Great Basin Naturalist

Volume 46 | Number 4 Article 1

10-31-1986

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The Great Basin Naturalist

PUBLISHED AT PROVO, UTAH BY
BRIGHAM YOUNG UNIVERSITY

ISSN 0017-3614

VOLUME 46 | 31 October 1986 | No. 4

HISTORY OF FISH HATCHERY DEVELOPMENT IN THE GREAT BASIN STATES OF UTAH AND NEVADA

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ABSTRACT.—Fish hatchery systems in both Utah and Nevada are now an integral part of the fishery management scheme. Historic development of hatcheries, including the early stocking of exotics, is presented. Disease control and dry pelleted feed are discussed in historical perspective and present status.

Waters in the Great Basin area were probably first fished by wandering bands whose ancestors had crossed the Bering Strait to Alaskan shores and subsequently inhabited a vast portion of what is now the western United States. These people were present on the shores of ancient Lakes Bonneville and Lahontan about 8,000 to 10,000 years ago. Recently published archaeological evidence indicates, however, that these people were not the direct ancestors of the Pyramid Paiute Indians who now inhabit the area surrounding Pyramid Lake, the remains of ancient Lake Lahontan, nor of the Indians found near Great Salt Lake by explorers in the early 1800s. These Indian tribes had been preceded by people of the Desert Culture as early as 10,000 years B.P. (before present) (Sigler and Sigler 1987).

EARLY HISTORY

When great numbers of white men arrived in the valleys of the Great Basin from 1847 to 1870, the streams and lakes in the area supported large populations of native fishes. Utah, Sevier, and Bear lakes in Utah, and Pyramid, Walker, and Tahoe lakes in Nevada, as well as the major streams of the basins (the Bear, Weber, Logan, Blacksmith Fork, Ogden, Jordan, Provo, and Sevier rivers in Utah, and the Truckee, Carson, Humboldt, and Walker rivers in Nevada), supported substantial numbers of native cutthroat trout, *Salmo clarki*, as well as endemic suckers, whitefishes, and chubs (minnows). These populations were essentially unexploited, in the present-day sense of the word, by the nomadic Indians who utilized them. Harvests of the fish during the spawning runs each year provided the Indian tribes with subsistence diets for much of the year. Some trading of excess fish occurred among the tribes and the early white explorers and trappers, but the fish populations were never endangered by the Indians.

The influx of whites in 1859 in Nevada following the discovery of the Comstock Lode, and the arrival of the Mormon pioneers in Utah in 1847, however, exerted heavy pressure on the fish populations in both states. The easily harvested fish, present by the thousands during spawning runs, became an integral part of the diet of the settlers near major lakes and streams of the Great Basin (Townley 1980, Yarrow 1874, Madsen 1910, Carter

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1969). Methods used to harvest fish included the use of "giant powder," dams, nets, and traps. At the same time, changes in water use patterns (for irrigation and industry) began to adversely affect the fish populations. Streams were blocked, and large numbers of mature fish were taken prior to spawning. Young-of-the-year fish were lost to irrigation canals. As a result, populations of native fish in some areas were drastically reduced. Additionally, the native populations were threatened by the unregulated introduction of nonnative species of fish into many of the waters of the Great Basin.

Initial Fish Stockings

In both Utah and Nevada, early fish introductions were made primarily for the purpose of increasing the food supply in the territories. This encouraged a wide and somewhat unstructured program of stocking whatever species were available. Prior to, or in some cases concurrent with, the development of "hatching stations," exotic species were distributed throughout the easily accessible waters of the two states.

Common carp, *Cyprinus carpio*, was one of the most frequently introduced fish. It was brought into the United States in 1876 by Rudolph Hessel (Hessel 1878). Utah received its first shipment of carp from the Washington, D.C., U.S. Fish Station in 1881, when 130 adult carp were distributed in five Utah counties and H. G. Parker, the first Fish Commissioner of Nevada, in his biennial report to the governor in 1878, expressed his intent to stock the waters of that state with this "superior food fish."

Over the next several years, thousands of carp were planted in streams in Utah and Nevada, sometimes as many as 17,000 annually. The shipments into Utah continued until 1903, and intrastate stockings from established populations persisted for several more years. In Nevada the stocking of carp continued until 1889, when George Mills became the third fish commissioner. Mr. Mills made public his sentiment concerning carp in his report to the governor, stating:

> Several years ago, during the carp furor, the general government, while not entirely to blame, was "particept criminis" in foisting upon this state, and in polluting our waters with, that undesirable fish, the carp. True, application for some were made by many of our citizens ignorant of the qualities and habits of the fish and unsuspecting as to the ruin their introduction would bring. Time has now established their worthlessness, and our waters are suffering their presence. As a food fish they are regarded inferior to the native chub and sucker, while their tenacity to life and everlasting hunger gives them a reputation for "stayers and feeders" unheard of in any fish reports I have seen to date. A resident of Humboldt, an "old Humboldter" informs me they have not only devoured all the fish food in the Humboldt River, but also the duck food and a band of sheep grazing along the banks.

Carp are now present at lower elevations in all the major drainages in Utah (Popov and Low 1950, Sigler and Miller 1963) and in Nevada (Miller and Alcorn 1945, La Rivers 1962).

Hatchery Development in Utah

The Period 1850–1900

In 1856 Utah's Deseret Agricultural and Manufacturing Society strongly supported fish planting programs. Salt Lake City raised capital to create the first private hatchery in the area by selling shares in the venture. Spawners (presumably cutthroat trout) were procured from the headwaters of the Weber River and from Utah Lake, and eggs were hatched.

Albert Perry Rockwell, warden of the Utah Territorial prison from 1862 to 1871, used prisoners to raise fish at what is now 2525 South 1100 East in Salt Lake City, Utah. Rockwell received more than 100,000 "salmon" eggs from the hatchery at McCloud River in California between 1877 and 1879.

The need for a state hatchery in Utah was first documented in the 1894 fish and game commissioner's report to the legislature. Joseph Musser, Fish and Game commissioner, stated:

> fish can be artificially multiplied almost indefinitely at very nominal cost. It is a great pity that Utah has not a liberally endowed hatchery system. Other states and territories have each from one to eight or ten public or private hatcheries. . . . From a well equipped hatchery, millions of choice fry could be annually distributed. This would mean thousands of dollars for the good of the territory.

In his 1897–98 report, John Sharp, Utah State Fish and Game warden, notes that distribution of trout (plantings) has been "comparatively insignificant to what it should be and will necessarily continue to be so until a state hatchery is established and provision

made for the stocking of our numerous mountain streams." During this period, thousands of fry, chiefly brook trout (*Salvelinus fontinalis*) obtained from the federal government, and black spotted or cutthroat trout were held in ponds, primarily in Parley's Canyon, until they were planted, generally in the spring.

The first state-controlled hatchery-type areas involved the closing of streams, one in each county. Commissioner Sharp states in his 1898 report:

> The reservation or the closing of one stream, lake or pond, in each county for the purpose of planting and propagating trout with which to stock other streams, is in my opinion, a very good provision, which will undoubtedly result in considerable benefit to the fish interests of the state in helping to restock the mountain streams.

Ten streams were reserved in 1897 in different parts (counties) of the state. Each stream was closed for varying periods of time, generally three or four years. Sharp notes, however, that "there remains much necessity for a state hatchery with capacity to hatch from one million to two million trout fry per year to be placed in the streams of the state." He also points out that this would benefit not only the residents of the state but, in concert with protection for game in the mountains, would become an alluring attraction for tourists, health seekers, and sportsmen of other states, resulting in considerable revenue for the state. Sharp urged the legislature to appropriate funds for the construction and maintenance of a state hatchery.

Utah's third biennial report of the Fish Commissioner is dated 1900. In it, Commissioner Sharp states that a legislative act has provided for the establishment and maintenance of a state fish hatchery. The commissioner was to supervise all fish culture matters of a public nature and to receive and care for the food fishes and ova that came into the possession of the state. He was to obtain fry and/or ova in such variety as he deemed most suitable to the waters of the state and to distribute them to the waters in an approved and equitable manner. He was empowered to furnish, at cost, to any person, corporation, or company owning any lake or reservoir as private property, the young or fry hatched in the state hatcheries. The commissioner also had a mandate to examine the waters of the state that were not naturally stocked with fish to determine their suitability for fish. He was then to stock them with the most suitable varieties of fish. Five thousand dollars was appropriated for the commissioner's use in carrying out these duties.

The site of the first hatchery was evaluated on the basis of its quantity and quality of water, having a constant temperature of 50 F and being free from all foreign matter. The availability of additional spring or creek water was also required for use in the rearing ponds. Sites were examined in Cache, Box Elder, Weber, Morgan, Summit, Juab, Utah, and Salt Lake counties. A site in Salt Lake county, 1.5 miles east of Murray, at the junction of two spring creeks known as "the spring runs" was selected. After 5.75 acres of land were purchased by the governor at a cost of $1,000, the hatchery was constructed at a cost of $922. It began operation 30 December 1899.

The first hatchery houses in Utah and Nevada were similar. Each consisted of wooden troughs, about 14 feet long, 14 inches wide, and 6 to 10 inches deep. Each trough could hold approximately 50,000 eggs.

Throughout this period, thousands of brook trout were distributed to public waters and private citizens in both states with the understanding that the commission retained access to the ponds and reservoirs for the purpose of taking eggs and fry.

The concept of "branch hatcheries" was discussed at this time. The idea was to hold fish at various locations to reduce long hauls. In addition to activating "branch hatcheries," rearing ponds were used to supplement the capacity of the hatchery rearing facilities.

The Period 1901–1920

In Utah this period was characterized by increasing awareness of the needs of the fish being hatched in the state hatchery and of the importance of stocking adequate numbers of fish in designated streams. Brook trout were extremely successful in many habitats, particularly the Logan River and the lakes in Big Cottonwood Canyon, which was producing seven-pound fish within six years. Utah's hatchery doubled its production in the first few years of this period, mostly because of the use of black-spotted trout eggs from Fish Lake. More than 2,000,000 eggs were processed in both 1901 and 1902. The establishment of a brood stock at the state hatchery also contributed to its success.

The use of "hatching ponds" began in 1902, when land north of Nephi was given to the state for use as a fish-rearing pond.

A private hatchery was started near the town of Mantua by J. S. Hull in 1906. (The general area of this hatchery was purchased from Beatrice Foods by the Utah Division of Wildlife Resources in 1973 and is now the site of the division's Bear Lake cutthroat trout hatchery.)

When the need for additional hatchery space became evident, the 1909 Utah legislature authorized the construction and operation of three additional hatcheries. One hatchery was constructed near Springville, one at Fish Lake, and one at Panguitch Lake. State hatchery capacity for hatching eggs subsequently reached 12,000,000. Also in use at this time were large ponds near the Telluride Power Plant on the Provo River. These ponds were used to hold black-spotted trout spawners migrating from Utah Lake.

Powell Slough, 4 miles north of the mouth of the Provo River on the shore of Utah Lake, was designated as the "bass hatchery" for the state, providing an ideal location and water supply for the rearing of this species. Some 3,000,000 or more fish were hatched annually during the next several years.

Between 1900 and 1905 the Murray Hatchery was producing in excess of 3,000,000 trout eggs per year in a hatchery designed for only 2,000,000. Approximately 18,000 brood fish were maintained at this hatchery, which provided fry throughout northern Utah. The Springville Hatchery maintained 10,000 brood fish and, in a hatchery designed to produce 2,000,000 eggs, was rearing 2,500,000 fry for stocking in Utah Lake and the central part of the state. The Panguitch Hatchery was used to hatch eggs from the Murray Hatchery and did not maintain a brood stock because of the prohibitively low temperature of its water. Fish from this hatchery were stocked in Panguitch Lake and the extreme southern part of the state.

By 1914 Utah no longer maintained domestic brood stock of brook trout but utilized brown trout, *Salmo trutta*, and rainbow trout, *Salmo gairdneri*, exclusively. Both brook and native (cutthroat) eggs were obtained from wild stocks from streams. At the same time, 2,000,000 brook trout and 4,000,000 cutthroat trout eggs were obtained from spawning stations at Fish Lake, Provo River, Panguitch Creek, and Puffer's Lake each year.

Success rates in hatching brown trout eggs were noted at 80% for this period. The most important aspect of rearing fry from eggs was providing them with proper food and feeding conditions. Finely ground beef livers were used predominantly. Careful feeding, several times per day, resulted in a 95% survival of the hatch to two-inch fingerlings in six weeks.

Costs of fish food rose rapidly during the war years of 1917–1919, and brood stocks at Utah hatcheries were reduced to conserve funds. Motor vehicles replaced teams of horses for stocking as a money-saving effort and provided the additional benefit of being faster.

In the fall of 1917, the federal government established a hatchery at Springville with the stipulation that a fair percentage of the spawn taken from state waters would be returned as fry.

The Period 1921–1940

Brood stock in Utah hatcheries had been reduced because of the high cost of fish food during World War 1. By 1921–22, this situation had reduced the production capacity of the Utah hatcheries, and it was decided to rebuild the brood stock and expand hatchery production capacity in response to increased public demand for additional stocking of Utah waters.

During this period and earlier, ground and canned carp was the principal fish feed. Canned carp mixed with low-grade flour produced exceptional growth, and the fish were free of gill infection problems. In the two-year period of 1928–1930, the state canned 160 tons of carp for fish food at a cost of less than 4 cents per pound. Cooperative efforts with such organizations as the Salt Lake County Fish and Game Protective Association and the Logan, Ogden, Vernal, Roosevelt, Duchesne, and Beaver fish and game associations boosted fish production by means of the state providing the fish and fish food, and the associations furnishing the care and rearing facilities.

As of 1924 Utah operated seven hatcheries: Logan, Murray, Springville, Timpanogos, Whiterocks, Glenwood, and Beaver. In excess of 17,000,000 fish were being raised at these hatcheries. Another hatchery con-

structed in 1926 on the headwaters of the Sevier River had a capacity of 2,500,000 fish per biennium.

Roy Hull operated a private hatchery at Mantua for 11 years from 1928 to 1939 and then operated a private hatchery in Murray, Utah, for E. C. Bennett. This hatchery was closed in 1948 because of the growth of Salt Lake City. The required city wells were depleting the hatchery water supply.

In 1948, Roy Hull moved his operation (Clearview) to a site in Provo Canyon that provides ideal rearing temperatures, 58 F with 2-degree annual fluctuation. Because of the temperature, which is unsuitable for eyeing eggs, Clearview currently purchases 200,000 Kamloops eggs annually. The Clearview Trout Farm now produces about 50,000 pounds of trout per year as food fish that are distributed throughout the western states. As with all private hatcheries, it is inspected and certified by the state.

Fry (fish less than 2 inches long) had been routinely stocked by most of the western states from the inception of their hatchery programs. By 1928 Utah had begun to also stock fingerling extensively along with larger fish, believing that better survival was achieved with the larger fish in many waters.

Prior to 1924 the stocking of fish in both Utah and Nevada, particularly at locations distant from the hatcheries, had been by 10-gallon milk cans on light trucks. This method of stocking fish was extremely expensive and limited the numbers of fish that could be transported in a single trip. Specially designed fish-planting trucks were constructed to alleviate this shortcoming. Utah's first modern trucks consisted of 150-gallon tanks with oxygen supplied under pressure and cooled with ice. This advance in planting techniques resulted not only in 75% reduction in stocking costs, but it also insured that the fish arrived at their destination in better condition.

In 1929 federal funds were made available for investigations of fish habitat in mountain lakes and streams of the west. Dr. Vasco M. Tanner, Brigham Young University, led the effort in Utah, compiling information on more than 70 lakes in the Uinta Mountains. Each lake was studied with regard to its size, depth, temperature, spawning area, etc. Recommendations as to species, size, and number of fish to be stocked were included in the reports.

The Period 1941–1970

Although funding was restricted during the years immediately preceding the involvement of the United States in World War II, existing hatcheries were maintained and some new facilities were constructed in Utah under the federal WPA program.

By 1956 Utah was operating 12 hatcheries. These hatcheries provided rainbow trout, brown trout, brook trout, lake trout, *Salvelinus namaycush*; largemouth bass, *Micropterus salmoides*; walleye, *Stizostedion vitreum vitreum*; and unnamed salmon. Most of the fish stocking was by insulated tank trucks equipped with water pumps and oxygen systems, but some areas were planted using pack horses and airplanes. Hatchery production was becoming increasingly necessary to satisfy public demands. This necessitated changes in the hatchery system. Manufactured dry food capable of growing rainbow and other trout from fry to catchable size, without meat supplement, was developed at the Glenwood Hatchery by June Powell, Clark Feed Company, Purina, and others. This reduced the cost of fish per pound and substantially increased production. The use of irrigation reservoirs as "natural" rearing areas for fry proved successful, allowing small fish to be stocked inexpensively in the spring, and seven-inch "wild" fish to be removed in the fall for stocking. Additional rearing facilities were added to many of the state hatcheries along with expanded water supplies. Ten production hatcheries are now operating in Utah: Fountain Green, Glenwood, Kamas, Loa, Midway, Mantua, Panguitch (now Mammoth Creek), Springville, Whiterocks, and J. Perry Egan. Total annual capacity is now 8,663,000 fish weighing 788,000 pounds.

Fish were reared to 8 to 10 inches in a move to provide fishermen with larger fish. Stream surveys, funded by Dingell-Johnson, were completed on many of Utah's waters.

Hatchery Development in Nevada

The Period 1875–1900

Nevada's Commissioner Parker had, in 1878, utilized a "hatching house" for some 250,000 McCloud River "salmon" (possibly rainbow trout) spawn. Parker's report for 1881–82 indicates the need for "means to

hatch and distribute the fish provided free by the General Government in Washington, D.C." This is probably the first official statement of Nevada's requirement for a hatchery system more elaborate than hatching trays.

W. N. Carey, Nevada's fish commissioner from 1885 to 1889, took the first structured steps toward developing a hatchery system and propagating fish for stocking. The hatching house used by Parker had evidently been his private property and, upon assuming the duties of fish commissioner, Carey used "such tanks and other appliances as found in the presence of his predecessor and belonging to the State." A hatchery house was constructed on Carey's property in Carson City, Nevada. In his 1885–86 report to the governor, Carey documented the need for a state-owned and controlled facility, stating that the cost would be approximately $500. Carey's 1887–88 report noted that the State Hatching House "is running to its full capacity," so construction must have been approved. During this same period, a brook trout egg-taking facility was established at Marlette Lake with the cooperation and aid of J. B. Overton, superintendent of the Virginia and Gold Hill Water Works.

George Mills became fish commissioner in 1889. His 1889–90 report to the governor states the "State Hatchery was unfitted (sic) for the work required and that he was forced to provide a more suitable building." He outfitted the new facility, expending $250 for fittings and plumbing and $300 for the transfer of state property to the new facility.

Mills, in his 1891–92 report, notes an attempt to establish a branch hatchery at Elko. However, he "entertained doubts as to the supply and temperature of water for hatching eggs." He therefore planted 140,000 trout eggs in the Humboldt River.

The Period 1901–1920

In 1905 the Nevada Legislature created a three-man State Fish Commission. The commission members soon realized that if the waters of the state were to be adequately stocked, additional hatching and rearing facilities were required. In 1907 ground was obtained for the Verdi Hatchery, and construction was completed in 1909. Nevada then hired its first Fish and Game employee to operate the Verdi facility. Eggs from the Carson City Hatchery were transferred to Verdi, and the Carson City facility was relegated to being an egg-eyeing station.

Between 1911 and 1920, the commission continued to hatch and distribute fry of several species of fish. New buildings to better facilitate egg and fry handling were completed at the Verdi Hatchery in 1912. A private hatchery authorized in White Pine County was operated successfully by Mr. E. L. Fletcher of Ely. Additional permits for hatcheries were granted to individuals or groups in Verdi and Reno after the requirements of the permits had been met and the areas inspected by state personnel.

In August 1916 the Carson City Hatchery was closed as an economic measure and all operations previously conducted there were transferred to the Verdi Hatchery. Attempts to hatch brook trout taken from Marlette Lake were continually plagued by unacceptable (low) water temperatures at the Verdi Hatchery. In 1919 a facility constructed at Lakeview, Washoe County, to handle all aspects of the brook trout culture proved very successful. The field station at Numana (on the Pyramid Lake Paiute Indian Reservation), which had been built to take spawn from Lahontan cutthroat trout, *Salmo clarki henshawi*, was operated on an annual basis and collected eggs from Lahontan cutthroat trout and rainbow trout. Rainbow trout eggs were also collected from spawners taken at the Reduction Works Dam on the Truckee River near Reno.

Throughout this period hatchery superintendents and the Nevada Fish Commissioner regularly remarked on the need for additional space or facilities in the hatchery system. An additional complaint of the fish commissioners of both states was the lack of proper screening on the canals and the lack of fish ladders on diversion dams. These two problems, coupled with industrial pollution, caused the loss of thousands of fish. It was estimated that 40% of the fish planted were lost to irrigation canals. A proposal was made to increase license fees to pay for screening of the canals on the major rivers. The solution, however, was long in coming.

The Period 1921–1940

Ground horse meat and beef liver were used as a fish food at this time, allowing greater quantities of feed to be readily obtained. Other than routine problems associ-

ated with weather and water supplies, the Nevada hatcheries were operated at full capacity during most of this period, stocking thousands of fingerling and larger fish.

The Period 1941–1970

Fishery surveys and efforts to map the water resources of the state were conducted between 1941 and 1970 in Nevada to "determine the food productivity and physical conditions for use in future management . . . and to determine the stocking needs of the counties." An extensive survey of the lower Truckee River was planned, and stream improvement projects, including the screening of all principal diversions in the Truckee, were proposed.

In the 1950–52 biennial report of the Nevada Fish and Game Commission, Director Frank Groves reported that hunting and fishing license purchases had reached staggering proportions, increasing from 61,207 in 1947 to 82,492 in 1951. He further stated that surveys in the neighboring states showed that for each dollar invested in a hunting or fishing license, $50 was spent in pursuit of hunting or fishing. Expanding these figures, he estimated a value in excess of $314,000,000 for the fish and wildlife resources of the state. These figures did not include the monetary outlays of the people who used the waters and lands of the state for recreation other than hunting and fishing.

Thomas J. Trelease, the first chief of fisheries for Neveda, developed management policies and fish stocking programs for state waters. These policies dictated how fish from the federal hatcheries at Hagerman, Idaho, and Springville, Utah, as well as those reared by state facilities, were to be used and distributed. It was decided that the state hatcheries would rear fish to either 1 inch or 1.5 inches for transport to the rearing stations, where they would be raised to approximately a 6-inch length. Surplus fingerlings from the hatcheries would then be distributed to the various counties.

The Period 1970–Present

In 1981 the Nevada Department of Wildlife operated five fish propagation facilities: the Verdi Hatchery at Verdi, the Washoe Rearing Station at Reno, the Gallagher Hatchery at Ruby Valley, the Spring Creek Rearing Station at Baker, and the Lake Mead Hatchery at Lake Mead. Total capacity was 400,000 pounds yearly.

Summary—Hatcheries

A general public awareness of the need to conserve resources as well as to eliminate pollution in water, air, and soil surfaced early in the 1970s. Whereas much benefit was gained by this new involvement of the public, the state hatcheries continued to experience restrictions on growth brought about by inflation.

Both Utah and Nevada now operate hatchery systems to satisfy, to the best possible extent, the demands of the fishing public. As new reservoirs are created, additional warm water or cool water fish production will be required. Hatchery programs will continue to play an important role in fisheries management and be prepared to expand to meet increasing public demands for stocked fish.

Hatcheries in both states have evolved from rather small, primitive "hatching houses," which served only to hatch eggs, into large sophisticated stations that maintain and produce large numbers of fish of several species of various sizes. Fish hatcheries are now an integral part of the management plans of both states.

Hatcheries and Fish Diseases

Two aspects of hatcheries in the Great Basin deserve discussion in light of the effect they had on hatchery management in Utah and Nevada. Disease control and the use of dry pelleted feed drastically altered hatchery operations in both states and elsewhere in North America.

Diseases in fish hatcheries can be broken into three categories: (1) historical aspects, (2) evolution of understanding, and (3) prevention and control: current status historical aspects.

Historical descriptions of diseases affecting fish originate at least as early as 330 B.C., when Aristotle described a crustacean parasite of tuna and swordfish (Post 1983). Fish cultural activities by the Chinese have included investigation and treatment of disease for several centuries.

Scientific descriptions of numerous diseases were written in Europe as early as the latter part of the 19th century. Among these

were such titles as "On Vegetable Structures Found Growing in Living Animals: Parasitic Fungi in Living Animals," Transactions of the Royal Society of Edinburgh by J. H. Bennett in 1844, and "Notes on the Salmon Diseases in the Esk and Eden," Transactions of the Botanical Society of Edinburgh, Volume 13, by Brook in 1879. Additional contributions included T. H. Huxley's 1882 paper, "A Contribution to the Pathology of the Epidemic Known as 'Salmon Disease'," Proceedings of the Royal Society of London, Volume 33, and T. Huxley's 1882 article, "*Saprolegnia* in its relation to an epidemic in salmon," Quarterly Journal of the Microbiological Society, Volume 22. In the first three decades of the 20th century, there was information on and descriptions of diseases and its effects.

North American historical information is rather sketchy prior to 1946. Several fish culturists, however, treated visible diseases of fish with salt, acetic acid, copper sulfate, potassium permanganate, lime, calcium hypochlorite, formalin, and other disinfectants. An additional treatment or means of control for pathogenic organisms in fish hatcheries was the complete drying out of the hatchery. This necessitated stopping all production for a period of up to two years. Although actual recognition of diseases (and their agents) was quite slow in developing, some recognition of disease mechanisms did occur. Livingston Stone first recognized the secondary infection characteristics of the fungus infections of fish eggs in 1872. Seth Green's dropsy, or blue-swelling, white spot of eggs and fry, blue patch deformities, and pin-headed conditions were given as causes of losses of fry. L. Stone, who was particularly interested in fish diseases, described 23 diseases on the basis of symptoms or known causes, attributing at least some of them to poor nutrition. He held that identifying the cause and describing the symptoms were the first steps in the discovery of cures. Stone also determined that some fish diseases could be treated by either salt or other mechanisms (Bowen 1970). It is interesting to note that Stone's first choice for disease treatment was to improve the environment, either by increasing water flow or reducing the number of fish, thus reducing crowding and stress. Additionally, he treated diseases with a liberal application of fresh earth to the trough containing sick fish. Although most fish diseases were not recognized as being caused by specific agents or pathogens, early fish culturists in North America did realize that the fish were sick or in distress and were in some cases able to treat or at least mitigate that distress. Treatment by reducing the amount of crowding (pond loading) is still effectively utilized today.

The principal limitations to effective disease control prior to 1946 included: (1) lack of understanding of factors and causative agents, (2) lack of effective drugs and/or other treatment chemicals, and (3) poor understanding of disease-spreading mechanisms.

In the early part of the 20th century, fish culturists became aware of the relationship between epizootics of fish and loading levels in rearing facilities. Relationships between overcrowding and infections of opportunistic bacteria, fungi, and animal parasites were noted. Treatment for most diseases of fish was limited to use of various disinfectants, closing of the fish hatchery, or stocking diseased fish into streams and lakes, a practice prevalent during the early 1900s (Post 1983).

Evolution of Understanding

Following World War II the increased manpower and research monies available for all aspects of fish culture, including disease control, led to a rapid accumulation of both quantitative and qualitative information on not only the causative agents of fish diseases but of the mechanisms of disease spread and infection. Frederick Fish, H. S. Davis, S. Snieszko, and R. Rucker, and associates of these individuals, started producing what became an immense body of information regarding fish diseases. The establishment of the Eastern Fish Disease Laboratory at Leetown, West Virginia, and the Western Fish Disease Laboratory in Seattle, Washington, were two centers where tremendous effort produced information regarding fish diseases. These laboratories pioneered the collection and publication of descriptive, qualitative information regarding numerous diseases of fish, providing an information base. With this information in hand, Snieszko and others proceeded to establish information dissemination channels to federal and state fish culturists. In the late 1950s, the U.S. Fish and Wildlife Service began their fish cultural schools, in-

cluding a warmwater one at Marion, Alabama, and the coldwater one at Cortland, New York (started by Abe Tunison), which is now the Tunison Fish Nutrition Laboratory. All federal hatchery superintendents or hatchery managers were required to attend the Cortland school. Stan Snieszko and other experts started training courses at Leetown and Seattle. Those individuals with interest and potential were selected to then complete the one-year Leetown disease school courses. Individuals who had completed both of these one-year training courses then became troubleshooters for hatcheries and initiated programs to work with biologists in solving fish disease programs. Many regional fish disease biologists were then available. Eventually this group became the diagnostic arm of the Fish and Wildlife Service's fish culture program. Emphasis at this time in the program was on diseases, nutrition, and the development of hatchery management programs. Diagnostic methods as well as chemotherapeutic treatment techniques were developed. State programs were initiated and state personnel were trained at Leetown, starting in the early 1960s. The basic emphasis at this time was to apply the acquired knowledge to the treatment of diseases.

In the early 1960s an unofficial network among fish pathologists and fish culturists developed. This was utilized to alert state and federal personnel when fish with known diseases were to be shipped to other locations. At the same time, development of improved methods for shipping both live fish and eggs (particularly salmonids) were developed. This had the effect of changing what had been local problems to a collection of substantial disease problems that were being spread from one state to another. Populations that were immunologically inexperienced were exposed to pathogens from other geographic areas, often resulting in complete destruction of existing populations, either wild or in hatcheries. Treatment technology at this time was extremely expensive, and in many cases the disease organisms were nonresponsive to available treatments (e.g., the sulfas in treatments of furunculosis). At this time the development of antibiotics and nitrofurans started but had the unfortunate result of being utilized to treat diseases as a method for increasing hatchery production. The diseases were not being eradicated but were rather suppressed by the chemotherapeutic treatments; thus the problem was not solved but simply masked (Goede 1985).

The concept of environmental stress and its relation to disease was more clearly elucidated in the early 1960s and subsequently resulted in efforts to reduce both the development and spread of diseases in hatcheries by better hatchery management practices. This came to include such things as pond loading indices based on water turnover rates, available dissolved oxygen, and crowding factors. At about the same time in the United States the federal Food and Drug Administration (FDA) and later the Environmental Protection Agency (EPA) began to restrict drugs and other treatments that could be utilized on hatchery fish that were going to be stocked and potentially consumed by humans.

Prevention and Control: Current Status

California was the first state to instigate border inspections of fish and fish eggs shipped into the state, but no federal legislation exists to date. The efforts to obtain federal legislation have involved at least eight legislative bills introduced into both houses of Congress. Each has failed to pass (Post 1983). The primary reason federal legislation has not been passed is that it must be umbrella legislation dealing with everything from tropical fish to catfish to the trout industry, plus mariculture enterprises. This includes such marine products as lobster and shrimp. No legislation acceptable to all parties has yet been proposed.

Utah has had a state inspection system since 1967. Since that time all shipments of eggs entering the state for the production of brood stock or other use are inspected and certified as "disease-free" before the shipment is accepted or allowed into the state. The Division of Wildlife Resources Fisheries Experiment Station at Logan, Utah, was constructed in 1962 and has been involved in the fish inspection effort since its introduction. A brood stock program was started in Utah in 1967, and once the brood stock had been certified as disease-free, it was transferred to the Egan state hatchery, near Bicknel (Goede 1985). At this time other states in the West were accepting shipments of eggs that were not certified disease-free simply because they required

larger numbers of fish than they could produce. The conflicts resulting from some states accepting noncertified eggs or fish versus those that would accept only certified eggs or fish eventually resulted in a request that blocks of states devise a uniform policy for handling disposition and movement of diseased stock. In 1971 the Colorado River Wildlife Council was authorized to develop a basin disease control plan. The council is composed of the four states of Nevada, Wyoming, Colorado, and Utah in the upper basin, and the three states of Arizona, New Mexico, and California in the lower basin. The appointed delegates to the first meeting, which was held in Page, Arizona, were to establish a disease policy that would be in effect in all seven states. This policy, which was submitted by the advisory group in 1972, went into effect in January 1973. Recommendations of the council were ratified by each of the fisheries agencies and became state policy. Features of this agreement were enforced through respective state statutes. The policy was designed to prevent shipment into the Colorado River drainage of any fish, fish eggs, or fish products that had not been certified as disease-free. In Utah the policy does not cover only Colorado River waters, but all waters of the state. This policy has been incorporated into Utah and Nevada proclamations that govern import and movement of fish, fish eggs, etc. This was unquestionably a significant event in disease control in the Colorado River Basin and within the states of Utah and Nevada. All fish-rearing stations in the Colorado River drainage are now inspected and certified. In addition, any fish eggs or live fish that are moved into the drainage must be certified. This includes (in addition to state-controlled hatcheries) all private hatcheries within the basin. Permits must be acquired to import stocks of fish for any use whatsoever within the boundaries of the Colorado River Basin, and the stocks must have a valid certification inspection by a recognized professional fish pathologist using acceptable techniques.

The certification program of the Colorado River Basin has been followed by comparable programs for the Great Lakes area. The Columbia River drainage states are presently working to define a similar policy.

Assisting the efforts for certification and inspection of fish stocks before they are moved from one geographic area to another has been the ad hoc Fish Disease Committee of the American Fisheries Society that was formed in 1964. The Fish Disease Committee encourages fish disease control and fish health in general. Among the efforts of the committee was an annually published list of the diseases of most interest. Voluntary restriction of movement of fishes exposed to these diseases was urged on an international, interprovince, and interstate basis (Post 1983). These efforts assisted in the development of the United States Fish and Wildlife Service Title 50 "Restrictions on Movements of Certain Food or Sport Fishes from Countries which have Pathogens Unknown in Fishes in the United States." This restriction became effective in 1969 and was followed by similar Canadian legislation in 1971. The Fish Disease Committee was replaced by a Fish Health Section in the American Fisheries Society in 1972. The Fish Health Section advocates certification of fish health specialists by an examining board and has prepared a publication on standardized disease diagnostic procedures. Additionally, the Fish Health Section strongly encourages colleges and universities to provide courses of training for fish health specialists (Post 1983).

In both Utah and Nevada, specific programs within the fish and wildlife agencies can be directly attributed to efforts to control the spread of fish diseases. The establishment of the Fisheries Experiment Station at Logan, Utah, in 1962 is a direct effort by Utah to provide expertise, information, and methodologies for controlling and preventing both the outbreak and the spread of diseases in fish hatchery and wild populations. One aspect of disease control that has effectively reduced the outbreaks of disease in fish cultural stations in both Utah and Nevada is the utilization of various methodologies for achieving stress reduction. Generally speaking, pathogens can be present in fish populations with no apparent disease symptoms, and as long as the fish populations are not stressed and depression of the inflammatory response does not occur, the presence of the infectious agent may be of little consequence. However, high densities of fish in rearing facilities allow the transmission of infection, both horizontally (transmitted from one fish to another or to other organisms) and vertically (transmitted

from parent to progeny) and must be regulated following currently accepted methodologies of pond-loading densities. In situations where diseases occur, environmental stress that is a direct precursor to the outbreak can generally be pinpointed and removed. In Utah chemotherapeutic agents have not been used more than five or six times since 1972 (Goede 1985). This is the result of more effective hatchery management. At present only a handful of diseases (principally viruses) that are transmitted vertically persist in Utah fish populations. These diseases are considered untreatable. It is these diseases that the current legislative statutes encompass in the inspection and certification program that is designed to prevent movement into currently certified disease-free populations.

DRY PELLETED FOOD

Since early efforts to propagate and raise fish artificially, hatchery managers have recognized the need for large amounts of food that is nutritionally balanced and provides necessary proteins, fats, minerals, and vitamins. In the late 1940s and early 1950s, prior to the advent of dry pelleted feeds (mid- to late 1950s), a diet referred to as a Cortland No. 3 diet was used extensively in many hatcheries. Only in the last three decades has the need for a complete, nutritionally sound diet been recognized. Research into more specific requirements for fats, protein levels, vitamins, amino acids, and other constituents is ongoing in an effort to improve production for several cultured species.

Utah, at one time, fed thousands of pounds of cornmeal and lesser amounts of fresh ground carp. An example of the amount of feed needed for one hatchery was provided by Red (John) Hansen (personal communication 1985). The Red River Hatchery in Questa, New Mexico, had a standing contract for 15,000 pounds of boned horse meat a month. One horse provided 250 to 300 pounds of usable meat, thus requiring 50 horses a month (600 a year) per hatchery. There were soon few available horses. The problems, cost, and nutritional inadequacies of fresh meat diets led to efforts to develop a manufactured dry (less than 10% moisture) feed that was nutritionally sound.

A load of dry feed from a manufacturer on the east coast was shipped to New Mexico in 1953 but was found to be lacking in nutritional qualities. This finding led to efforts to develop an acceptable dry feed. Early in 1953 Mr. J. R. Clark, a poultry nutritionist in Albuquerque, New Mexico, was contacted as a potential supplier of dry feed by the New Mexico Game and Fish Department. Initially, experimental diets for fry and fingerling were developed and tested at the New Mexico Red River Hatchery. These feeds were than taken to Arizona (Page Springs Hatchery), Utah (Glenwood Hatchery), and Colorado (Rifle Creek Hatchery) to be tested under varied environmental conditions. By 1956–57, several feed mills were producing dry feed. Currently several mills in the western United States produce a nutritionally sound trout diet. In other areas of the country, dry feed is produced for warm water species.

Early results of the feed tests were better than expected, and a technique for monitoring red blood cell count was employed to track nutritional changes in test fish. The greatest problem encountered early on was convincing hatchery personnel that fish would grow well, if not better, on one-half the weight of feed required with previous feeds. By 1956 dry feeds were being utilized in several states, and large-scale experimental feeding programs were underway.

Currently most feed manufacturers produce three different diets for trout: the fry diet, for fish up to about 2.5 inches long; a crumble diet for fish up to 4.5 to 5 inches long; and a pelleted diet for large catchable or market-size fish (8 to 10 inches long). There is considerable variation between these diets, principally in the content of protein and fat.

One new technology developed in Europe and used in the United States since about 1978 is spray fat application. Normally fat content of dry pelleted food is limited in content by the tendency of fat-saturated (8%) feed to crumble. Spray application allows use of 14% fat. Food conversion rates are also much higher. Historically a 2:1 feed:weight gain ration has been considered good. Presently most hatcheries achieve 1.5:1 and some are as high as 1.09:1. (By comparison, cattle are 8:1.) A pound of trout can now be reared for $0.30 to $0.35.

The complexity of dry diets for trout is impressive, and although improvements are

constantly being made, the basic components are well established and documented. These ingredients are documented in the U.S. Fish and Wildlife Services Open Formula Diet. Nutrient requirements for cold water species are listed in a National Academy publication, one of a series on nutrient requirements of animals.

The Morgan Hatchery (now closed) was evidently the first Utah Hatchery to regularly feed dry feed. In 1954 the hatchery used dry food, along with meat products fed intermittently.

Utah's state hatcheries now utilize 670 tons of dry feed annually, and commercial users purchase another 1,250 tons. Nevada's state hatcheries purchase 570,900 pounds of dry feed annually.

ACKNOWLEDGMENTS

We thank Thomas J. Trelease, Chief of Fisheries of Nevada (retired); John King, Nevada Department of Wildlife; Bruce Schmidt, John Leppink, and Ron Goede, Utah Division of Wildlife Resources; Roy Hull, Clearview Trout Farm; Don and Chris Nelson, Murray Elevators; Jack Coates, Makah Tribal Council; and Larry Lee and Red (John) Hansen, Moore-Clark Company, for input and review of various sections of this article.

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