The brown trout catch from the Firehole in 1969 was distinctly different from previous years. The percentage of brown trout to rainbow trout as well as total brown trout caught appears much lower than in 1953–1957.

If rainbow trout were already overexploited in 1957 as reported by Benson *et al.* (1959), it appears that little improvement has occurred since then. Regarding brown trout in the Firehole, it would appear that either standing crop has been depleted or else the September fishing accounts for the major share of brown trout harvest.

New restrictions on size (16 inches) and creel limits (3 fish) were initiated on the Madison-Firehole Rivers in 1970. Further surveys will be needed to determine the effect of these new regulations.

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LITERATURE CITED

Benson, N. G., O. B. Cope, and R. V. Bulkley. 1959. Fishery management studies on the Madison River system in Yellowstone National Park. U. S. Fish and Wildl. Serv., Spec. Sci. Rep. Fish. No. 307. 29 p.

Brown, B. E. 1969. An analysis of the Oklahoma State lake creel survey to improve creel survey design. Ph.D. Thesis. Oklahoma State Univ. 164 p.

Neuhold, J. M. and K. H. Lu. 1957. Creel census method. Utah State Dept. Fish and Game, Publ. No. 8. 36 p.

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Lethal pH for the White Sucker *Catostomus commersoni* (Lacépède)

In recent years much information on the kinds and quantities of pollutants that are present in our aquatic environment has become available. There is, however, little information to relate water quality with its short- and long-term effects on fishes.

Recently a study was made on a population of white suckers from Lumsden Lake, Killarney Provincial Park, Ontario, Canada, in which the water quality of the lake had been altered as a result of atmospheric fallout of sulfur dioxide (Beamish 1970). The population of suckers in the lake gradually was reduced to the point of extinction over a period of 2 years. Coincident with elimination of the sucker population, the pH of the lake water dropped to 4.4. Because lethal pH values were available for only a few species of fishes, the present study was initiated to determine the lethal levels of pH and to describe behavior of young white suckers in water acidified with hydrochloric and sulfuric acids.

MATERIALS AND METHODS

Suckers were reared in the laboratory for 16 months prior to use in the pH experiments. Parental stock was obtained from two lakes in Ontario. Fish were reared in the laboratory under a photoperiod of 13 hours, water temperature of 16 C, and pH of 7.6. Seven months after hatching the fish were fed a liver diet (to satiation) once daily instead of twice.

In all experiments, suckers were removed from rearing tanks into a small transfer tank. The pH in the transfer tank was reduced gradually over a period of 3 minutes to that of the 180 liter experimental tank. Fish were then transferred directly into the experimental tank. A continuous-flow system (Fig. 1) was necessary in order that long-term experiments could be undertaken. Temperature-regulating valves maintained a controlled flow of constant temperature water. Water and acid flowed at constant rates into a shallow, well-aerated, plexiglass tray for mixing (labelled

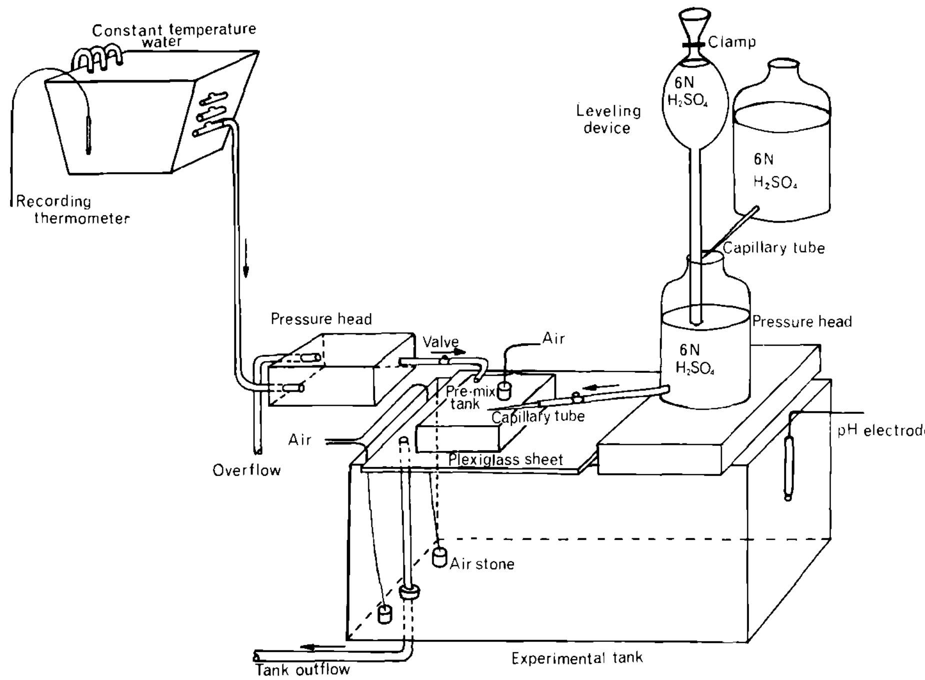

FIGURE 1.—Diagram of apparatus used to produce water of a constant pH in a flowing system.

pre-mix tank in Fig. 1). The diluted acid flowed from this tray over a plexiglass sheet and entered the experimental tank in a series of drops from the under side of the sheet. No variation in pH was detectable to within ± 0.005 pH units, indicating the acid and water were well mixed. Good mixing could not be achieved by allowing the solution to flow directly from the pre-mix tank into the experimental tank. Levels of acid were checked twice daily. Results of analyses of the water before and after acidification with 6 N sulfuric acid are given in Table 1. For most of the experiments, sulfuric acid was used to acidify the water. Hydrochloric acid (4 N) was used in two experiments. This permitted a comparison of the median time to death using two different acids.

The concentration of acid during an experiment was maintained within ± 0.02 pH units for all experimental acid concentrations from pH 3.0 to pH 3.8. At pH 3.9 the acid concentration varied ± 0.05 pH units. At pH 4.0, the range was ± 0.1 units, and at pH 4.2 the concentration varied ± 0.2 units. For pH values from 3.0 to 3.8, 15 suckers were used for an experiment. At higher pH, 20 fish were used. Fish were weighed immediately after mortality occurred except in one experiment. In this experiment, the weights of 20 suckers were compared before and after a 2-week period at pH 4.0.

Median survival time represented the interval after which 50% of the fish remained alive. Fish were assumed dead when loss of

TABLE 1.—*Analysis of acidified and nonacidified University of Toronto water*

Constituent	Acidified water* ppm	Nonacidified water* ppm
Sodium	12.2	12.3
Potassium	1.9	1.9
Calcium	43.3	43.5
Magnesium	8.75	8.50
Sulphate as SO_4	145	29
Sulphite as SO_3	4.0	2.0
Alkalinity as $CaCO_3$	1	89
Hardness as $CaCO_3$	144	144
Solids total	290	270
Suspended	5	5
Dissolved	285	265
pH	4.0	7.6

* All values except pH are expressed as ppm.

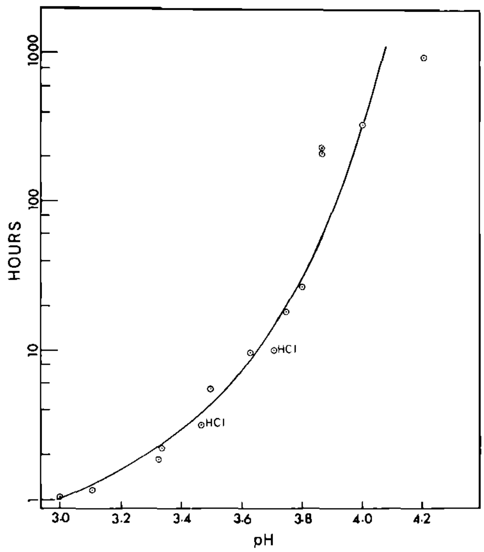

FIGURE 2.—Median survival time of white suckers in relation to pH. Sulfuric acid was used to alter pH except where noted. The line was fitted by eye to the points.

equilibrium occurred. For each experiment, a control was maintained under the conditions described for the rearing tanks.

RESULTS AND DISCUSSION

The median survival times in relation to pH are presented in Figure 2. Throughout all experiments, the control fish remained healthy and grew at the normal rate for suckers in the laboratory. In the experiments at pH 4.0 and 4.2, if the pH of the water was increased to a value greater than 5.0, the fish resumed feeding. A subsequent lowering of pH below 4.5 caused cessation of feeding. At pH 4.0, 20 fish lost an average of 8% of their original weight over a 2-week period. In the two experiments in which hydrochloric acid was used, the median survival times were not appreciably different from the median survival times where sulfuric acid was used to acidify the water (Fig. 2). Jonas *et al.* (1962) found that when lactic acid or hydrochloric acid was injected into rainbow trout, death occurred if the blood pH fell into the range of 6.8 to 6.9. The injection of much larger quantities of lactate or chloride ion in the form of sodium salts did not cause fatalities.

The behaviour of the fish varied with pH. At low and lethal pH values (3.0–3.8) fish initially displayed a short period of extreme activity followed by prolonged periods of inactivity. Prior to loss of equilibrium, activity again increased, as did ventilatory movements. Moreover, fish were coated with a white film similar to that observed for rainbow trout in lethal acid concentrations (Lloyd and Jordan 1964). Suckers could not be revived once this film was well formed. At pH 4.2 this film did not develop. When experiments lasted longer than 24 hours, fish ceased feeding. Fish maintained in experiments lasting longer than 24 hours lost weight, became emaciated, and developed muscular and spinal deformities. Death usually resulted several weeks after these symptoms developed. Fish from these experiments could be revived, although they suffered permanent deformities. It appears that the cause of death was not the same at pH values above and below pH 3.9 and this may be the reason for the change in the shape of the survival curve in Figure 2.

Höglund and Härdig (1969) and Jonas *et al.* (1962) suggested that at lower pH values where coagulation of gill surfaces results, death was due to asphyxia. Lloyd and Jordan (1964) suggested this was not the cause of death among the rainbow trout they studied. Their comparisons of the pH value and total carbon dioxide content of the blood of rainbow trout killed in acid solutions, with those of the control fish, suggested to them that death was due to acidaemia. The median survival times they described for rainbow trout were considerably shorter than those observed in this experiment for white suckers. For example, at pH 4.0 the median survival time for rainbow trout was approximately 35 hours, whereas for suckers it was approximately 200 hours.

Acidosis in humans results in hydrogen ions being taken up by bone mineral and simultaneously these hydrogen ions are replaced in the plasma by neutral cations from the surface of the crystallites of the skeleton. Prolonged acidosis can be associated with decalcification of the skeleton as the calcium ions removed from the bone are excreted in the urine (Fourman, 1960; Robinson, 1962). It is possible that the spinal deformities which developed in the fish held for over 4 weeks at pH 4.2 may have resulted from some degree of decalcification of the vertebrae.

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LITERATURE CITED

BEAMISH, R. J. 1970. Factors affecting the age and size of white suckers at maturity. Ph.D. thesis, Department of Zoology, University of Toronto.

FOURMAN, P. 1960. Calcium metabolism and the bone. Blackwell Scientific Publications, Oxford. [Cited by J. R. Robinson (1962), p. 47].

HÖGLUND, L. B., AND J. HÄRDIG. 1969. Reactions of young salmonids to sudden changes of pH, carbon dioxide tension, and oxygen content. Rept. Inst. Freshwater Res. Drottningholm 49: 76–119.

JONAS, R. E. E., S. H. SEHDEV, AND N. TOMLINSON. 1962. Blood pH and mortality in rainbow trout (*Salmo gairdnerii*) and sockeye salmon (*Oncorhyncus nerka*). J. Fish. Res. Bd. Canada 19: 619–624.

LLOYD, R., AND D. H. M. JORDAN. 1964. Some factors affecting the resistance of rainbow trout (*Salmo gairdnerii* Richardson) to acid waters. Int. J. Air Water Pollut. 8: 393–403.

ROBINSON, J. R. 1962. Fundamentals of acid-base regulation. Blackwell Scientific Publication, Oxford. 81 p.

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Results of a Pilot Shrimp Tagging Project Using Internal Anchor Tags

INTRODUCTION

Tagging and marking of marine fishes and invertebrates have been standard techniques in coastal fisheries research and management programs since the turn of the century. During the late 1930's and early 1940's adult white shrimp, *Penaeus setiferus*, were successfully tagged with Petersen disk tags (Lindner and Anderson, 1956). Recently, however, a stain-injection method of marking commercial shrimp has been successfully employed by many federal and state fisheries agencies. Menzel (1955) conceived the use of biological stains on shrimp. Dawson (1957) substantiated this potential through laboratory experimentation and Costello (1964) applied this method in the field. This note reports results of a newer method of tagging adult shrimp where speed and mass tagging applications were desirable.

During October and December 1970, the South Carolina Marine Resources Division implemented a pilot project to determine the feasibility of tagging Penaeid shrimp with internal anchor tags. The experiment was of a preliminary nature, and expanded efforts were to be planned only if a reasonable degree of success was achieved. Results of the pilot project indicate that this method of marking shrimp has considerable promise for future studies.

White shrimp were tagged with FD-67C internal anchor tags developed by the Floy Tag Manufacturing Company. Dell (1968) gives a description of the tagging method and its field application. The tags were applied by means of a cartridge-fed applicator gun which reduced the tagging time considerably. Personnel of this Division conceived the idea of using the tag applicator on shrimp from previous tagging experiments on black sea bass (*Centropristis striata*). These tags are also reportedly being used in Australia where some 50,000 prawns are expected to be tagged.

METHODS AND PROCEDURES

A rather well defined stock of white shrimp in Charleston Harbor was selected for the pilot tagging study. The experiment was oriented in time and space so that exploitation of the tagged shrimp would be simultaneous with onset of the heaviest seasonal fishing intensity just offshore. The tagging area was situated so that the tagged shrimp would enter the open fishing grounds with a supporting population of commercial size shrimp from the surrounding nursery areas.