WHITE STURGEON CULTURE AT SIERRA AQUAFARMS, INC.

Michaels, James T.
Sierra AquaFarms, Inc.
9149 East Levee Rd.
Elverta, California, U.S.A. 95626
phone:916-991-4420/fax:916-991-4334

Bunter, A.
Sierra AquaFarms, Inc.

Sierra AquaFarms, Inc. (SAF) is an intensive, partially recirculated White Sturgeon (Acipenser transmontanus) farm located in Elverta, California, a small community approximately 10 miles north of Sacramento. The company was originated in 1983 with the specific intent of developing methods for the culture of white sturgeon and the successful marketing of the finished product. SAF started out as a small research and development facility at another location. This facility was used to determine the suitability of white sturgeon as a culture animal. At this time white sturgeon culture in this country was in its infancy with the first successful artificial spawning accomplished by team of researchers led by Dr. Serge Doroshov at the University of California, Davis in 1979.

Utilizing the techniques developed by Dr. Doroshov, SAF began spawning fish in 1984 and looking at basic culture questions regarding feed types, stocking densities, disease considerations, and growth rates. Initial indications were that white sturgeon had culture potential. Despite the fact that many questions remained unanswered, the financial backers of the operation had sufficient confidence in the culture characteristics and marketability of the fish that in 1985 the decision was made to build a commercial size facility.

Four major site selection criteria were considered when deciding on the location for the commercial facility. The first criteria was to be geographically close to the migrating wild broodstock. At that time, wild gametes were the only source for fry production. Adult white sturgeon migrated annually up the Sacramento River and were a viable source of broodstock.

The second criteria was to be within close proximity to the expertise available at University of California, Davis. At that time research was underway on reproduction, disease, nutrition, and physiology. These resources have proven to be invaluable over the course of our commercial development.

In order to balance the needs of fish production with those of marketing and distribution, we felt that it was important to locate near good highways and an airport for product distribution and for easy access and egress for supplies and personnel.

The fourth criteria was an adequate water supply of appropriate water quality that would allow us to meet our production goals. This consideration proved the most difficult to satisfy. For the quantities of fish that we wanted to produce we would need water quantities in the order of tens of thousands of gallons per minute. If we simply intensified using pure oxygen,we could reduce this water requirement to thousands of gallons per minute. Additional technology could further reduce this water demand.

In an attempt to satisfy these four site selection criteria, it became apparent that we would need to utilize some form of recycle technology. Our goal was then to design and operate a system that would use approximately 3,800 liters per minute of pumped ground water and produce approximately 450,000 kilograms per year of white sturgeon. We purchased 21 acres of farmland and engaged a Scandinavian consulting firm in 1985 to collaborate on the design of our first building.

This building is approximately 2600 m^2 and houses a non-recirculated hatchery and a partially recirculated fingerling sizing area. We use pure oxygen injection throughout the facility but have chosen not to recirculate water in the hatchery due to the sensitive nature of the sturgeon fry and smaller fingerlings to water quality parameters.

The hatchery consists of 116 fiberglass tanks that are 0.9 x 3.7 x 0.5 meters deep. These tanks are built on two levels for space considerations. We chose this tank design because we wanted a long residence time of the feed in the tank so that the fry /small fingerlings would have a chance to ingest the feed before the feed goes down the drain. This feeding strategy was implemented due to our incomplete knowledge at that time of the nutritional requirements and the lack of aggressive behavior of the fish to the commercial diets available. The tanks worked very well in this respect but had one large disadvantage in that uneaten food and feces would tend to stay in the tank. We developed an automatic cleaning system that would periodically sweep the sides and bottom of the tank clean and push the feces/feed to the screened outlet. This outlet screen also has a set of brushes rotating at 1 rpm to eliminate any biofouling from clogging the screens. This system reduced our personnel requirements by 90% and increase fry/fingerling survival dramatically.

Control and monitoring systems in the hatchery are relatively simplistic. Systems include flow meters/alarms, feeder time delay relays, and dissolved oxygen meters. We inject pure oxygen in the hatchery via an Air Liquide oxygen cone. This system is set up as a two step control and allows us to maintain our oxygen levels at +\-0.5 ppm of our target dissolved oxygen level.

When the farm was first designed, reliance on wild broodstock for progeny was the only choice. Domestic male and female broodstock are now available. Males generally range in weight from 18 to 45 kilograms and are a minimum of three years old. Females range from 30 to 100 kilograms in weight and have an average time to maturation of 7 to 8 years.

Water temperature at SAF ranges from 20 to 23 degrees Centigrade. This appears to be an optimal growing temperature but too high of a temperature for successful spawning. Mature males will successfully spermiate at these temperatures with the injection of spawning agents such as Common Carp Pituitary (CCP) or $LHRH_a$. Females require a period of cooler temperatures, preferably below 15 degrees Centigrade for several months, to complete their maturation process. For this reason, SAF currently moves our female broodstock to a cold water source at another location.

Selected females are biopsied by making a small ventral incision and aspirating about 50 oocytes. These oocytes are assayed for their suitability for spawning using a progesterone assay procedure. If the assay goes well, ovulation is induced by injection of CCP or $LHRH_a$. If all goes well, 24 to 36 hours after injection the female will ovulate. At this point the fish is transported by stretcher to an area where the surgery is to occur. A hose is inserted in the mouth of the fish to allow irrigation of the gills with oxygenated water. An incision approximately 12 centimeters in length is made ventrally in order to manually remove the eggs. After the eggs are remove, the female is sewn back up and returned to a tank.

The eggs are then fertilized with previously collected sperm. The eggs exude a sticky coating when fertilized. To eliminate this problem, the eggs are gently mixed with silt to deadhere them. The eggs are then placed in MacDonald incubation jars for 7-10 days at which point hatching occurs.

Newly hatched larvae are self sufficient for 7-10 days at which point external feeding begins. Fry are started out on powdered feeds administered as a slurry and progress to crumbles and ultimately pellets. At the end of the first year our average selected fish are approximately 200-300 grams in weight.

At this stage the fish are transferred into our fingerling sizing system. This system consists of approximately 1000 m^3 of tanks and utilizes recycle technology to treat the water. Water in this portion of the system is received from the hatchery, where it has already been utilized once, and is then recycled another 10 times in this system. This fingerling sizing system consists of 56 tanks measuring 2 x 2 x 1.2 meters and 20 tanks measuring 6 x 6 x 1.2 meters. The water in these tanks is exchanged one time per hour. After the water exits a given culture tank, it is degassed of CO_2 via degassing towers and atmospheric oxygen is added via a counterflow of air. The water then enters screen filters which remove suspended solids down to 180 microns in diameter. The sludge is then separated by these filters and exits the system while the comparatively clean water is pumped into oxygen cones for pure oxygen injection, through pressure regulating valves, and back to the culture tanks. Concurrently another loop exists where the water exiting the screen filters is pumped to fluidized sand beds where nitrification occurs converting NH_3 to NO_3.

Because of the degree of recirculation that is used in this room, the automatic control and monitoring capabilities are more sophisticated. Control capabilities include oxygen injection rates, pressure regulation, pump speeds and pump on/off conditions. This system is monitored for 22 parameters including tank water levels, dissolved oxygen levels, water flows, air flows, and pressure alarms. Total water flow rates in this system are approximately 19,000 liters per minute.

Feeding is done automatically 20 hours per day at 20 minute intervals. The fish are fed extruded sinking pellets ranging in size from 1.5 to 7mm. Currently we are using a diet that is 43% protein and 14% fat. Fish are held in this system during the second year of their life until they reach a size of approximately 1.7 kilograms.

In 1990 we expanded our system into a second building approximately 3000 m^2 in size. This allowed us to have another 5500 m^3 of production tanks. Our fish typically enter this system when they are approximately 1.7 Kgs in weight and then stay in these tanks until they reach a marketable weight of 7 - 9 Kgs. This entire growth cycle takes about 4 years. When designing this building we were able to rely on the experience base we had acquired running the first building for 4 years. We were able to modify the design to create a more effective and efficient growing environment.

There are 13 tanks in this building. Each tank is 13 x 13 x 3 meters in size. Water flow exits the center of these tanks and flows directly to our fluidized sand beds for nitrification. These fluidized beds are considerably larger than the beds that we have in the other building. These beds measure 3 meters in diameter and 5 meters high. This increase in the filter/feed rate ratio allows us to reuse the water in this building to a higher degree than in the previous building. Water passes from the beds to a stripping tower for CO2 removal and then to an atmospheric pressure pure oxygenation column for reoxygenation. The water then returns to the culture tank. We then have a separate loop that is taking solids and water from the bottom of the tank and sending it to a set of screen filters where the solids are filtered out and the clean water is distributed back to the fluidized sand beds. Total flow rates in this building are 136,000 lpm.

Oxygen control on this system is a seven step control rather than the 2 step control that is found in our earlier systems. This seven step control is a more efficient method for injecting oxygen. We could justify the extra expense for this type of oxygen control based on the increase biomass in this portion of the system. Oxygen is monitored in the tank, in the discharge of the tank, and on the top of each our fluidized sand beds.

Target densities are around 60 Kg/m^3. Combined building biomass capacities are approximately 400,000 Kgs. Feeding is done by a feeding robot that runs around the building on a rail. We currently feed 7mm and 10.5 mm pellets to the fish in this system every 20 to 25 minutes. The robot accurately meters the type and amount of feed we want into the tank in whatever schedule that we decide upon. It has an infrared communications link to our computers and downloads information every feeding cycle.

The entire system is run by a programmable logic controller otherwise known as a PLC. This is an industrial process control that takes care of the system for us and is a step up from the basic electrical relay system we are using in the building that we designed earlier. This PLC monitors and controls oxygen, tank levels, valve conditions, water temperatures, pump operations, etc.. It also monitors alarm conditions and either takes care of the situation itself of decides to wake one of us up so that we can deal with the problem.

The farm complex includes two employee residences so that 24 hour coverage is maintained. Alarm systems are wired into both residences as well as to a central alarm company that will start calling/paging personnel if a problem arises. Rapid response times are critical in an operation such as this when the potential downside of more than 400,000 kgs of fish expiring in hours is considered.

The PLC has a communications link with a personal computer (PC) that graphically shows us what is happening in the system at any given time. The PC uses a generic process control program that was customized to our needs. The PC not only gives us current conditions, but allows us to archive data that trends parameters such as temperatures, dissolved oxygen levels, feeding profiles, condition reports, etc.. We can display screens for instance that will show us dissolved oxygen readings for the past hours or weeks so that we can see how the system is interacting. By monitoring trending of parameters such as this we can, on many occasions, observe the progression of conditions in the system that can be corrected before they become a serious production issue.

Once the fish have completed their growing cycle, that is attained a swimming weight of 7 - 9 kilograms, they are transferred to processing staging tanks. These tanks are supplied with pure well water and serve two purposes. The first purpose is to give our sales and marketing staff an understanding of how much fish is available to sell over the next several weeks. The second purpose is to allow the fish to purge any flavor conditions that have been acquired during the 4 year growth cycle in the recycle water.

Sierra AquaFarms has full fresh processing capabilities on site. Final form of our fresh product ranges from gutted to filleted. We also have a subcontractor smoke our product in hot and cold smoked forms that are then vacuum packaged and frozen. We are processing and shipping our product six days a week which assures our customers a high quality product available on a schedule that meets their demands.