Two Warm-water Recirculating Hatcheries Used for Propagation of Endangered Species in the Upper Colorado River Drainage System

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ABSTRACT

The U.S. Fish and Wildlife Service (USFWS) has built two warm water recirculating hatchery facilities to enhance populations of endangered fish in the upper Colorado River Drainage System. The Grand Valley Propagation Facility in Grand Junction, Colorado, was built in 1996 inside a warehouse donated to the USFWS by the Bureau of Reclamation (USBR). In 1997, the hatchery was expanded, adding a second recirculating hatchery. The second hatchery more than doubled the capacity of the original facility. The Grand Valley Propagation Facility currently has the capacity to rear approximately forty thousand 200-mm endangered razorback suckers (*Xyrauchen texanus*) to stock into ponds for grow out to 300 mm. The resulting razorback suckers are stocked into the Colorado, Gunnison, and San Juan rivers.

In 1996, the Ouray National Fish Hatchery (ONFH) was constructed at Ouray National Wildlife Refuge (ONWR) to replace a small experimental facility practicing extensive culture. In 1998, the hatchery was completed and consisted of 36 lined ponds and a recirculating facility. Poor water quality, design flaws, and poor research have led to a nearly complete replacement of all water filtration components. The ONFH currently has the capacity to rear approximately twenty-five thousand 300-mm

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razorback suckers. The resulting razorback suckers are stocked into the Green River. As problems and limitations were encountered, both facilities were upgraded and improved to their current configurations. All of the modifications have led to insight into many types of filtration, filtration media, and intensive fish culture techniques.

INTRODUCTION

Four native fish are currently endangered in the Upper Colorado River Basin: the razorback sucker (*Xyrauchen texanus*), the Colorado pikeminnow (*Ptychocheilus lucius*), the bonytail chub (*Gila elegans*), and the humpback chub (*G. cypha*). In 1987, the Recovery Implementation Program (RIP) was developed in a coordinated effort to recover these four endangered native fish species. One goal of the RIP was to conserve genetic variability of wild endangered fish stocks through recovery efforts that would reestablish viable wild stocks by removing or significantly reducing the limiting factors that caused population declines. Captive propagation was required for some species because of inadequate recruitment in the wild (Wydowski 1994) and near extirpation of certain species from their historical habitats.

Two fish culture facilities were established by the USFWS to hold endangered fish in refugia and for potential brood stock development. In 1987, the Colorado River Fisheries Project (CRFP), in Vernal, UT, USA, established a small, experimental pond-culture facility at ONWR. In 1992, the USFWS, CRFP, in Grand Junction, CO, USA, established the Horsethief Refugia Ponds located near Fruita, CO, USA, at Horsethief State Wildlife Area. The need for additional propagation facilities to produce endangered Colorado River fish was recognized in 1994 (Wydowski 1994), and these two facilities were expanded to meet this need.

The experimental facility at ONWR was expanded and became Ouray National Fish Hatchery in 1996. ONFH has continued to expand and currently consists of twenty-four 0.08-hectare and twelve 0.2-hectare lined ponds and an indoor water recirculating system. The propagation program in Grand Junction was expanded in 1996 with the addition of an indoor water recirculating facility. In 1997, this facility was expanded and a second recirculating hatchery was built. In addition to the hatchery expansion, numerous private ponds have been leased for grow-out purposes.

The purpose of this paper is to relate experiences with the various recirculating systems and filtration techniques at these facilities. Both facilities have been upgraded and improved over the years as problems and limitations have led to alteration of their original configurations. This has yielded insight into a wide variety of filtration, filtration media, and intensive fish culture techniques.

System Descriptions and Methods

While the facilities at Ouray have been in existence longer, when talking about the recirculating water systems, it is necessary to first look at the Grand Valley Propagation Facilities (GVPF). The design and construction of the facilities at Ouray, including the recirculating system, had major problems due to poor water quality, poor engineering, and poor construction. Most of the original components have been replaced or abandoned and a new system, modeled after the Grand Valley Facilities, has been installed and is currently in use.

Grand Valley Propagation Facilities

In 1996, the USBR donated an old warehouse to the USFWS and aided in the design and building of a warm-water recirculating intensive fish-culture facility. At full capacity, the system contains over 52,990 L of water, circulated at 795 Lpm to thirty 1.2 m-diameter circular fiberglass tanks (750-L capacity each and a flow rate of 19 Lpm), and six 2.4-m diameter circular tanks (3,550-L capacity each and a flow rate of 38 Lpm). In 1997, the hatchery was expanded with the addition of a second recirculating system. The second and separate recirculating system contains over 75,700 L of water, circulated at 1,254 Lpm to fifty 1.2-m diameter circular tanks and eight 2.4-m diameter circular tanks (same capacities and flow rates as mentioned previously).

Water Source

The hatchery uses domestic municipal water purchased from the Ute Water Conservancy District. The incoming water is chlorinated, and must be de-chlorinated by packed columns or by sodium thiosulfate. The 3,385 L of water in the original hatchery and 7,570 L of water in the expansion hatchery (more if needed) are replaced each day, requiring 10 to 14 days for full replacement. The incoming water is stored in holding tanks inside of the hatchery and reaches ambient temperature of the hatchery building

(23°C) in 24 hours. Water temperature is maintained by heating or cooling the hatchery building itself.

Nitrification

Nitrification in the original hatchery is accomplished by both a Water Management Technologies (WMT, Baton Rouge, LA, USA) 0.7-m^3 floating bead filter, and a 0.91-m diameter cyclonic sand filter. The floating bead filter was the original biofilter, but when the bag filters being used for clarification purposes were abandoned due to excessive clogging (resulting in system failure and alarm calls), the bead filter was employed for water clarification as well. The resulting loss in potential TAN removal led to the addition of another biofiltration device.

The cyclonic sand filter, from Marine Biotech (Beverly, MA, USA), has a 0.91-m diameter and is 4.88 m in height. It contains approximately 1.18 m^3 (static volume) of 20/40 (0.8 to 0.4 mm) silica sand, with a bed expansion of 60 percent to 70 percent at 950 Lpm. The maximum amount of feed needed at full capacity of this hatchery is approximately 27 kg/day or a 0.55-kg/day total ammonia-nitrogen (TAN) load. Using a nitrification rate of 1.0 kg/day/m^3 (Timmons and Summerfelt 1998), there is sufficient sand volume (1.18 m^3) to handle the heaviest loading, and the filter could theoretically handle 39 kg/day. Additionally, the bead filter used for clarification purposes also performs nitrification and therefore, TAN removal capacity is higher still. The maximum feed rate this hatchery has experienced is 11.4 kg per day and water quality has not been a concern (nitrites were 0.3 ppm or less, and ammonia was 0.02 ppm or less).

A rotating biological contactor, approximately 1.2 m in diameter and 1.83 m long, was the original biofilter for the expansion hatchery, but proved to be inadequate to handle the necessary feed rates. The construction of this filter was also substandard as the fiberglass holding tank would flex and the contactor would come off of its axis and jam. At 4.5 kg of feed/day nitrite levels were high (0.9 ppm and above) as were ammonia levels (0.3 ppm). This water quality was unacceptable and a new solution was sought.

Two 0.91-m diameter, 4.27 m tall, cyclonic sand filters were installed. The sand (same sand parameters as for the previously discussed cyclonic sand filter) was expanded 40 percent to 50 percent at 660 Lpm per filter. These filters (added together) have a potential of handling 78 kg of feed per day.

The maximum feed rate this hatchery has experienced is 20.4 kg per day and water quality has not been a concern (nitrites 0.25 ppm or less and ammonia 0.02 ppm or less).

Clarification

As previously mentioned, clarification in the original hatchery was first performed with bag filters that were abandoned in favor of the existing floating bead filter. The bag filters proved unable to handle the feed rate and clogged after a few hours of use. In the expansion hatchery, a self-cleaning PRA Rotofilter (PRA Manufacturing Ltd., Nanaimo, B.C., Canada), 1.98-m^2 filter screen area, fitted originally with a 30-μm screen and later a with a 60-μm screen, was responsible for clarification. Typical problems are leaking or improperly installed seals, fouling, holes in the screens, and water loss from cleaning, but overall, this filter performs well when properly maintained.

Sterilization

Both the original and expansion hatchery use UV filtration for water sterilization. The original hatchery makes use of a Wedeco-Ideal Horizons Inc. (Poultney, VT, USA) IH Series 10-bulb UV water treatment system, capable of disinfecting water at a rate of 985 Lpm. The expansion hatchery uses an Ideal Horizons IH Series 40-bulb UV water treatment system, capable of disinfecting water at a rate of 3,935 Lpm. No water quality data has been taken on these filters, it has just been assumed that they are doing their job, as there has been no major spread of the few disease outbreaks that have occurred (columnaris is the only disease experienced in the system).

Oxygenation and Degassing

Both hatcheries use packed columns to strip carbon dioxide and nitrogen gasses from the water as well as to re-oxygenate the water before recirculating to the fish. Dissolved oxygen levels greater than 5.0 ppm are maintained even at the highest loading (forty thousand 200-mm fish, approximately 3,200 kg, both hatcheries combined) prior to stocking. No oxygen injection or supplemental oxygen is added to the water at this facility.

Backup Systems

Both hatcheries have back-up oxygen systems that run off pressure switches and solenoid valves. If power is interrupted or the pressure drops due to pump or other equipment failure, a solenoid opens and distributes oxygen through air stones in each tank. At the same time the Sensaphone Express 6500 (Aston, PA, USA) alarm system is triggered and attempts to contact hatchery personnel by phone. The oxygen system can also be used to supply oxygen to fish during chemical treatments.

Ouray National Fish Hatchery

ONFH was established in 1996 to replace a small experimental extensive pond-culture facility. ONFH has continued to expand and now consists of twenty-four 0.08-hectare lined ponds, twelve 0.2-hectare lined ponds, and an indoor warm-water recirculating system.

Originally, up to 3,000 Lpm was to be pumped from the wells to the water treatment building and undergo sterilization by ozone, as well as sand filtration for iron and manganese removal. Of the 3,000 Lpm, 115 Lpm was to be used for the recirculating system, and the rest was split between the 36 lined ponds used for grow out and to hold broodstock.

The incoming water for the recirculating hatchery comes in at a temperature of 11°C and was to originally run through water heaters and be heated to 20°C. The heated water would then be continuously added to the system at 115 Lpm or 10 percent continuous make-up. The ozone system in the hatchery building was to sterilize the recirculating water as it passed through the mechanical room. The recirculating water was pumped at 1,500 Lpm through a 1.4-m^3 propeller-washed bead filter made by WMT (for biofiltration), through a degassing tower, out to the tanks by gravity flow, and then through a packed column for additional degassing (necessary due to high levels of nitrogen gas from the wells, and the heating of the incoming water with propane water heaters). There are twenty-one 2.4-m diameter circular tanks (3,030-L capacity and a flow rate of 38 Lpm) and thirty 1.2-m diameter circular tanks (380-L capacity and a flow rate of 19 Lpm). After circulating through the tanks, the water passed through a PRA Rotofilter (PRA Manufacturing Ltd., Nanaimo, B.C., Canada), with a 30-μm screen for clarification before returning to the sump.

The design and construction of the facilities at ONFH, including the recirculating system, had major problems due to bad water quality, poor engineering, and poor construction. These problems have led to the replacement and abandonment of most of the original components, yet if the water quality problem had been addressed first, many of the original components may have proved salvageable.

Water Source

The water at ONFH came from 6 shallow wells that pumped water to a lift station sump and were then pumped to the water treatment building using a variable frequency pump to control the quantity of water delivered. The well water contained high concentrations of the heavy metals iron (1.0 ppm) and manganese (0.2 ppm). An ozone system was in place to sterilize the incoming water. The iron and manganese were to be filtered out by the Commercial Hi-Rate Permanent Media Filter System, from Environmental Products Division (Rancho Cucamonga, CA, USA) in the water treatment building. These were a series of 8 filters with 0.56 m^3 of silica sand per filter. The sand filtration was able to reduce iron concentrations to 0.7 ppm, but did little to reduce manganese concentrations. Due to the problems caused by the iron and manganese in the water, many of the components proved unusable at that time. The heavy metals began to choke off pipes and small orifices, coat impellers, and slow flow in the re-use system. The ozone changed the manganese into permanganate at concentrations lethal to fish. The permanganate problem led to the abandonment of the ozone system, and replacement with an Ideal Horizons IH Series 40-bulb UV water treatment system (Wedeco Ideal Horizons, Poultney, VT, USA) for sterilization.

A small scale Burgess iron removal media (BIRM) filtration system was installed in the recirculating hatchery to further filter the water entering that system. This system consisted of 4 filters containing a total of 0.22 m^3 of BIRM with a flow of 115 Lpm (2-minute contact time), that reduces the iron concentration to 0.3 ppm, and manganese becomes undetectable. Due to the success of the small scale BIRM filtration system installed in the recirculating hatchery, the sand in the permanent media filters in the water treatment building was replaced with BIRM. The water has a 1.5-minute contact time (although 2 minutes is suggested by the manufacturer) with the BIRM at 3,030 Lpm. This reduces iron concentrations to 0.4 ppm and manganese to 0.1 ppm. At lower flow rates, contact time increases, and more iron and manganese are removed. The BIRM is a manmade product that needs to be replaced periodically, but does not need regeneration like some other products used for iron and manganese removal. Proper flow and backflush rates are critical to the success of the media. Flows higher than recommended reduce contact time which reduces the BIRM's filtration ability. Backflushing rates higher than recommended flush the BIRM out of the filters, necessitating premature replacement of the media.

Recirculating System

The recirculating system contains 90,800 L of water at capacity. Currently, incoming well water enters the building at 11°C, passes through the previously mentioned small BIRM filtration system at 115 Lpm and into a 7,570-L make-up water storage tank where it warms up to the ambient hatchery temperature. Water temperature (23°C) is maintained by ambient temperature of the hatchery building itself. Each day 7,570 L of water is drained from the fish tanks in the daily cleaning processes and the 7,570 L of make-up water is added to the system.

Nitrification

A 1.4-m^3 propeller-washed bead filter was originally installed for biofiltration. A series of errors in the installation and the operation of the bead filter and other components of the system, led to the mothballing of the recirculating system and the hatchery was run as a cold-water pass through spawning building for a few years. Subsequently, the bead filter was replumbed and various other problems were worked out so that the re-use system could be put back into use. The bead filter eventually failed as colloidal iron and manganese clung to the beads, making them heavier, and causing them to be expelled during backflushing. Thus, biofiltration was poor to nonexistent.

The bead filter was replaced by two 0.091-m (3-foot) diameter, 4.88-m (16-foot) tall cyclonic sand filters from Marine Biotech containing 0.98 m^3 (static volume) of 20/40 silica sand. Bed expansion is ~ 60 percent at 750 Lpm. These 2 sand filters are theoretically capable of handling up to 78 kg of feed per day. The maximum feed rate this hatchery has experienced is 27.3 kg per day and water quality has not been a concern (nitrites were 0.25 ppm or less, and ammonia was 0.02 ppm or less).

Sterilization

Due to the previously mentioned water quality problems, the ozone system was removed and replaced with an Ideal Horizons IH Series 40-bulb UV water treatment system.

Water Delivery and Circulation

The gravity flow method of water delivery to the tanks was replaced by circulation pumps able to circulate up to 1,420 Lpm jetted into the tanks. After circulation through the tanks, the water is clarified by the original self-cleaning PRA Rotofilter, and returned to the sump.

Back-up Systems

There is a backup oxygen system that runs off pressure switches and solenoid valves. If the pressure drops due to pump failure or power failure, the solenoids open and oxygen is delivered to the tanks through air stones. At the same time, the Sensaphone Express 6500 alarm (Aston, PA, USA) is triggered and starts to call hatchery personnel on the phone.

RESULTS AND DISCUSSION

The modification of a recirculating hatchery is not unusual. The Grand Valley facility was a typical example of this. Problems were encountered and improvements were made that increased the abilities of the systems to maximize production potential. ONFH on the other hand, is an example of what can happen if the most basic factors of building a hatchery are ignored. In the book that every fish hatchery manager in the USFWS consults, *Fish Hatchery Management*, (Piper *et al.* 1982), it states in the second paragraph:

> Water quality determines to a great extent the success or failure of a fish cultural operation. Physical and chemical characteristics such as suspended solids, temperature, dissolved gases, pH, mineral content, and the potential danger of toxic metals must be considered in the selection of a suitable water source.

Had available water quantity and quality been considered prior to selection of this site, it most likely would have been disqualified as the final location. As a result, besides the problems normally associated with basic fish culture, the operation of this hatchery includes the operation of a water treatment facility that would rival many municipal water treatment facilities. The cost of the choice of the site is incalculable in time, money and effort due to the poor water quality that must be dealt with. Had this choice been made by a commercial fish farmer rather than the federal government, it likely would have resulted in a financial failure.

Both facilities are now meeting their current production quotas. A large-scale recirculating system is a viable option for rearing warm-water endangered fish where water and space are a concern.

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