EFFECTS OF SUBOPTIMAL DISSOLVED OXYGEN CONCENTRATIONS ON DEVELOPING STRIPED BASS EMBRYOS

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Abstract: Various concentrations of dissolved oxygen were tested against normal embryonic development of striped bass, *Morone saxatilis*, eggs. Lowest level of dissolved oxygen necessary for normal development was established as 3.0 ppm. Abnormalities associated with suboptimal levels of dissolved oxygen are described, and the number for each concentration quantified.

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Development of techniques for culture of striped bass, *Morone saxatilis*, (Walbaum), has proven to be a tedious and frustrating task. While considerable progress has been made, rearing success has been erratic and mortality, especially among embryos, yolk-sac, and post yolk-sac larvae, has been largely unexplained. Efforts to account for these losses have been poorly organized and, for the most part, confined to speculation.

Environmental parameters either individually or in combination have long been suspected as important factors affecting development of striped bass embryos (Mansueti 1958). Most previous environmental studies affecting striped bass embryonic development have been concerned mainly with temperature (Albrecht 1964, Shannon and Smith 1967, Shannon 1969, Turner and Farley 1971, Koo and Johnston 1978) and salinity (Albrecht 1964, Turner and Farley 1971).

Studies of dissolved oxygen requirements of developing striped bass have usually varied other parameters along with oxygen or have been concerned with either fry (post yolk-sac) or young-of-the-year fish (Albrecht 1964, Krouse 1968, Chittenden 1971, Davies 1973, Turner and Farley 1971). However, Turner and Farley (1971) found that a dissolved oxygen concentration less than 4.0 ppm caused various abnormalities in embryonic development as well as a lower hatch percentage. Similiar information reported by O'Mally and Boone (1972) showed the incidence of abnormalities increased as the percent oxygen saturation decreased.

Prior to introduction of a Venturi system in 1978, dissolved oxygen levels at Moncks Corner Striped Bass Hatchery were consistently between 3.0 to 4.0 ppm which is below the optimal level suggested by Turner and Farley (1971). Therefore, objectives of this study were to determine the critical oxygen level to which developing embryos could be subjected for normal development and to describe effects of dissolved oxygen concentrations below this critical point.

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METHODS

Three different dissolved oxygen concentrations were tested with 3 replicates per test. Preliminary studies indicated exposure of developing embryos to dissolved oxygen concentrations of 1.15 ppm and less resulted in total mortality and little or no embryonic development. Therefore, treatment values were designed to be 2.0 ppm, 2.5 ppm and 3.0 ppm.

Concentrations of dissolved oxygen were varied by mixing unoxygenated well water from the same source which had been aerated by passing it through a Venturi system in an elevated holding tank. Desired concentrations were obtained by manipulation of valves to mix unaerated with aerated water prior to egg introduction. Replicates were effected for each dissolved oxygen concentration by gravity feeding 3 1000-ml graduated cylinders through tygon tubing from a central reservoir consisting of a standard McDonald hatching jar tapped at the bottom for outlets.

Hydrogen sulfide levels were checked before and during experimentation and pH was checked every 6 hours. Oxygen levels and temperature in each reservoir were checked prior to experiment initiation and once each hour throughout the study. A periodic check of the oxygen meter's accuracy was accomplished by comparison of levels found with those determined by Winkler titration as described in American Public Health Association et al. (1975). If the meter varied more than 0.1 ppm from standard methods, the meter was recalibrated. Oxygen levels within the graduated cylinders were also checked before egg introduction to determine if any variation existed between reservoir and test containers.

Approximately 100 fertilized eggs were hand-picked and placed in each test container as soon as it was possible to differentiate between fertilized and unfertilized eggs. Containers were then covered by nylon stockings to prevent egg escape. Dead eggs were periodically removed and counted to prevent unaccounted for losses through decomposition.

The experiment was considered completed when all eggs in the control containers had hatched. All fry or unhatched eggs were examined under a microscope and classed abnormal, normal or dead eggs. Abnormalities were classified by description and severity.

Statistical analyses were performed in 2 ways. First, the types of abnormalities were grouped together and tested against the number of normal embryos by a single classification analysis of variance and Student-Newman-Keuls procedure (Sokal and Rohlf 1969). The types of abnormalities were segregated and tested against treatments by the same means. All levels of confidence were at $\alpha = 0.05$.

RESULTS

Fluctuations in mean values of oxygen concentrations for the experiment varied no more than 0.03 ppm at each level. At no time did readings exceed 0.15 ppm variance from the designed treatment level.

Temperature ranged between 18.5 and 20 C with a mean of 19.0 C. Hydrogen sulfide content was monitored but none was detected. During the experiment pH

ranged from 8.1 - 9.0 with a mean of 8.4. Twice during the study the oxygen meter had to be recalibrated because of variance from Winkler titration measurements.

Mean dissolved oxygen concentration in the control was 8.23 ppm which represented a 90.3% saturation at a mean temperature value of 19 C. Other levels expressed as percent saturation were 2.0 ppm = 21.9%, 2.5 ppm = 27.4% and 3.0 ppm = 32.9%

All of the treatment replicates had unaccounted for variation in egg mortality. However, statistical analysis of this phenomenon revealed no significant difference among the replicates.

Two different types of developmental abnormalities were noted in varying degrees of severity. These were truncation (clubtail) and lateral spinal curvature, or scoliosis (Hickey et al. 1977). Some degree of truncation occurred in embryos from each treatment while scoliosis was found only at the 2 lower oxygen concentrations, 2.0 ppm and 2.5 ppm.

One replicate of the 2.0 ppm treatment had to be discarded because water intake for its container had been inadvertantly disconnected for an unknown period of time between hours 30 and 38 (Table 1). All eggs in this container died except one which exhibited acute truncation.

Table 1. Number and percent live eggs/treatment of normal and abnormal (by type) developing striped bass embryos subjected to varying dissolved oxygen concentrations.

D. O.	Normal		Abnormal				Total	
Conc.			Truncation		Socliosis			
(ppm)	Number	%	Number	%	Number	%	Number	%
2.0	1	0.5	182	99.5			183	100
2.5	14	5.4	124	47.9	121	46.7	259	100
3.0	187	87.4	27	12.6			214	100
Control	223	97.8	5	2.2			228	100

Statistical analysis revealed no significant difference in the number of normal embryos between 3.0 ppm and the control. Likewise, there was no significant difference in the number of normal embryos at oxygen concentrations of 2.5 ppm and 2.0 ppm. By comparison, there was a significantly higher number of normal embryos in both the 3.0 ppm and the control when tested independently as well as jointly with the 2 lower concentrations.

Upon testing the 2 types of abnormalities associated with the treatments, a significant difference in the number of truncated embryos between each treatment level was found. Only 1 treatment (2.5 ppm oxygen concentration) exhibited scolosis and was not tested for significance.

DISCUSSION

The design of experimental apparatus for this study was not complicated as oxygen stripping columns used in previous studies (Alderdice et al. 1958, Mount 1961, 1964, Shumway et al. 1964, Siefert and Spoor 1973, Siefert and Syrett 1973, and Seifert et al. 1974), and it proved to be quite satisfactory. Initial

concern was expressed over possible high concentrations of hydrogen sulfide since our water source was of well origin. However, as stated previously, hydrogen sulfide levels were negligible.

During pilot studies, problems arose in testing unequal numbers of eggs and unaccounted for mortality. Originally the study was designed to test eggs from fertilization, however, due to the unaccountability in numbers and unknown fertilization rates it was necessary to wait until division of egg cells could be detected (1.5 to 3 hrs.). Once the 2-4 cell stage was reached, approximately 100 eggs were hand-picked and placed in each container. The physical damage in sorting fertilized from unfertilized eggs probably caused some mortality among the treatments. This is a possible explanation for the unaccounted mortality of eggs from each treatment. Since statistical analysis showed no significance between treatments, this mortality was assumed random.

Results of this experiment were similar to those found by O'Mally and Boone (1972). As the levels of oxygen concentration increased, the incidence of abnormalities decreased (Fig. 1).

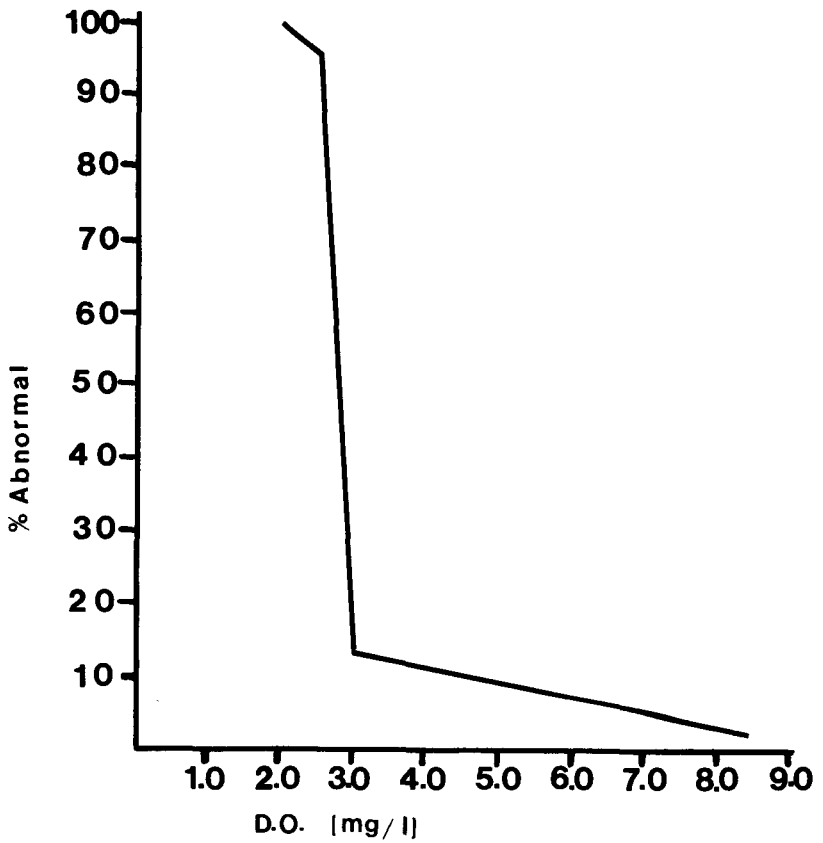

Fig. 1. Percent abnormalities associated with dissolved oxygen treatments.

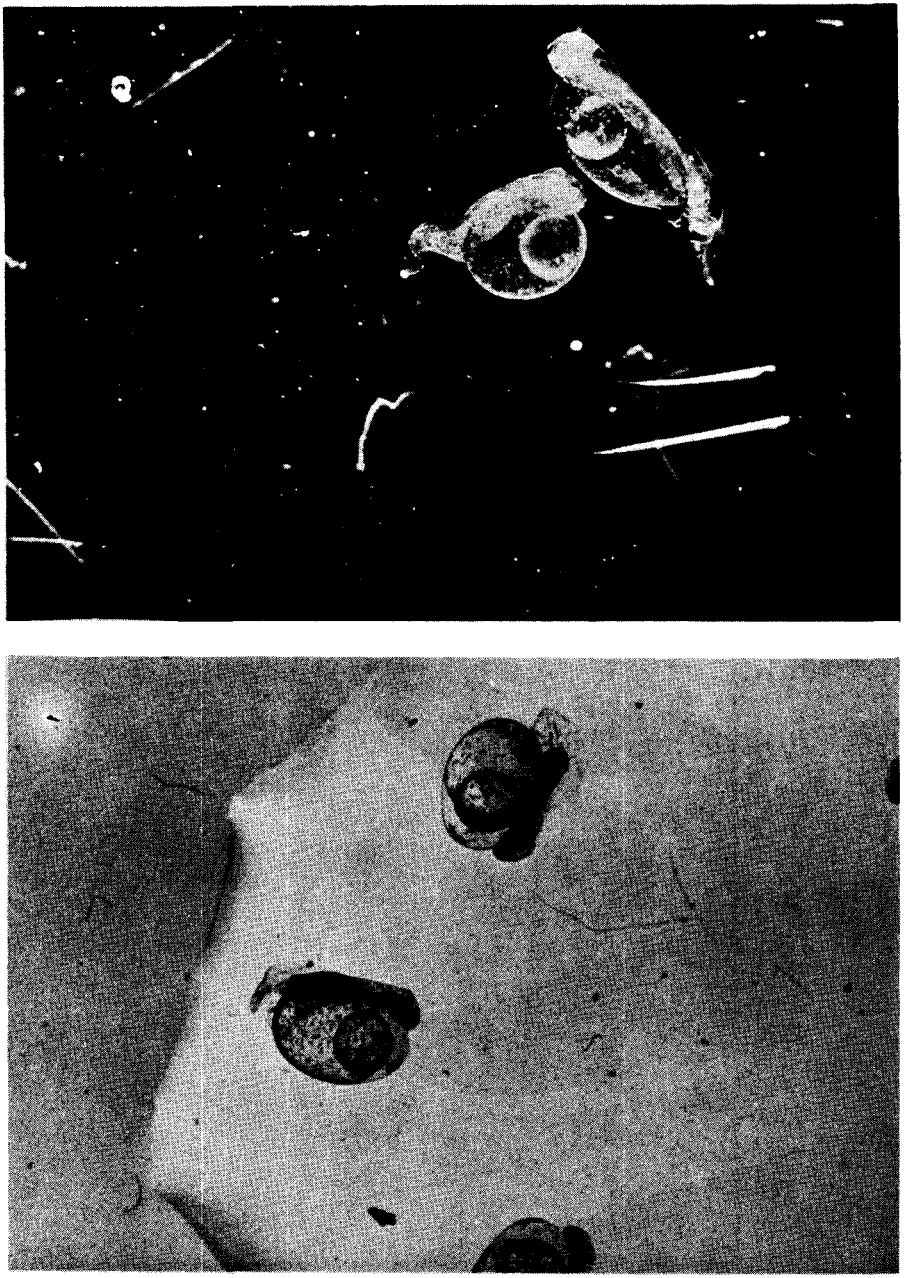

Fig. 2. Striped bass abnormalities associated with low dissolved oxygen content. Top: fry hatched at 2.5 ppm (note spinal curvature). Bottom: fry hatched at 2.0 ppm (note extreme caudal truncation).

Results indicate a lower critical level for normal development of our striped bass embryos than those described for developing embryos from California (Turner and Farley 1971). Their (Turner and Farley 1971) study revealed a dissolved oxygen concentration of at least 4.0 ppm was necessary for normal development while the present study indicates no significant difference in development between 3.0 ppm and 8.2 ppm dissolved oxygen. The present study deals with examination of variable oxygen levels as a single parameter while Turner and Farley (1971) varied other environmental parameters in addition to oxygen (temperature and salinity).

Truncation, the more frequent of the 2 abnormalities occurred in variations from slight, which had the appearance of shortened caudal (tail) region, to acute where no caudal (tail) region existed at all (Fig. 2). Although some embryos at the 3.0 ppm oxygen concentration as well as the control exhibited varying degrees of truncation, the vast majority of embryos at 2.0 ppm and 2.5 ppm oxygen concentrations exhibited a higher incidence with greater severity (Table 1). Abnormalities associated with the control and the 3.0 ppm treatment levels were likely related to micro-defiencies of oxygen concentration immediately surrounding the embryo as suggested by Mansueti (1958) and Albrecht (1964).

An additional observation associated with low dissolved oxygen concentrations was a delay in hatch time. The experiment was considered terminated when all eggs in the control container had hatched. This occurred within 45 hours after fertilization. At that time, none of the embryos in the 2.0 ppm treatment, less than 50% of the embryos in the 2.5 ppm treatment and all except the deformed embryos in the 3.0 ppm treatment had hatched. An increased hatch time has also been documented in previous studies (Turner and Farley 1971). It was statistically demonstrated in this study that normal development of striped bass embryos requires a dissolved oxygen concentration $\geq$3.0 ppm.

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