Francisco Bay killed millions of juvenile salmon with their fine-meshed nets.[11] Some fishermen went so far as to advocate the slaughter of sea lions, whose depredations could not be countenanced in a time of scarcity. However the blame may have been apportioned, by 1864 one salmon-packing entrepreneur stated that the Sacramento was no longer fit for commercial fishing.[12] The Columbia River, the second of the great salmon streams to be exploited, began to show similar deterioration by the mid 1870's.

At least in part, then, desire to naturalize salmon in new waters was an attempt at preservation. Although the salmon was not literally endangered in 1872, the lesson of the bison's precipitous decline to near extinction was not lost on naturalists. A much closer biological parallel, somewhat more distant in time, was the history of the Atlantic salmon (*Salmo salar*) in the United States. When the Fish Commission began its work in 1872, spawning populations of the Atlantic salmon occurred only in five small rivers of northern Maine. Yet in colonial times the species had ascended rivers as far south as Long Island Sound, and in such numbers as to inspire contempt; a common stipulation in the contracts of indentured serv-

ants was they not have to eat salmon more than twice a week.

Hatchery Experiences

Early experiences in collecting, fertilizing, and transporting eggs made the salmon seem to be a remarkably hardy species. Livingstone Stone, the architect and supervisor of the McCloud River hatchery, noted that the eggs were taken in late summer, when air temperatures often reached 110° F. The fertilized eggs, packed in moss, endured a twenty-two mile wagon trip over a rough mountain road and then a rail journey of up to 3,000 miles. In spite of these hardships, one of the first consignments sent to the east coast suffered a loss of only 11 percent during shipment and hatching.[13]

Survival rates on the much longer journey to New Zealand were even more impressive. Stone described the rigors of the trip:

> In the first place, we had to pack the eggs on a warm day, because the salmon spawn in warm weather. The day I came away the thermometer stood at 104° in the shade and 125° in the sun. After they get to the railroad terminus, they are taken three hundred miles to San Francisco, and there they stay two nights and a day, and then are carried to the steamer, and then are carried by the steamer seventy-six miles [*sic*], most of which is through the tropics and across the equator, and at the end of that distance are taken out; and I think it is perfectly surprising that the eggs of any fish whatever can be carried so far in unfavorable circumstances and come out alive.[14]

In this case, five consignments of eggs sent to New Zealand acclimatization societies withstood the journey very well, in that hatching rates ranged from 75 to 90 percent.[15] By contrast, several efforts to ship Atlantic salmon eggs from Britain to New Zealand during the same period failed almost completely, when some 772,000 eggs packed in Britain ultimately produced fewer than 4,000 fry to be liberated in New Zealand streams.[16]

Once hatched, the Pacific salmon continued to impress fish culturists. An eastern hatchery operator who had worked with the Atlantic species reported that the "California salmon" grew as much in three months as the Atlantic salmon would in a year.[17] A similar report from Germany stated that the Pacific salmon grew to the length of a hand in less than a year, a size that European salmon did not achieve for eighteen months.[18] Growth rates were not the only praiseworthy trait. An anxious Australian cast a fly over his hatchery pond, and reported that the young Pacific salmon fed at the surface as eagerly as the Atlantic variety he remembered from Britain.[19]

Planting Strategies in the United States

That these salmon were so widely dispersed in the United States indicates optimism that the fish could survive and reproduce in a variety of alien environments. Analysis of the number of salmon stocked in each state reveals several strategies (Table 2). One major hope was that the Pacific salmon could colonize the streams of New England. Dams built in the colonial and early national period had damaged Atlantic salmon more than overfishing, and construction of fish ladders could once again give anadromous fish access to upstream spawning areas. Because so few Atlantic salmon remained in the United States by the 1870's, rehabilitation could proceed more rapidly with the relatively abundant Pacific variety. Success seemed likely; for biologists were not yet certain that the two populations represented different species, let alone different genuses, until after planting efforts had started. The early, intense, planting in the New England states, particularly Connecticut (Table 2), reflects this hope.

Obviously, plans for the salmon went far beyond this limited strategy; sanguine analogies were drawn between the home range of the genus and almost every region in the temperate and subtropical world. The major flaw in such reasoning sprang from very sketchy knowledge of

Table 2: SALMON PLANTING BY STATE, 1872-1880

State	Number of Fish	Number of Plantings
Maryland	2,999,000	201
Pennsylvania	1,860,000	77
New Jersey	1,650,000	79
Michigan	1,460,000	167
Connecticut	1,330,000	19
Virginia	1,120,000	46
Wisconsin	830,000	46
New York	795,000	66
North Carolina	759,000	33
West Virginia	709,000	49
Ohio	620,000	27
Minnesota	600,000	325
New Hampshire	567,000	17
Iowa	555,000	150
Missouri	546,000	29
Nebraska	490,000	9
Utah	456,000	21
Indiana	443,000	8
Illinois	430,000	27
Kansas	389,000	89
Massachusetts	288,000	12
Texas	214,000	N/A
Nevada	200,000	2
Rhode Island	183,000	8
Kentucky	144,000	70
Tennessee	78,000	6
Mississippi	72,000	4
South Carolina	71,000	33
Maine	47,000	5
Louisiana	43,000	3
Vermont	35,000	4
Alabama	30,000	2
Georgia	29,000	16
Colorado	23,000	4
Delaware	21,000	4
Arkansas	11,000	9

Source: U. S. Bureau of Fisheries, *Report*, 1881.

the salmon's life cycle and environmental requirements. As an example, the controversy over whether all Pacific salmon die after spawning persisted for years after planting efforts started. One authority of the period thought that Pacific salmon spent only about four months in salt water, and that near the mouth of their natal streams.[20] In fact, every species of the the genus stays at sea for at least one and one-half years, and individuals may remain in salt water for six years. During this time, the fish may travel 2,000 miles. This misunderstanding led to an overemphasis on stream conditions as predictors of successful naturalization, and a corresponding neglect of oceanic environments. In this light, it seemed particularly noteworthy that salmon ascended the Sacramento and San Joaquin Rivers. Both of these streams supported spring runs of Chinook that spawn in tributary streams in late summer. Adult spawners successfully navigated hundreds of miles of river at a season when water temperatures rose as high as 83° F. Moreover, the Sacramento was a particularly dirty stream, choked with the sediment of hydraulic mining. The California salmon was a welcome exception to the dictum that salmonids demand cold, clear streams, and so seemed fit to colonize waters unsuited to other members of the family. Spencer F. Baird, first director of the Fish Commission, said in 1874:

> Taking into consideration the temperature, the turbidity, the volume, the velocity, and the character of the sources, as well as other physical conditions of the rivers inhabited by the California salmon, it seems probable that a very large number of the rivers of the eastern United States are equally adapted for the production and growth of this species.[21]

Baird also noted that few rivers of the Atlantic slope were as turbid as the Sacramento, and that both they and the larger rivers of the Gulf states had as their sources the cool, spring-fed brooks of the Appalachian uplands. These mountain tributaries were to be the spawning grounds of the salmon, like the Sierran tributaries of the

Sacramento and San Joaquin. Even some Texas rivers showed promise:

> The Brazos and Colorado Rivers of Texas have their sources among the the springs of the southern hills and spurs of the Rocky Mountains, and the Guadalupe and San Antonio Rivers are spring fed.[22]

A large part of the planting effort, accordingly, went to establish the salmon in Atlantic rivers south of the native range of the Atlantic salmon. The Delaware and Chesapeake Bay drainages in particular seemed analogous to the home waters of the salmon in California. Apart from latitudinal similarity, mountain-born rivers reaching the sea through large estuaries made these two Atlantic drainage basins much akin to the Sacramento-San Joaquin system. The concentration of effort here is indicated by Maryland, Pennsylvania, and New Jersey's positions as the the leading states in the number of salmon planted. Another large number of salmon were stocked in the James River system of Virginia.

On the Atlantic coast, the Pacific salmon were to help rebuild a deteriorating fishery. Fish culturists saw the Mississippi drainage as another region in need of help, its problems due more to the stinginess of nature than human despoliations. One ardent advocate of large-scale introductions depicted the fisheries of the interior, in the early 1870's, in terms so bleak as to be unrecognizable to natives:

> . . . the residents along the eastern bays and lagoons and upon the larger rivers derive their principal means of sustenance directly from these waters, and in all of these districts far more families are supported by the waters than by the land. In the west there is nothing of this sort. The markets are almost bare of fish; a few catfish, suckers and pickerel constitute the wretched and meager bill of fare they offer. The muddy Mississippi contains little or nothing. The beautiful Ohio has but one or two sorts of pike and perch, which the inhabitants flatteringly call salmon, while catfish hide in most of the discolored streams of our continent, and suckers explore the

> bottom for their food . . . there is no reason why the waters of the west should be less prolific than those of the east, providing the right species were introduced; and were trout, salmon, shad, bass and sturgeon to take the place of catfish, pickerel and suckers, the gain would be manifest.[23]

Indeed, once temperature and turbidity had been dismissed, the possibility of making the Mississippi a salmon river seemed bright. Baird agreed that sheer distance from the mouth to the northern tributaries might be an obstacle, but cited migrations of salmon in their native range as evidence that the fish could overcome this problem. After noting that spawning grounds on the Snake River are some 1,800 miles from the mouth of the Columbia, and that the shad of China reportedly migrate 3,000 miles up the Yangtze, he concluded:

> . . . we may infer that the instinct of location is probably sufficient to attract a colony of fishes as far inland as the headwaters of the longest river, whenever their home has once been established there.

Further:

> The vigorous strength and energy exhibited by the California salmon during its migrations up the Sacramento and Columbia Rivers afford the evidence that its capacity for a long migration from the sea to its spawning grounds, is unsurpassed by any species of fish known.[24]

Salmon were planted extensively, though thinly, in the tributaries of the Mississippi. The experiment ranged from sources of the Ohio in Pennsylvania to the headwaters of the Platte in Colorado. Northern tributaries in Wisconsin, Minnesota, and Iowa were more heavily stocked than the southern, perhaps in the hope that latitude could compensate for low elevation in providing cool spawning streams. Approximately 1.5 million young salmon were liberated in the streams of these states between 1875 and 1881. If any of them did migrate down the Mississippi, none returned.

The Pacific salmon is an anadromous genus, but other plantings were made to produce a purely fresh water variant. The basis for this hope—ultimately justified by the twentieth-century establishment of the salmon in the Great Lakes—was the accidental creation of land-locked populations in three small reservoirs near San Francisco. In each case, the construction of dams prevented young salmon from reaching the sea in their downstream migration. These salmon matured in the reservoirs and spawned upstream; freshwater populations persisted for at least nine years.[25] One fisherman noted in 1875 that it was possible to take a hundred salmon a day from the San Andreas Reservoir.[26]

Although salmon survived and multiplied in these small impoundments, lack of food cut growth rates so that mature fish were considerably smaller than their seagoing counterparts. Adults averaged only about two pounds after three generations. Larger lakes, with more food, should produce larger salmon. To test this theory, Pyramid Lake in Nevada, Lake Tahoe, and Great Salt Lake each received consignments of salmon. Tulare and Buena Vista Lakes, in the southern end of California's San Joaquin Valley, were also stocked. Far larger numbers went into the Great Lakes. Michigan alone received almost 1.5 million salmon, and a part of the number planted in Wisconsin, Minnesota, and other midwest states were in the Great Lakes, rather than the Mississippi drainage. Farther east, the Pacific salmon were to replace extirpated populations of landlocked salmon (*Salmo salar sebago*) in Lake Ontario and Lake Champlain. None of these efforts to establish fresh-water populations succeeded.

The Salmon Overseas

European fish culturists also found the environmental tolerance of the Pacific salmon attractive. Herr von Behr, director of the German Fishery Association, saw the

species as an ideal colonizer for the Danube system, one that would:

> . . . bring the vast fish food of the Black Sea to the beautiful Danube country changed to delicious salmon. The journey which the salmon would have to make, as far as Sigmarigen, would not be much longer than that of the California salmon in its home, not to mention the numerous tributaries of the Danube. If the Lower Danube is, during the summer, as 'hot as hell' as we are told, the California streams, where they flow into the sea are certainly not much cooler. As the Rhine (Atlantic) salmon is not suited to the Danube, it was worthwhile to attempt the introduction of the California salmon.[27]

In this case, as in other efforts, the plan failed. Some 350- to 400,000 young salmon were planted in the upper Danube and its tributaries with no results.

Declining populations of Rhine salmon led in 1878 to similar experiments in the Netherlands. More particularly, the Pacific salmon was to prove the benefits of pisciculture to a skeptical public. The chief fisheries official of southern Holland noted that his research had been complicated by unwillingness of fishermen to report capture of marked Rhine salmon produced in hatcheries. Because tabulation of such fish was the only way to measure the success of hatchery operations, he concluded that introduction of the exotic salmon, one easily distinguished from the native species, was necessary. Nearly 100,000 juvenile Pacific salmon were, accordingly, planted in the Meuse River, again with no success.[28]

European interest in the Pacific salmon was basically as an exotic that could complement the native Atlantic salmon as a sport or food fish. Failure to establish one more salmonid on a continent whose streams already held several species was in no sense critical. In New Zealand and Australia, however, the need seemed more urgent; for apart from a native grayling (*Prototroctes oxyrhynchus*), New Zealand rivers, many of which seemed to be classic trout and salmon waters, contained no sport fish equivalent to the British salmonids. A native stream

species commonly called "trout" by the colonists was described as ". . . a fat, sluggish fish which lurks under logs and stones, furnishes no sport, and is not particularly good to eat."[29] Australian waters were similarly unrewarding compared to those of Britain.

Apart from utilitarian motives, naturalizing salmon would have helped to achieve a sort of ecological democracy, much as did the establishment of red deer. Fishing and hunting of a quality denied the common man in Britain could be available to all in the southern colonies.

Australian hopes for establishing the prized Atlantic salmon were rather effectively dashed by temperature. The seeming ability of the Pacific variety to thrive in subtropical regimes made it a likely substitute. In Europe the Atlantic salmon spawned only in rivers north of 42°. The California salmon were abundant in streams extending as far south as 35°, and occurred, at least in the sea, south of 30°. By latitudinal analogy, Australia's Murray River system, lying between 35-1/2 and 37° S, seemed to be a suitable home. Although water temperatures in the lower Murray rose as high as 76° F, those in the Sacramento and San Joaquin were even higher during the spawning migrations. The results of planting were, as everywhere, disappointing. Two shipments of eggs, totalling, about 100,000, arrived in good condition and hatched successfully. The young salmon, once liberated in Gippsland streams, promptly disappeared.[30]

In retrospect, failure in the marginal waters of Australia seems to be expected; the most suitable Australian streams are near the temperature limits of the salmon. New Zealand, however, appears to be a much more likely home. In fact, twentieth-century efforts have been successful in establishing the Chinook salmon in several South Island rivers. Here, latitude, stream temperatures, climate, and the character of the rivers are similar to those in the salmon's native range. Persistent and costly attempts to naturalize the more familiar Atlantic salmon failed, in

large part because most of the eggs perished on the long journey from Britain. Between 1874 and 1878 the United States Fish Commission sent 1.175 million Pacific salmon eggs to New Zealand, making that country the largest foreign egg recipient after Canada.[31] Local acclimatization societies dispersed the eggs and fry widely in suitable rivers, and Maori rulers, who had lately been at war with the colonists, enthusiastically helped stock the streams in their domains.[32] Optimism here was perhaps greater than in any other region to which the salmon had been introduced. Hatching rates of up to 90 percent contrasted with the almost complete mortality of Atlantic salmon ova. New Zealand streams seemed admirably suited to the new arrivals. The president of the Auckland Acclimatization Society, after liberating some 50,000 fry in the Mangakahia River, observed that it was:

> . . . a fine river for salmon, flowing, as it does, through a wooded country, fed by streams from high ranges, with clear, bright, cold water rippling over shingle beds, rushing over little falls, now dashing through a long rapid, and anon loitering in deep and placid pools.[33]

Where the fertilized eggs were placed in stream gravels, rather than tended in hatcheries, initial results were promising; the same correspondent reported to the United States Fish Commission that in the Rapurapu River,

> . . . in the shingle beds of which I last year placed a large number of the salmon ova you so kindly sent, a great success has been achieved; large numbers of young salmon 5 inches in length being reported as swarming in the river for miles.[34]

In fact, planting ended in 1878, not because of discouragement, but because all suitable rivers had been stocked.

The Great Failure

An enormous amount of effort, hope, and planning ended, at least for a time, with the closing of the McCloud River salmon hatchery in 1883. Much of the failure was anticipated, since the period was one of scattergun experi-

ments more than carefully-planned transplantation. The supervisor of the McCloud hatchery observed:

> The United States Fish Commission is introducing California salmon into many places in the Eastern states, where they will, undoubtedly, be a total failure, but should the Commission make a success of a single river of the size, or half the size of the Sacramento, it would pay for all that has been expended on all the other waters of the United States.[35]

The Commission's strategy of using fish transplants to gain public support accentuated this approach. Salmon ova were, depending on supply, available to any state requesting them. State agencies, in turn, allocated young salmon to virtually any and every citizen willing to assist in planting. Most probably, the ultimate distribution of the fish reflected the imagination and energy of individual sportsmen, rather than ecological rationality. Salmon not only were stocked in waters totally unfit for their survival, but also scattered very thinly over many lakes and streams.

Yet, in spite of these obstacles, the totality of failure is surprising. Several contemporaneous long-range transplants, equally casual in their planning, succeeded admirably. Two anadromous species from the Atlantic coast, the striped bass and the American shad (*Alosa sapidissima*), now share Pacific rivers with the salmon. Somewhat later attempts to disperse the rainbow trout proved so successful that this Pacific slope species is now the most widely distributed salmonid in the world. Ironically, the first hatchery to collect and ship rainbow eggs was built on the McCloud River in 1879.

Current Strategies

Renewed efforts in the twentieth century have met with limited success. Several species of Pacific salmon have been established, at least tenuously, in a few locations outside their native range. These include the South Island of New Zealand, the Great Lakes, and the Kola Pen-

insula of the Soviet Union. Persistent attempts to naturalize salmon in various streams of southern South America have failed, but a small hatchery-based population was established on Chiloe Island.[36] Chinook and coho (*O. kisutch*) have been stocked as sport fish in some western reservoirs, although no natural reproduction yet occurs in these settings.

These successes do not provide a clear answer as to why all of the earlier efforts failed so completely, but at least they indicate some possibilities. Most importantly, modern planting emphasizes persistence and saturation; pink salmon (*O. gorbuscha*) were established in the Kola Peninsula only after some 200 million fry were released over a period of twenty years. The entire number went to stock four relatively small river systems in the White and Barents Sea drainages.[37] By comparison, earlier transplants often released fewer than a hundred fish in large rivers. Such small numbers are especially inappropriate for salmon, which experience heavy mortality on downstream migrations and upon entering the sea.

A century's accumulation of knowledge concerning the salmon's genetic makeup and oceanic life also helps to explain early failures. Six species of salmon inhabit the North Pacific. Because of their strong homing instinct, the salmon of each river form a reproductively isolated population; the six species are a mosaic made up of perhaps 10,000 of these distinctive ecological subraces. Species and subraces differ markedly in route and duration of oceanic migration, seasonality of spawning, and length of time that juveniles remain in fresh water. That all of the millions of salmon involved in the first dispersals were McCloud River Chinook, a single subrace of a single species, hindered chances for adaptation to new environments by limiting genetic variability. Even in those places where the streams were demonstrably suited to juvenile salmon, failure was guaranteed with the introduction of a race which ranged far afield in its oceanic sojourn, or

emerged into ocean currents that differed greatly from those of its home waters. Adult salmon may have matured in salt water, but could not return to their natal streams.

The Future

As knowledge of behavioral differences among subraces increases, and as hatchery-maintained stocks continue to grow, ability to match appropriate varieties to new environments could improve the success of colonization. Where early experiments relied on establishing naturally-spawning populations, more recent successes emphasize continued hatchery reproduction. Great Lakes salmon, for example, stem mostly from hatcheries. Behavioral manipulations promise to give more control over the salmon's oceanic life. If coho and chinook juveniles remain in hatcheries for several months after normal release time, they will stay relatively close to the release point during their oceanic years. This knowledge has been used in the salmon's home range to prevent hatchery fish from Washington from straying into Canadian waters. In colonization efforts, it might help keep fish from disappearing into unfamiliar ocean currents.

Hatchery technology has, in fact, progressed to the point where spawning streams are no longer necessary. Sea ranching operations rear young salmon in artificial environments, then transport the juveniles to coastal release stations. Mature fish return from the sea to these same release stations. Although the first sea ranching establishments in Oregon have not been economically successful, this technique opens the possibility of introducing salmon to suitable ocean feeding grounds even if the bordering lands have no spawning rivers.

Certainly, hopes of colonizing new waters extend beyond the few places where salmon have succeeded as aliens. Gains from hatchery production may have reached some sort of limit in the native range of the fish. Oceanic

feeding grounds of the North Pacific are, according to some interpretations, near the saturation point.[38] One advocate of renewed colonization points to southern Chile, where land-based release and recapture stations could launch salmon into the productive waters of the Antarctic Convergence Zone. In words reminiscent of Herr von Behr's plan for the Danube, he states:

> . . . mechanical harvesting of krill is proving to be very expensive, as it requires powerful ships dragging fine-meshed nets in what is often very foul weather. The establishment of appropriate stocks of salmon in southern Chile should prove to be an economical, readily manageable and ecologically sensible system for harvesting the krill resources of the Antarctic. With the abundant runoff from the Andes forming a freshwater plume extending into the West Wind Drift, ocean-feeding salmon should have little difficulty in finding their way back to the Magallanes to spawn.[39]

The first dispersals of Pacific salmon were to establish wild fish in alien waters. Failure did not end the dream so much as alter it. If the salmon are, indeed, to colonize new waters, it will be as hatchery-bred, semi-domesticated creatures.

NOTES

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