http://www.cqs.washington.edu/~hinrich/foundation.html ISSN 1094-4990

■ THE SHAD FOUNDATION'S ■

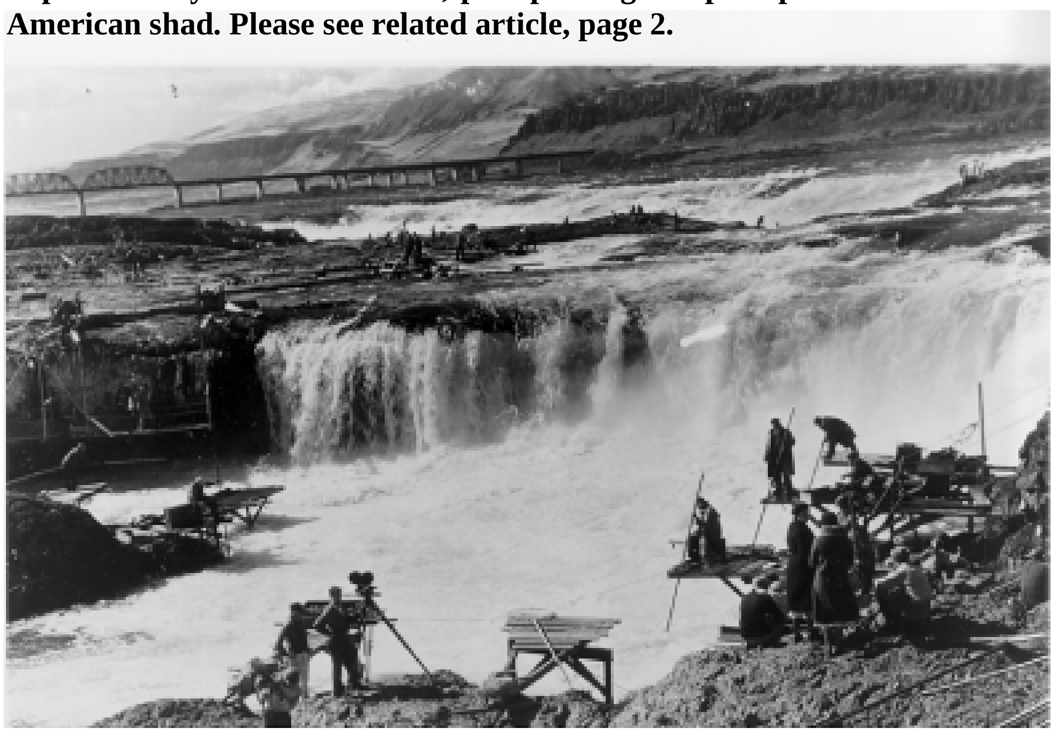
SHAD JOURNAL

"For the study, protection, and celebration of shad around the world"

The Celilo Invasion: It's raining shad on the Columbia

VOLUME 3, NUMBER 2, SPRING 1998

NATIVE AMERICANS dip-net for salmon at Celilo Falls on the Columbia River. In 1957, this traditional fishing site was inundated by waters impounded by The Dalles Dam, precipitating a rapid upstream invasion of American shad. Please see related article, page 2.



COURTESY OF THE OREGON HISTORICAL SOCIETY, NEGATIVE NUMBER ORHI88625

President's Note:

In this issue is part II of the story of the American shad colonization of the Columbia River, covering what happened after the American shad's initial invasion of the Columbia River. Recall that after the 1871 planting of American shad in the Sacramento River, American shad migrated northward and by 1885 were plentiful in the Columbia.

One of the great ironies examined is that though dam construction on the mainstem Columbia River aided the American shad run, it is considered largely to blame for decreasing Columbia River salmon runs, many which are endangered or threatened.

The Columbia shad story demonstrates that anadromous fish can thrive in the presence of dams—if—and this is a big if—there are adequate fish passage facilities in place and the myriad other factors contributing to mortality (such as harvest, pollution, and habitat loss) are under control.

This sounds a hopeful note for the managers on the East Coast and elsewhere who—in the face of dams—strive to rebuild dwindling shad runs.

-R. Hinrichsen

INSIDE

Salmon and Shad: A Tale of Two Fish

By considering Pacific salmon and American shad together we see new ways to understand them both

by Richard A. Hinrichsen and Curtis C. Ebbesmeyer

On the Columbia River, at the Bradford Island Visitor's Center of Bonneville Dam, visitors peer through windows into a fish ladder, hoping to witness the pageant of Pacific salmon swimming upriver. In the summer, however, onlookers see a few salmon among enormous schools of American shad—a native of the East Coast that invaded the Columbia River in the 1870s [see "Oceanography of the Pacific Shad Invasion," by Curtis C. Ebbesmeyer and Richard A. Hinrichsen; SHAD JOURNAL, February 1997]. Above Bonneville, each year, American shad now outnumber all salmon roughly four to one.

Since the 1930s, the dominance of shad on the Columbia River is more a result of a shad explosion than a salmon decline. Upstream of Bonneville, the shad population averaged just 22,000 between 1938 and 1947, increasing 100-fold to 2,141,000 between 1984 and 1993. By 1977, shad dominated salmon. The Columbia became a river of shad. The current average annual spawning population of shad in the Columbia Basin probably exceeds four million fish. Given an approximate weight of 3.5 pounds per adult shad, this amounts to about 14 million pounds (7,000 tons).

The success of American shad in the western United States has gone largely unnoticed. It is out of concern for endangered salmon that biologists now seriously contemplate the ecological role shad play on the Columbia, and what impact shad may have on salmon. What has been the scientific response? Some biologists have adopted the new attitude toward exotic species: guilty until proven innocent. The Endangered Species Recovery Team, charged with developing a plan to save salmon, recommended reducing the shad population on the Columbia River, and eliminating shad above Bonneville Dam.

AMERICAN SHAD (*top*) AND CHINOOK SALMON share a similar life history on the Columbia River, but have very different fates. Populations of chinook salmon are officially declared threatened in certain parts of the Columbia and are protected whereas shad are generally unwelcome.

It seems that shad have been added to the list of villains which includes zebra mussels, *Dreissena plymorpha*, a native of the Caspian Sea that invaded the Great Lakes in 1988 and began impeding commerce by clogging water intake pipes and sinking buoys. Do the shad belong on this list? Perhaps.

Certainly the large shad population has altered the Columbia's ecosystem. But how? And what impact does it have on salmon?

The hypotheses describing negative impacts of shad on salmon have not been

THE SHAD JOURNAL ®

Editor-in-Chief: Richard Hinrichsen

The Shad Journal is published quarterly in association with the Shad Foundation, P.O. Box 21748, Seattle, Washington 98111-3748. Direct inquiries to **(206) 633-5725** or hinrich@accessone.com.

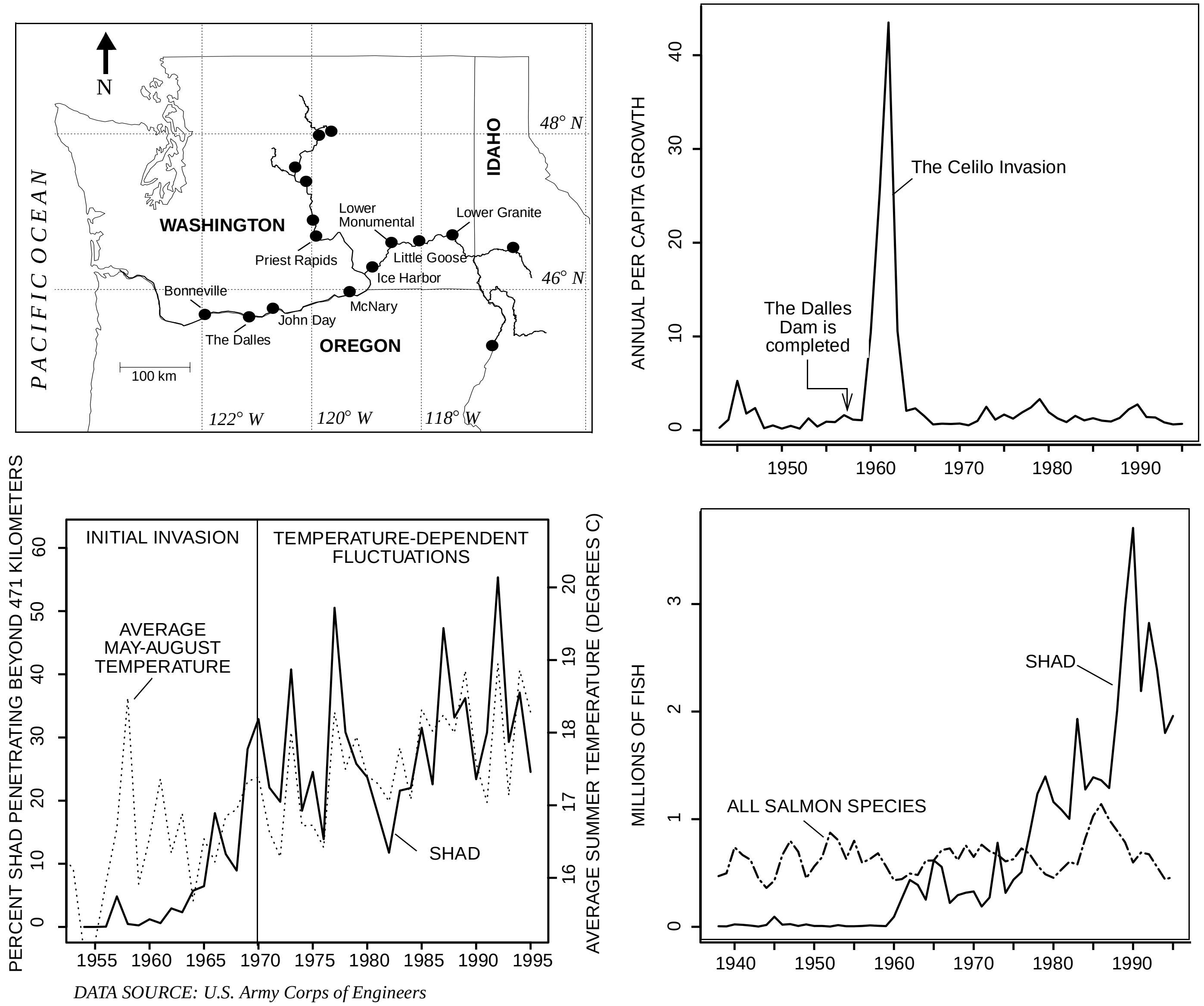
Subscriptions. The annual membership/subscription rate is $20.00 (U.S.). Make checks or money orders payable to:

SHAD FOUNDATION
P.O. Box 21748
Seattle, WA 98111-3748
USA

The *Shad Foundation* is a Washington State non-profit corporation that was established in 1996 to promote a greater understanding of shad for the purpose of restoration where depleted, or their responsible use where sufficiently abundant.

Submissions. The editors welcome submission of articles on any aspect of shad. The Journal publishes letters, commentaries, histories, scientific articles, interviews, reviews, and philosophical and methodological items related to shad the world over. (See back cover of previous issues.)

ISSN 1094-4990



THE CELILO INVASION was precipitated by the building of The Dalles Dam (river kilometer 309) on the Columbia River (*upper left*). The dam's reservoir inundated Celilo Falls (river kilometer 323) allowing shad to swim past the falls to upstream spawning locations. During the initial invasion, which began in 1957, the annual population growth of shad counted at Bonneville Dam skyrocketed (*upper right*). Soon shad began penetrating beyond McNary Dam (river kilometer 470) and their upriver distribution became synchronous with temperature (*lower left*). By 1977, shad at Bonneville Dam outnumbered salmon (river kilometer 236) (*lower right*).

struck against fundamental observations, but there are sound scientific research proposals to test whether negative impacts do exist. The latest, written by a seasoned research group, sought to identify interactions between shad and salmon, determine the shad's role in supporting salmon predators, describe the shad's life cycle, and develop methods to control the shad population. But this research has been given low priority.

Despite the lack of rigorous research, possible ways in which shad interact with salmon have been articulated. Adult shad may feed on juvenile salmon during their upstream spawning migration or during their seaward migration after spawning. (The information on this, however, is anecdotal.) Juvenile shad are abundant in the Columbia's reservoirs from August through November, and their diet is close to that of the fall chinook young present during the same period. The dietary overlap of shad and salmon may continue into the spring for fish remaining in the Columbia estuary. In 1992, Kaczynski and Palmisano estimated that each year more than 600 million juvenile shad enter the estuary compared with about 350 million juvenile salmonids.

Shad are known to interfere with salmonid juveniles during downstream migration through bypass systems designed to guide young salmon away from turbine intakes. Adult shad may delay upstream migration of adult salmon by crowding the fish ladders at dams. What's more, the shad juveniles may serve as a food base for salmon predators during the fall and winter, thus maintaining large predator populations. These predators are known to make large inroads on juvenile salmon migrating seaward.

To most, shad are not welcome guests on the Columbia. On the East Coast, it is a different story. Maryland and Virginia, for instance, have worked to protect the American shad, placing a moratorium on their capture in Chesapeake Bay. Expensive efforts are underway to restore shad to rivers where they once flourished.

On the Susquehanna, one of the largest rivers on the Atlantic seaboard, shad, which may have once numbered 10 million, dwindled to thousands. Several East Coast states have responded by starting shad hatcheries and by building fish ladders and lifts to boost shad over the dams so that adults can reach their native spawning grounds.

The different attitudes toward shad on the U.S. West and East coasts is just one of the ironies we noted while examining American shad and Pacific salmon. For example, American shad flourished in the face of dam construction on the Columbia River but were decimated by dams on the East Coast. For another, the success of shad on the Columbia was accompanied by the failure of native salmon.

We sought scientific reasons behind these ironies, searching for solutions to the problem of restoring Pacific salmon on the West Coast and shad on the East Coast. We believe that solutions require ecologists to adopt a larger vision of ecosystems, one in which exotic species (or naturalized species) and humans both participate.

When we alter ecosystems, exotic species fill new niches while indigenous species, occupying shrinking niches, fail. In an altered ecosystem, extirpating the exotic species that have grown to fill the empty niches may not accomplish the larger goal: it will not eliminate the new niche created by dams and it will not restore the original niche on which the displaced natives depended. As long as we have dams on the Columbia— which, as we explain below, created a large niche for shad—it may be best to manage and value the shad rather than attempt to extirpate them.

Dams and Niches

To understand how the ecology of salmon and shad have been influenced by hydro-development, we use the concept of an ecological niche. Briefly, niche is the ecological role—the "profession"—of a species in its community. The niche of a species is restricted to time and space according to the environment and the presence of interacting species. On the Columbia, alterations of the river have squeezed the niche of salmon, while expanding that of shad. Dams alter the riverine ecosystem, and, since shad and salmon have different biological requirements, dams affect them differently.

THE DALLES DAM, located at river kilometer 309 of the Columbia, rises above glassy reservoirs. In 1957, it raised the water level nearly 20 meters in four-and-a-half hours, drowning Celilo Falls, which before was a barrier to upstream shad migration.

There are two fundamental ways in which dams change a river's ecosystem: 1) they block animal movement; and 2) they fragment the river into a series of lakes, thereby reducing current velocity and increasing water depth. This also serves to alter flows, temperature, and the estuarine environment. Both changes work against salmon, but only the first works against shad, the second being beneficial. Herein, we believe, lies the reason why shad can flourish in the presence of dams while salmon do not.

What are the different biological requirements of shad and salmon? For one, salmon require a fast-flowing stream to oxygenate their unusually large eggs which number only in the thousands. In contrast, shad deposit smaller eggs, numbering hundreds of thousands, in the water column where they sink to the bottom. They then develop normally without a strong current. Shad are adapted to slower-moving, warmer rivers of the East Coast, whereas salmon are adapted to the swifter-moving rivers and streams of the West Coast.

Columbia River dams have ladders that allow both salmon and shad to move upstream, but salmon simply do not spawn in lake environments (except sockeye salmon populations) and hence are displaced by the reservoirs created by dams. Fall chinook salmon once spawned in parts of the mainstem Columbia now covered by reservoirs. Spring chinook spawned in the Columbia's tributaries, where dams have also turned streams to pools.

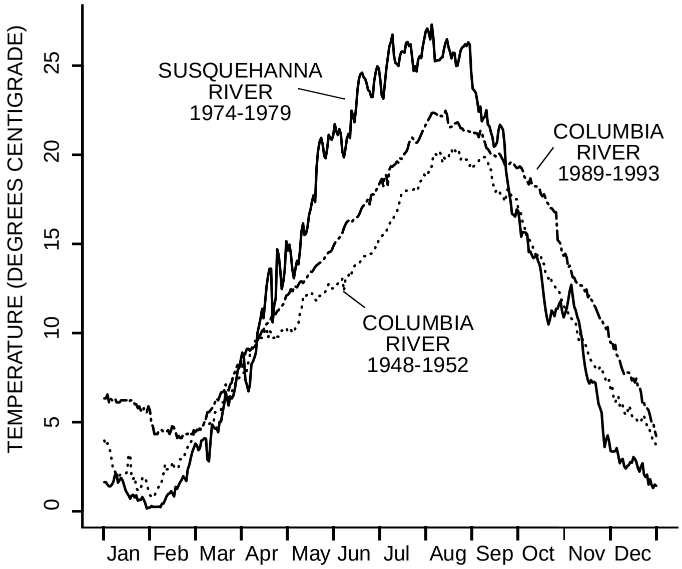
Dams: Habitat Destroyers and Builders

Tracking the histories of the Susquehanna and Columbia river basins leads one to appreciate the two faces of a dam. Beginning in the mid-eighteenth century, a wave of development in the United States swept east to west. In most cases, dam development destroyed the niche occupied by anadromous fish populations while opening new niches for resident and exotic fish populations. Anadromous fish, such as the salmon and shad, migrate to the ocean as juveniles, and return to freshwater for the sole purpose of spawning.

Dams work against this life history strategy by changing the geography of energy in a river basin, blocking access to suitable spawning grounds where embryos can develop. Power dams focus the river's energy at certain locations, to ease its transformation into kinetic energy, which in turn is harnessed for electricity. For anadromous fish, the river becomes a staircase, each step at a dam, any one of which may present an insurmountable barrier. If impassable, these barriers eliminate the niche occupied by anadromous fish in a riverine community, and theirs becomes an untenable "profession" in the altered "workplace."

In the Susquehanna River Basin, the greatest declines in shad spawning habitat occurred in 1830 and 1840 when the "feeder dams" began to siphon water into canals used for navigation. Together, these dams eliminated 90 percent of the potential spawning habitat of American shad,

Columbia and Susquehanna River Temperatures



DATA SOURCES: U.S. Army Corp of Engineers, U.S. Geological Survey

SPRING-SUMMER TEMPERATURES on the Columbia River have increased over the past 50 years, approaching the temperatures of the Susquehanna, a river that once boasted a very large American shad run—perhaps the largest in the world. Warming of the Columbia River favors shad at the expense of salmon.

devastating their numbers and those who fished them. As Harrison Wright, historian of the upper Susquehanna, reported in 1881: "The cutting off of this staple of food from tens of thousands of people in this section of the country [the north branch of the Susquehanna] could not but be a great loss, and it has been questioned if it was not greater than the benefits derived from the great internal improvements [dams and canals]."

Later, in 1910 and 1928, two large power dams, without ladders capable of passing shad, left only 16 kilometers for spawning, representing 2.4 percent of their original 684 kilometers of habitat. It was not until 1980, 52 years after they were almost extirpated from the Susquehanna River, that the alarm was sounded for American shad in the Chesapeake Bay; Maryland declared them a species in need of conservation and placed a moratorium on their capture.

In the Columbia River Basin the greatest decreases in salmon spawning habitat occurred when the Grand Coulee Dam was installed on the Columbia River in 1941 and when the Hells Canyon complex was installed on the Snake River from 1959 to 1967. In pre-development times, there were 23,700 kilometers of original salmon spawning habitat. By 1975, only 16,250 kilometers of stream remained accessible to anadromous fish. These habitat losses and other factors contributed to the decline of salmon from their historical run size of 8-16 million fish to their current run size of 2.5 million fish.

In 1957, amid the destruction, an amazing event unveiled the other face of a dam. The Dalles Dam was completed and, on 10 March, the dam's waters were raised nearly 20 meters in 4.5 hours, silencing Celilo Falls. Celilo Falls was a cataract located 323 kilometers up the mainstem of the Columbia that was largely impassable to shad. This precipitated an event we call the "The Celilo Invasion of 1957" in which American shad penetrated beyond Celilo Falls, leading to an explosion in shad population.

Nature abhors a vacuum. The shad rushed to fill the large empty niche created by dams. The shad counts at Bonneville Dam increased 43-fold from the 1956-58 average to 1962. The counts at McNary Dam, located 148 kilometers upstream of Celilo Falls, increased from four shad in 1956 to 13,000 in 1962. The proportion of fish migrating above McNary Dam continued increasing until about 1970, when it leveled off to an average of 30 percent of those passed at Bonneville.

In 1995, shad spawned up to Priest Rapids Dam (river kilometer 640) on the Columbia, and penetrated beyond Lower Granite Dam (river kilometer 697, measured from the Columbia's mouth) on the Snake River, the largest tributary of the Columbia. Hydroelectric development increased the habitat of American shad from 323 kilometers prior to 1957, to 815 kilometers at present. The expanding niche allowed the shad population above Bonneville Dam to increase from 22,000 (1938-1947 average) to 2,141,318 (1984-1993 average). [Note: Some shad slip unnoticed past Bonneville by swimming through the locks, so counts at an upstream dam, The Dalles, are used to estimate these population sizes.]

Nature abhors a vacuum. American shad rushed to fill the large empty niche created by dams.

The success of shad was accompanied by (but did not necessarily cause) the failure of salmon. The number of shad in 1977 equaled 860,000, surpassing the number of salmon above Bonneville Dam for the first time. On 20 November 1991, Snake River sockeye salmon were formally listed as an endangered species and soon after, on 22 April 1992, Snake River chinook were listed as threatened. These populations are so low that, without protection under the Endangered Species Act, they are soon likely to disappear from the Columbia Basin. Since these initial listings, steelhead in the Snake and upper Columbia River have been listed as threatened and endangered, respectively.

Overfishing, Pollution, Further Habitat Destruction and Other Effects

Although dams can do great harm, they are not alone in causing the declines in shad and salmon populations. For example, overfishing, pollution, logging, agriculture, land development, irrigation, and grazing each work against anadromous

Some of the Numerous Factors Affecting Salmon on the Columbia

Water diversions and withdrawals
Expanded agriculture and timbering
Siltation and nutrient enrichment
Water quality alteration
Flow fluctuations and dams
Downstream migration through impoundments
Turbine and spill mortality of juvenile migrants
Changes in competition and predation
Impacts of hatcheries (displacement of wild fish; genetic concerns)
Overfishing at sea and in the river (foreign, domestic commercial subsistence and sports angling)
Changes in river temperature regime
Inundation of spawning grounds caused by dams
Barging and trucking of juveniles around dams
El Niño and other ocean/climate fluctuations

Livingston Stone's Big Adventure

Seth Green rightly receives credit for being the first to successfully transport shad to the West Coast, but others, enduring greater hardships, followed in his footsteps. Another man, Livingston Stone, also deserves special recognition, if for no other reason than his first-hand account of his disastrous first attempt to acclimatize shad and other fish to the Pacific Coast.

The second attempt at planting shad on the West Coast came in 1873, with a well-equipped aquarium car paid for by the California Fish Commission. Like a modern-day Noah, Livingston Stone loaded the aquarium car with an assortment of East Coast fish and shell fish intending to transport them to California. His aquarium car contained black bass, glass-eyed perch, bull-heads, freshwater eels, lobsters, eastern trout, catfish, yellow perch, tautogs, salt-water eels, oysters, and 20,000 young Hudson River shad. Stone and his entourage made it as far as the Elkhorn River in Nebraska.


SETH GREEN (*left*) AND LIVINGSTON STONE were pioneer fish culturists. Both successfully brought shad from the East Coast to the West Coast via the transcontinental railroad—Green in 1871 and Stone in 1873. During his first attempt, Stone nearly died when a train bridge collapsed and his aquarium car plunged into Nebraska's Elkhorn River.

As Stone told it:

"After leaving Omaha, we stowed away as well as we could the immense amount of ice we had on the car; and, having regulated the temperature of all the tanks, and aerated the water all around, we made our tea and were sitting down to dinner, when suddenly there came a terrible crash, and tanks, ice, and everything in the car seemed to strike us in every direction. We were, every one of us, at once wedged in by the heavy weights upon us, so that we could not move or stir. A moment after, the car began to fill rapidly with water, the heavy weights upon us began to loosen, and, in some unaccountable way, we were washed out into the river. Swimming around our car, we climbed up on one end of it, which was still out of water, and looked around to see where we were. We found our car detached from the train and nearly all under water, both couplings having parted. The tender [car for carrying fuel and water] was out of sight, and the upper end of our car resting on it. The engine was three-fourths under water, and one man in the engine-cab crushed to death. Two men were floating down the swift current in a drowning condition, and the balance of the train still stood on the track, with the forward car within a very few inches of the water's edge. The Westinghouse air-brake had saved the train. If we had been without it, the destruction would have been fearful.

"One look was sufficient to show that the contents of the aquarium-car were a total loss. No care or labor had been spared in bringing the fish to this point, and now, almost on the verge of success, everything was lost."

Not deterred from his mission to transport shad to the West Coast, and not to be outdone by Mr. Green, Stone immediately set out for the Hudson to procure young shad for another attempt. This time—still 1873—it was a success. He transported 35,000 young shad safely over 4,500 kilometers and released them in the Sacramento River. On his way, he stopped at the site of his mishap on the Elkhorn River to take on fresh water. His experience swimming in the river led him to think that it would be good for the shad. When the water containing shad became too cold as the train climbed the Sierra Nevadas, Stone's resourceful crew used iron couplings heated in the train's furnace to warm the water and save the young shad from freezing.

-Hinrichsen

fishes. [See a partial list of numerous factors that can affect salmon or shad, below.] Tellingly, on the Columbia River where salmon are native, these anthropogenic factors exert greater pressure on remaining wild populations than they do on the introduced American shad.

Let's examine spawning habitat quality, for example. Shad spawn successfully in the Columbia's large reservoirs, but generally, salmon do not. Salmon eggs require gravel containing low silt content; otherwise, developing embryos may smother and die. The only suitable spawning gravel remaining for salmon lies in the undammed sections of the Columbia River and its tributaries. Consequently, on the Columbia, wild salmon are more sensitive than shad to land development.

Temperature Effects and Global Warming

Our studies of shad on the Columbia River show that temperature is an important factor in determining the spatial and temporal distribution of American shad. In the late 19th century, Marshall McDonald discovered that shad change the timing of their spawning migration according to temperature [see "The Migrations of the Shad," by William C. Leggett; SCIENTIFIC AMERICAN, March 1973]. In warmer years, shad tend to migrate earlier than in cooler years, with the peak of migration occurring between 16.5 and 21.5 degrees Celsius [data from Leggett and Whitney, Connecticut River].

With the warming of the Columbia River due to dam construction, removal of riparian vegetation, and perhaps the effects of global warming, the American shad now migrate upstream a full month earlier than they once did, peaking in June rather than July. This corresponds to a warming of 2 degrees Celsius in the Columbia River at Bonneville from 16 degrees Celsius (1949-1958) to 18 degrees Celsius (1984-1993) (May-August averages).

This sensitivity to temperature is not surprising since hatching and survival of juvenile shad are at a maximum when the water temperature is between 15.5 and 26.5 degrees Celsius, and optimal around 17 degrees Celsius [from A. H. Leim]. Most spawning is completed by the time temperatures reach 21-22 degrees Celsius. The temperature-regulated river migrations of shad bring them home at a time when river temperatures are approaching the level that is best for spawning and survival of offspring.

Our most recent research shows not only a temporal pattern in migration corresponding to temperature, but a spatial one as well. After the Celilo invasion on the Columbia River, American shad migrating beyond McNary Dam (river kilometer 471) has varied from 12 to 55 percent (1970-1993) of the shad passing Bonneville Dam. In warmer years a greater proportion of shad are penetrating further upstream, so spawning location is related to temperature. Fish counts on the lower Columbia River between 1970 and 1993 show that an average increase of 1 degree Celsius during May-August produces an increase of 11.4 percent in numbers of shad migrating above McNary Dam.

While American shad apparently respond favorably to increasing temperatures in the Columbia River, Pacific salmon have not. Higher temperatures lead to greater risk of disease, greater activity of fish that prey on salmon, and reduced levels of dissolved oxygen. Higher temperature also increases the energy cost of a migration that can carry salmon populations over 800 to 1,600 kilometers, against strong currents, over rapids and waterfalls and of course—dams.

Although high temperatures can also pose problems for American shad, the Columbia River's temperatures have not yet exceeded the thresholds at which spawning and developing shad can prosper. Furthermore, American shad have the amazing ability to adjust their spawning timing to the optimal conditions for spawning—a behavior unobserved in salmon populations.

Shad also have the ability to abort spawning if conditions are unfavorable and try again another year. Pacific salmon (excluding steelhead) must spawn and die once they return to freshwater. In short, American shad have much more plastic behavior than salmon and can escape unfavorable spawning conditions more easily. Pacific salmon are more genetically locked into spawning behaviors.

In the 1960s, J. R. Brett measured the energetic cost of swimming using a respirometer. He found that at 24 degrees Celsius a young salmon at rest burned as much oxygen as it did while swimming about 1.6 kilometers an hour at five degrees Celsius. Investigators following a female sockeye salmon over a migration distance of 1032 kilometers on the Fraser River showed that it consumed 96 percent of its body fat and 53 percent of its protein reserves. The Fraser River migrants expended energy at nearly 80 percent of the maximum rate that could be maintained, leaving little margin for additional demand [see "The Swimming Energetics of Salmon," by J. R. Brett; SCIENTIFIC AMERICAN, August 1965]. Higher temperatures, which increase energy demand, can deplete the reserves of salmon before they reach the spawning grounds.

The West Coast needs to discover why American shad's Latin name means "shad most delicious."

Global warming models suggest water temperature rises of a degree centigrade may be expected within the next 25 years. If temperatures reach the maximum predicted by the year 2100—a 4.5 degree Celsius increase—American shad (with their plastic spawning timing and location) may continue to flourish in the Columbia while salmon either adapt or go extinct. In the long run, improvement in the myriad other factors affecting salmon survival may count for nothing if these high temperature rises are realized and salmon are unable to adapt over their next 25+ generations (100 years).

Appealing to Power Interests—Modern Restoration Efforts

The will to recover shad on the East Coast and salmon (and other wildlife) on the West Coast is evident in the money spent to recover the resources. Power companies pay roughly 5 percent of their generation revenue on recovery measures. On the Columbia River, Bonneville Power Administration (BPA) spent a total of $300 million in 1993 on fish and wildlife measures. BPA's projected salmon (and other fish and wildlife) budget for fiscal year 1999 is $408 million. Over the last several years BPA has spent roughly 10 percent of its revenue on Fish and Wildlife measures (mostly for salmon in the Columbia Basin).

On the Susquehanna, utilities paid for trap and transfer of shad, expanded hatchery operations, and studies related to shad restoration ($4 million over the 10-year period 1985-1994). Philadelphia Electric Company constructed a $1 million fish trap that was completed in 1972. The first permanent passage facility, the East Lift at Conowingo Dam, cost $12 million and began operation in 1991.

Next, fish passage facilities were completed at Holtwood and Safe Harbor dams in the spring of 1997, and there are plans to construct a fish ladder at York Haven by spring 2000. By 2000, the cumulative cost could reach $70 million for fish lifts, trucking expenses and hundreds of millions of hatchery-raised shad on the Susquehanna River. Total costs have amounted to 5 percent of generation revenue over the past 30 years.

Lessons and Opportunities

There are many lessons to be learned from looking at shad and salmon on both coasts of the United States. Observations of Columbia River shad show that once American shad have unrestricted access to spawning habitat their populations can penetrate upriver, and increase rapidly.

Global warming, in addition to warming due to dams, could squeeze the niche of salmon, further endangering salmon runs, while potentially boosting runs of American shad on the Columbia.

If successful, Susquehanna passage facilities could precipitate a shad population explosion similar to the one after the Celilo invasion. Why use fish lifts on the Susquehanna? There, temperatures can rise steeply enough that shad are caught in the fish ladder during spawning. Fish lifts move shad quickly over the dams.

Some have argued that shad will continue to suffer on the Susquehanna because there is no provision for the young to migrate downstream past the dams. Perhaps. But look at the Columbia River. There shad continue to flourish despite juvenile losses through turbines and collection facilities, and over spillways.

Do shad interfere with salmon on the Columbia? If so, there may be a market solution. If a large shad market materializes, fishermen could concentrate on shad fishing, leaving salmon alone. Natives from the Yakima Tribe are experimenting with fishing that selects shad and leaves salmon unmolested. They fish surface waters of the top of fish ladders where shad tend to be less deep than salmon.

The West Coast needs to discover why American shad's Latin name means "shad most delicious." (Note that on the East Coast, China, or India, a large run of shad would be treasured.) Perhaps then will a local market develop and thrive, and Seth Green, who first transported shad to the West Coast, will be revered as another Johnny Appleseed.

The Authors

RICHARD A. HINRICHSEN is a fisheries research consultant in Seattle, Washington, U.S.A. For further information, contact the author at 302 N.E. 45th Street, Suite B, Seattle, Washington, 98105, USA or send e-mail to hinrich@accessone.com.

CURTIS C. EBBESMEYER is a consulting oceanographer specializing in estuaries, climate, and drifting objects. He is the founder of the Beachcombers and Oceanographers International Association, Inc., which fosters the understanding of objects afloat on the sea. You may contact the author at curt@evansham.com.

The authors wish to thank Richard St. Pierre for reviewing this article. Any errors that remain are solely the authors's responsibility. We also thank Lisa Palmer of the Smithsonian Institution, Division of Fishes, Washington, D.C., for locating the photograph of Livingston Stone.

Further Reading

THE SWIMMING ENERGETICS OF SALMON. J. R. Brett in *Scientific American*; August 1965.

THE MIGRATIONS OF THE SHAD. William C. Leggett in *Scientific American*, Vol. 228, No. 3, pages 92-98; March 1973.

INFLUENCES OF ORIGIN, LIFE HISTORY, AND CHANCE ON THE ATLANTIC COAST MIGRATION OF AMERICAN SHAD. Michael J. Dadswell, Gary D. Melvin, P. James Williams and Daphne E. Themelis in *American Fisheries Society Symposium*, Vol. 1, pages 313-330; 1987.

THE HISTORY OF SHAD FISHING ON THE SUSQUEHANNA RIVER AND CURRENT EFFORTS TO RESTORE THE SPECIES. Charles E. Meyers, Wilkes University Press; 1991.

REDUCING THE RISKS OF NONINDIGENOUS SPECIES INTRODUCTIONS. J. L. Ruesink, I. M. Parker, M. J. Groom and Peter M. Kareiva in *Bioscience*, Vol. 47, No. 7, pages 465-477; July/August 1995.

THE ORGANIC MACHINE. Richard White. Hill and Wang; 1995.

SHAD BITES

Ocean-intercept Fisheries to be Phased Out Over a 5-Year Period

On August 5, 1998, the Atlantic States Marine Fisheries Commission Shad & River Herring Management Board drafted an amendment to the Shad and River Herring Fishery Management Plan (FMP) that called for tight harvest controls. The amendment is slated for full Commission approval in October 1998.

Three primary regulatory measures will be used to manage American shad stocks along the Atlantic coast. These measures are:

(1) a five-year phase-out of the ocean intercept fishery; (2) the management of in-river fisheries at levels not to exceed F30 for evaluated stocks, establishment of Commission-approved plans for all other in-river stocks, and the maintenance of existing or more conservative regulations on commercial in-river fisheries for river herring and hickory shad; and (3) an aggregate 10 fish daily creel limit in recreational fisheries for American shad or hickory shad, with all jurisdictions maintaining existing or more conservative recreational regulations for river herring.

Probably the most significant was the Board's decision to implement a five-year phase-out of the ocean intercept fishery, with the provision that states must achieve at least a 40 percent reduction in effort in the first three years. For in-river fisheries, states are required to manage American shad fisheries for which stock assessments have been performed at levels not to exceed F30. For all other American shad stocks, states must establish Commission-approved fishing plans. States will be required to maintain their existing or more conservative regulations on commercial in-river fisheries for river herring and hickory shad.

Declines in commercial landings of shad and river herring and other indicators prompted the member states of the Commission to adopt the 1985 Interstate Fishery Management Plan for American Shad and River Herring. This management plan addressed four species of anadromous herrings found along the coast from Maine to Florida: American shad, hickory shad, blueback herring and alewives.

With the passage of the Atlantic Coastal Fisheries Cooperative Management Act all Commission management plans became mandatory for the states but the 1985 shad and river herring FMP still lacked specific standards by which the states could control exploitation and analyze state-by-state implementation.

Final approval of the Amendment is slated for October 1998 during the Commission's 57th Annual Meeting on Jekyll Island, Georgia.

For more information, please contact: John Field, Anadromous Species Coordinator, at (202) 289-6400, ext. 301.

Rahman's Thesis Now Available

Mizanur Rahman's thesis, "Studies on population structure of shad in Bangladesh water with emphasis on population genetics of Hilsa shad (*Tenualosa ilisha*)," is now available through the Shad Foundation. In 1997, Dr. Rahman completed his doctoral studies at the Department of Fisheries and Marine Biology, University of Bergen, Bergen, Norway. His dissertation features six separate papers, including a review of the taxonomy, distribution, life history and past and present economic importance of tropical shads, from the Bay of Bengal region. If you would like a copy of the thesis, please send $5.00 (U.S.) to the Shad Foundation at P.O. Box 21748, Seattle, Washington, 98111-3748, USA.