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TOLERANCE OF SELECTED FISH SPECIES TO ATMOSPHERIC GAS SUPERSATURATION

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ABSTRACT

Several fish species were collected in SE Washington, acclimated to 20°C and 100-150% gas supersaturation, and exposed to high gas content waters (100-140% supersaturation) at 20°C under standard acute bioassay conditions. The fish were monitored to determine death time and necropsyed to determine the cause of death. The species exhibited a differential tolerance to high gas levels with smallmouth bass more tolerant and salmonids less tolerant. Nearly all fish which died during the test exhibited signs of gas bubble disease, ranging from massive heart embolism to mild subepidermal emphysema. These signs were related to exposure time and to gas supersaturation levels. Gas concentrations were monitored by molecular sieve gas chromatography. The research was supported by the AEC under contract AT(45-1)-1830.

Introduction

This paper presents the results of a preliminary scanning study to determine approximate lethal levels of dissolved atmospheric gasses to various fish species. The program was designed to indicate which species should receive further attention to determine more precise tolerance limits in future bioassay work. (While I describe techniques of collecting, holding the test organisms, creating supersaturated water, and monitoring dissolved gasses, I will show you a few slides of signs of gas bubble disease displayed by the fishes used in this study).

With only a few exceptions, the organisms used were collected by beach seine in streams and ponds near the Hanford Reservation in eastern Washington. The exceptions are channel catfish and rainbow trout which were obtained from commercial hatcheries, whitefish which were collected by electroshocking, and rainbow trout fry which were hatched out from eggs spawned at Battelle's facilities. On return to the laboratory, the fishes were acclimated to 20°C at about one degree temperature increase per day and held at the test temperature for at least two weeks prior to exposure to supersaturated water. The holding facilities were aerated to reduce gas levels to 95 to 105 percent of saturation.

Two systems were employed to artificially supersaturate water with dissolved atmospheric gasses in the laboratory for test purposes. The first operates on a principle of decreasing solubility by increasing temperature. Columbia River water was chilled to about 5°C and aerated, causing it to be nearly equilibrium saturated (100%). This cold, air-saturated water was then heated in a large-capacity circulation heater to 20°C (the test temperature in all tests), causing the gas solubilities to decrease. Since little change in gas content too place, the water delivered to test troughs was supersaturated. This was mixed with water at 20°C which had been aerated to control gas concentrations at four pre-determined levels for each test. Test troughs were 18 inches wide and five feet long with the water a foot deep. Flow rates were 20 liters per minute, giving a replacement time of 12 minutes. The temperature-differential system was subject to mechanical failures

due to the number of complex components and did not perform with the desired reliability. Based on experience of other researchers, a pressure system was designed and installed. In it compressed air is injected into the incoming water which enters a pressure tank, allowing gasses to dissolve into the water. At a pressure of 40 psi and an air flow of 10 to 20 cf/hr water became sufficiently saturated to supply the test troughs. Fine control on the gas content was provided by adjusting the air flow into the system.

Analysis of the test water for dissolved gasses (oxygen and nitrogen plus argon) was performed by gas chromatography, using a stripping chamber to inject a one ml water sample. The gas chromatography was standardized externally by the Van Slyke manometric determination for nitrogen plus argon and by a Winkler titration for oxygen. The detector signal was fed to an electronic digital integrator to aid in the computation of gas content. Saturation levels are based on the tables of Weiss (1970) and are expressed as standard pressure (760 mm Hg). Water analysis was performed just prior to the introduction of fishes, at the end of the test, and during the test. The values reported are means of some three samples, which typically ranged two percent about the mean. Test temperatures were maintained at 20 $\pm$ 1/2 degree C. Fishes were observed at 1, 2, 4, 8 and every 24 hours after the test began. Mortalities were removed and some were randomly necropsied to determine the cause of death which was in nearly all cases clearly gas bubble disease. Coronary arrest due to embolism accounted for approximately 85% of the mortalities with gill occlusion and external hemorrhaging accounting for 10 and 5 percent, respectively.

I am now going to present tolerance charts for each of the ten species bioassayed. As you can see, the abcissa is a logarithmic scale of death time in hours, the ordinate is the total gas saturation. Each point represents a single fish unless it is accompanied by a number indicating the number of fish represented. The vertical dashed line indicates the end of a test and the arrow with a numberal indicates the number of fish alive at the end of the test at that gas level. Of course, a highly tolerant species will be represented by points far away from the origin and one less tolerant will appear near the origin. On the side of the figure is a checklist of species studied in approximate order of increasing tolerance.

The first figure depicts one of the most and the least tolerant species tested, smallmouth bass and mountain whitefish, respectively. At 130% gas supersaturation, the bass lived for greater than one day, while whitefish at the same concentration lived less than nine hours. The next figure shows carp and largescale sucker data. Note that no mortality occurred to carp in nearly four days at 130 percent, although it was found that they died in less than six hours at 150% in tests conducted after this figure was drawn. Bluegill and pumpkinseed have tolerances similar to each other, although the pumpkinseed appears slightly more tolerant. There was little mortality to either species at 130 percent in six days. Channel catfish and black bullhead were also similar to each other with the bullhead perhaps slightly more tolerant than the catfish. These were less tolerant than the sunfishes, however, and mortalities occurred in less than 20 hours at 130 percent saturation. Two age classes of rainbow trout were tested, 4 months and 22 months, again with little difference between them. It would appear that the younger fish might be more tolerant. It is interesting to note that yolk-sac fry exposed to 113.7% dissolved gas saturation developed blebs in the yolk-sac which were lethal in many cases but disappeared at 108.5% of saturation.

In summary, I have a figure indicating the relative tolerances which you have just seen. In this figure, the names indicate the relative positions of the points you have just seen for individual fishes. These preliminary studies have demonstrated an apparent species difference in the tolerance of fishes to dissolved gas supersaturation. However, more importantly, I think, is the fact that when tested at 20°C, the fishes having a cold water preferendum (whitefish, trout, and sucker) appear less tolerant than do those preferring warm water. Dr. Bouck has some preliminary data describing temperature effects on tolerance which indicate a possible change in the <u>direction</u> of the slope of temperature vs tolerance curves with different species. That is, fishes appear most tolerant at or near their "optimum" temperature. It is possible that our data reflects that hypothesis and we intend to determine more precise tolerances for selected species at different temperatures in the future.

Finally, I would like to add a few notes on signs of gas bubble disease. Random necropsies of fishes exposed to gas bubble disease have been conducted by us and we have found that at higher concentrations of dissolved gasses (greater than 125%), signs are generally internal rather than external. This may be the result of mortality occurring at higher gas levels before externally visible emphysema or hemorrhage appears. Carp exposed to high concentrations (>140%) developed many externally visible signs while suckers did not. Typically the internal signs include occlusion of the heart, congestion of the liver, and in some species (carp and suckers), a great deal of pressure builds up in the swim bladder, which is distended, despite these being physostomous. At concentrations lower than 125%, external signs are more generally observed, including emphysema of fins and operculae, exopthalmis, and gill congestion, all of which you saw earlier.

Weiss, R. F. 1970. Solubility of Nitrogen and Oxygen in Water and Sea Water. Deep Sea Res. 1970:17(4):721-735.