1973

Water Quality And Bioassay Study From Crawford National Fish Hatchery

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TRANSACTIONS OF THE NEBRASKA ACADEMY OF SCIENCES

WATER QUALITY AND BIOASSAY STUDY FROM CRAWFORD NATIONAL FISH HATCHERY

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ABSTRACT: Water from Crawford National Fish Hatchery, Crawford, Nebraska is of high quality for rearing rainbow *(Salmo gairdnerii)* and brown trout *(Salmo trutta)*. Analyses were conducted for two months during the summer of 1971 with mean results as follows: Acidity 16 mg/l, alkalinity 202 mg/l, ammonia 0.6 mg/l, calcium hardness 201 mg/l, carbon dioxide 23 mg/l, dissolved oxygen 8 mg/l, nitrates 6 mg/l, nitrites 0.02 mg/l, pH 7.6, temperature 16° C. and turbidity 4.6 J.T.U.. Bioassay studies indicated lethal concentrations of ammonia and carbon dioxide to brown trout to be 12 mg/l and 150 mg/l respectively.

INTRODUCTION

Water quality is a major factor in obtaining maximum production in salmonid fish hatcheries. Crawford National Fish Hatchery, Crawford, Nebraska has a limited supply of fresh spring water necessitating recirculation of the water several times to obtain adequate flow through the ponds. Certain chemical compounds may be depleted or increased so as to lower the productivity of the water as it is used in the hatchery. Due to the inherent high cost of production in these hatcheries, maximum production per cubic foot of water is of prime importance. Previously no substantial evaluation had been made of the quality of water the Crawford Hatchery was using. This study was conducted to facilitate more efficient management practices.

The hatchery produces about 30,000 pounds of rainbow *(Salmo gairdnerii)* and brown trout *(Salmo trutta)* per year which are stocked in lakes and streams of Nebraska, South Dakota and Wyoming. Water for the hatchery is piped three miles from a spring source to the tankroom. This tankroom, which is used for hatching and fry stages, receives 350 to 500 g.p.m. and its tanks contain 1448 cubic feet of water. Seven earthen rearing ponds receive water from the tankroom plus 325 g.p.m. recirculated water. These ponds have a capacity of approximately 14,916 cubic feet of water. The diagram in Figure 1. shows the plan of the hatchery and water flow patterns through it.

Twelve of the most important factors of water quality relating to fish production were analyzed to aid in management decisions. Bioassay studies were conducted to determine maximum levels of ammonia and carbon dioxide that could be allowed in this water for trout production.

METHODS

Hatchery water was analyzed 56 times from June 20 to August 18, 1971. Water samples were collected at random times and locations from all ponds

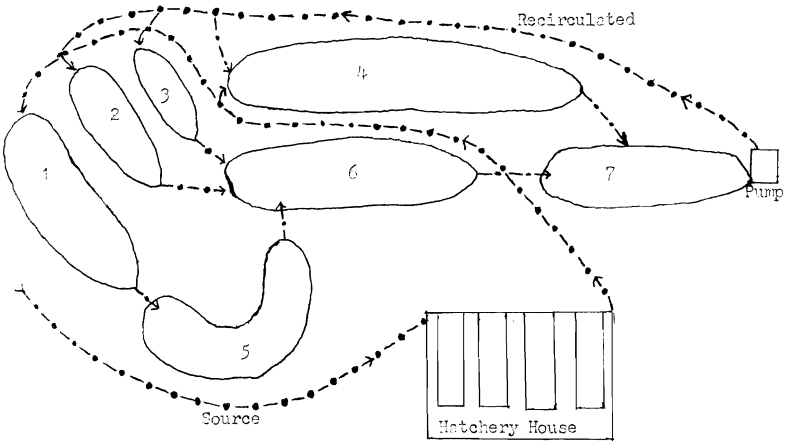

Figure 1. Dotted lines show the location of underground pressure flow systems from the source spring and recirculating pump.

and the source water. Samples were taken at median depth in a 300 ml. B.O.D. bottle for dissolved oxygen and a 1 liter polyethylene bottle for the remainder of the sample. During the collection B.O.D. bottles were held under water to the top of the stopper with a siphon tube running from the sample depth to the bottom of the bottle and a short tube in the other stopper hole was used to start the siphon by mouth. The bottle was filled to the stopper and the siphon tube was raised out of the water with the bottle. The stopper was then raised just out of the bottle mouth allowing the water remaining in the siphon tube to over-flow the bottle. The polyethylene bottle was held at the sample depth and allowed to fill completely. Then it was squeezed slowly and allowed to refill several times. The screw-on lid was put on under water to exclude all gas bubbles. These methods of sampling work quite well in shallow water and were considered to be representative of the water sampled.

Titration analyses were made for acidity, alkalinity, calcium hardness, carbon dioxide and dissolved oxygen using standard laboratory procedures (Hach Chemical Co., 1967). A Bausch and Lomb Spectronic 20 was used to analyze for ammonia, nitrates, nitrites, pH and turbidity (Hach Chemical Co., 1970).

Bioassays were carried out in 189 liter hatching troughs using water tapped from the source water pipe. Water was allowed to flow through the tanks at a constant rate of 1.8 liter per minute. This allowed a complete turn-over of water in the tanks overy 105 minutes. The tanks used in the test were considered to be at maximum carrying capacity as compared to the

average pounds of fish carried per cubic meter of water in the hatchery ponds. One-half pound or 22 brown trout were restricted to a proportional volume of water by a screen divider in the troughs. The upper portion of the troughs were used as mixing areas for the compounds to be introduced.

Bottled carbon dioxide gas was used in the carbon dioxide bioassays. This was applied to the test tanks by a pressure control valve and a silicon carbide dispersal stone.

For the ammonia bioassay, ammonium hydroxide was dripped into the mixing area of the test tank using apparatus as described by Jones (1964). This was easily adjusted and quite accurate until the fluid level drops below one-fourth capacity of the supply bottle.

RESULTS & DISSCUSSION

Dissolved oxygen, in the source water, ranged from 7 to 8.4 mg/l with a mean of 7.8 mg/l. In the rearing ponds the dissolved oxygen range was 4.6 mg/l in pond six at 5 A.M. to 9.3 mg/l in pond one at 2 P.M. The mean for all ponds was 7.7 mg/l dissolved oxygen. The photosynthetic activity of algal growth apparently supplies about 2.5 mg/l of the oxygen in the ponds as the average night-time readings were lower by this amount. This night-time concentration is marginal, according to Doudoroff (1957) and Water Quality Criteria (1968); dissolved oxygen concentrations in trout waters should not be allowed to drop below 5 mg/l for more than a few hours. Graphs by Alabaster, Herbert and Hemens (1957) show that dissolved oxygen concentrations below 40% saturation can be lethal in less than six hours in water with carbon dioxide concentrations comparable to those in this hatchery.

Source water temperature remained near 11° C. during the sample period. The recirculated water increased the temperature of the pond water about 5° C. after being mixed with fresh water. For ponds that were in a series, a 1° C. increase per pond was apparent. The average in all ponds was 16° C. during the sample period.

Water entering the hatchery had a carbon dioxide range from 16 to 28 mg/l with an average of 23 mg/l. This is apparently due to the limestone deposits in the substrata where this water originates. An unexplained sharp decline in carbon dioxide was noted during the first two weeks of July after which the content gradually returned to near the mean. Carbon dioxide content decreased about 1 mg/l as the water flows into the ponds. It was noted that in pond six, where the oxygen content was the lowest, the carbon dioxide was highest.

Source water had an average pH value of 7.3 while the rearing ponds had an average pH of 7.6. This increase in pH was attributable to the decrease in carbon dioxide or carbonic acid as noted in the preceding paragraph.

Acidity, as calcium carbonate, drops from a mean of 20 mg/l in the source water to 16 mg/l in the ponds. Total alkalinity, expressed as mg/l calcium carbonate, drops from source to rearing ponds with means of 252 to 202 mg/l respectively. These changes in acidity and alkalinity may also be reflected by the changes of the pH value and carbon dioxide content. Calcium hardness, as calcium carbonate, also drops from 220 mg/l in the source water to 201 mg/l in the ponds. According to Hickling (1962) et al. these alkalinity and pH values are representative of highly productive water for fish.

Ammonia was not present in the source water. The recirculated water increased ammonia levels to about 0.5 mg/l and it increases about 0.1 mg/l per pond in series. This produces a mean of 0.6 mg/l for all ponds. Early morning readings as high as 1.0 mg/l reflect the increased activity of trout during this period.

Nitrate and nitrite readings were quite stable with means of 5.5 mg/l and 0.2 mg/l respectively. Turbidity ranged from 0 to 7.7 mg/l Jackson Turbidity Units and averaged 4.2 J.T.U.. The highest turbidity readings were taken during pond cleaning operations which are of short duration. Table 1 gives the mean of all analyses taken from each pond and the source water.

TABLE 1.* Indicates mg/l $CaCO_3$. Mean readings for each pond and source water compared to over-all mean.

	Mean Readings								
Pond #	**1**	**3**	**4**	**5**	**6**	**7**	**Source**	**Mean**	**Range**
Acidity *	19	17	14	14	15	17	20	16	11-21
Alkalinity *	209	194	204	215	189	202	252	210	169-265
Ammonia	0.5	0.4	0.6	0.6	0.7	0.8	0.0	0.6	0.0-1.2
Ca+ Hardness *	201	199	203	197	202	206	220	204	187-231
Carbon Dioxide	19	19	17	21	21	19	23	20	13-28
Dissolved 0_2	7.9	8.3	8.1	7.7	6.7	7.7	7.8	7.8	4.6-9.4
Nitrate	6.2	5.4	5.4	5.0	5.3	5.5	5.9	5.5	4.5-6.3
Nitrite	.03	.02	.02	.03	.03	.03	.01	.02	.00-.03
pH	7.7	7.7	7.8	7.5	7.7	7.7	7.3	7.6	7.2-7.8
Temperature C°	15	14	16	15	16	16	11	15	11-17
Turbidity	3.8	-----	4.8	3.7	3.7	7.7	1.3	4.2	0.0-9.1

In the 60 mg/l carbon dioxide bioassay water conditions were as follows: Temperature 11° C., pH 6.9, acidity 26 mg/l, alkalinity 267 mg/l, calcium hardness 228 mg/l and dissolved oxygen 7.9 mg/l. The fish remained normal in this water for 96 hours except for a slight increase in depth of gilling. They began feeding after 64 hours as did control fish. Apparently the fish were off feed because of the change in surroundings and not because of water composition. At 100 mg/l carbon dioxide the pH was 6.8, acidity 27 mg/l, alkalinity 274 mg/l and calcium hardness 230 mg/l with temperature and dissolved oxygen the same as in all tests. These fish showed some stress by hyper-activity when first introduced and deep gilling through-out the test. They began feeding after 60 hours but were sluggish. At 96 hours all fish were alive and still feeding. In the 150 mg/l carbon dioxide test water conditions were as follows: pH 6.7, acidity 28 mg/l, alkalinity 282 mg/l and calcium hardness 238 mg/l. In this water the rate and depth of gilling were both increased and the fish were very sluggish during the test. At 48 hours two fish were dead, eight were on their backs and the remaining twelve were slow to react to stimuli. The test was terminated at this time as it was evident that the fish would not survive 96 hours.

These findings correspond to conclusions drawn by Doudoross, (1957) but are slightly higher than lethal carbon dioxide concentrations for rainbow trout reported by Alabaster, Herbert and Hemens, (1957). The more general statement that carbon dioxide should not exceed 25 mg/l, in Water Quality Criteria, (1968) does not take into account the different water conditions that may be encountered in fisheries. As Jones, (1964) points out, the effect of any harmful compound may be varied by the chemical composition of the water containing such compounds.

The 6 mg/l ammonia bioassay was conducted for 96 hours. Water conditions were as follows: pH 7.6, temperature 11° C., carbon dioxide 31 mg/l, alkalinity 264 mg/l and dissolved oxygen 9.4 mg/l. All fish remained visibly normal through-out the test and began feeding after 52 hours. In the 9 mg/l ammonia bioassay all water conditions were the same as above except the pH was 7.7. During the 96 hour test period none of the fish appeared to be sick but they would not feed. This may support statements made by Hickling, (1962) that high concentrations of ammonia are a "natural" depressant on fish metabolism. The pH in the 12 mg/l ammonia bioassay was 7.8 with all other factors remaining the same. Eight fish died during the first 18 hours and after 48 hours ten of the remaining fourteen fish had lost their balance and were gasping frantically. As it was apparent that this concentration was above the threshold level for this water, the test was terminated at 48 hours to conserve time. The fish that were sick from this high concentration of ammonia required nearly 24 hours to recover whereas those from the 150 mg/l carbon dioxide test were fully recovered after one-half hour in normal hatch-

ery water. This demonstrates that carbon dioxide affects the respiratory system while ammonia may affect deeper physiological functions.

Doudoroff (1957) states that 2 to 7 mg/l ammonia has been found to be lethal to fish but no other water composition factors were stated. Methods for calculation of toxicity of ammonia given by Lloyd, (1961) do not correspond with the results of this bioassay. The calculated threshold for rainbow trout was 36 mg/l and the observed threshold for brown trout was 12 mg/l. The differences between species and methods of study may account for these different values.

CONCLUSIONS

The water used in Crawford National Fish Hatchery was found to be satisfactory for trout propogation and rearing. The high alkalinity and a pH of 7.6 are ideal. The 13 to 16° C. water allows maximum growth in the rearing ponds and the 11° C. source water is ideal for hatching. Dissolved oxygen levels remain above 6 mg/l in all water except pond six where better aeration is needed. Nitrogen as nitrates and nitrites does not show the presence of large amounts of dangerous nitrogenous products. Turbidity was never greater than 10 J.T.U. and thus within recommendations made in Water Quality Criteria, (1968).

Bioassay results for carbon dioxide demonstrated that the 22 mg/l carbon dioxide content of this water is of no apparent danger as brown trout *(Salmo trutta)* survived up to 100 mg/l carbon dioxide for 96 hours.

The 0.5 mg/l ammonia level in the hatchery water is well below the 9 mg/l ammonia concentration found to be a limiting factor on fish metabolism in bioassays using brown trout.

No evidence of harmful effects from using recirculated water was found in this study; even more recirculated water could be reused without danger to the fish.

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