Endangered Atlantic Sturgeon in the Delaware River Require Higher Standards for Dissolved Oxygen

Desmond M. Kahn and Matthew Fisher

Delaware Division of Fish and Wildlife

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The Delaware River spawning stock of Atlantic sturgeon has been grouped with the Hudson River stock into the New York Bight Stock Complex. This stock complex has been declared Endangered by the National Marine Fisheries Service earlier this year. Because of this endangered status of the Delaware River spawning stock, threats to survival and growth of this stock of Atlantic sturgeon should be eliminated, if possible.

Over several continuous decades of the mid-twentieth century, oxygen was essentially zero for summer and fall months in twenty miles or more of tidal River in the spawning and nursery zones that sturgeon now inhabit (Albert 1988, Sharp 2010), a condition known as anoxia (complete depletion of oxygen in water bodies). We should consider the proposition that this anoxia in past decades (ca. 1945 to 1970) almost certainly caused virtual failure of reproduction of the Delaware River spawning stock of Atlantic sturgeon over that period. As explained below, current oxygen levels in the River are still a threat to reproduction of Atlantic sturgeon. An improvement in the goal for dissolved oxygen could pay benefits in enhanced survival and growth of Atlantic sturgeon in the Delaware River.

Published research indicates that juvenile sturgeon of various species require relatively high levels of dissolved oxygen, comparable to the needs of rainbow trout. One peer-reviewed paper reported the effect of several combinations of temperature and dissolved oxygen levels on 90 day old juvenile Atlantic sturgeon in a laboratory study (Secor and Gunderson 1998). When dissolved oxygen levels are reduced well below the saturation level, the resulting condition is termed hypoxia (low oxygen levels). Secor and Gunderson employed an upper temperature of 26 degrees C. Freshwater at sea level at this temperature is saturated with oxygen at a concentration of 8.1 mg/l. The paper reported that a hypoxic oxygen level of only 3 mg/liter at 26 degrees C (79 degrees F) caused 85% mortality when the fish were held for 10 days at this level. This low level of oxygen also caused a decline in growth rate prior to mortality.

While Secor and Gunderson's paper is important and very helpful, the information supplied by their study is limited. First, we do not know what the effect of 4 mg/liter of dissolved oxygen would be, or of 5 mg/liter, because the experiment did not employ these oxygen concentrations. These levels could possibly also cause mortality or growth suppression.

A second limitation of Secor and Gunderson (1998) is the upper temperature level employed in the experiment, 26 degrees C. Peak summer temperatures in the tidal Delaware River in recent years have been 30 degrees C (86 degrees F). An experiment on the closely related shortnose sturgeon (also inhabiting the tidal Delaware River) did employ a temperature of 30 degrees C, however. This study found the fish required more oxygen to survive at 30 degrees C than they did at a lower temperature (Campbell and

Goodman 2004). Consequently, Atlantic sturgeon in summertime conditions in the Delaware River could be expected to suffer mortality at higher oxygen levels than the 3 mg/l employed by Secor and Gunderson.

A third limitation in Secor and Gunderson's experiment is the age of the sturgeon tested. They tested the response of 90 day old sturgeon, and their results may not be representative of the response of younger sturgeon. Although there are no published experiments testing the response of younger Atlantic sturgeon to hypoxia combined with elevated temperatures, one paper examined the response of younger shortnose sturgeon (Jenkins et al. 1993). The results indicate that younger shortnose (<30 days) are significantly less tolerant than shortnose >90 days. Jenkins et al. found that 19 day old shortnose held at 3.5 mg/L and 22.5 C (72.5 D F) had 22% mortality after 6 hours. In contrast, 90 day old sturgeon had no mortality under the same conditions. Although these results were for sturgeon even younger than 30 days and for a closely related species, they suggest that the hypoxia and peak temperatures in the Delaware could have a more severe impact on very young Atlantic sturgeon than Secor and Gunderson reported.

The available oxygen and temperature data for the Delaware River show that oxygen reaches its lowest level and temperature reaches its highest level in July and August. At that time, young-of-year Atlantic sturgeon are only between 30 days and 60 days old, compared to the age of 90 days of sturgeon tested by Secor and Gunderson. Consequently, hypoxia in the Delaware may have a more severe impact on growth and survival of young-of-year Atlantic sturgeon than indicated by the response of the 90 day old sturgeon tested by Secor and Gunderson.

Measured levels of dissolved oxygen in the tidal Delaware River have been dangerously low for juvenile sturgeon in some recent summers. Currently, likely spawning locations of Atlantic sturgeon in the Delaware, though not known with certainty, are considered to exist both upstream and downstream of Philadelphia. Dissolved oxygen levels in the tidal Delaware River are measured routinely at the Benjamin Franklin Bridge in Philadelphia, at Chester, at the Cherry Island Flats adjacent to Wilmington and at Reedy Island near Port Penn, Delaware, below the mouth of the Chesapeake and Delaware Canal. The Benjamin Franklin Bridge gauge is centrally located in the likely spawning areas of sturgeon, while the Chester gauge is only a few miles upstream from the Marcus Hook reach of the River, which usually holds a concentration of juvenile Atlantic sturgeon, according to field research conducted by Matt Fisher of the Delaware Division of Fish and Wildlife.

Among all of these gauges, oxygen levels are usually lowest at the Benjamin Franklin Bridge. Results from 2010 at this site showed oxygen dropping below 3.5 mg/liter, while in 2011 oxygen dropped below 4 mg/liter. At the Chester gauge, oxygen dropped down to 4 mg/liter in 2010. In 2011, oxygen readings at Chester declined almost to 4 mg/liter and were below 5 mg/liter for much of August.

Among the last five years, oxygen levels reached their lowest level in 2010, according to these data. While young-of-year Atlantic sturgeon were first collected in the River in 2009 and were again collected in 2011, none were found in 2010 (Delaware Division of Fish and Wildlife, unpublished data). This raises the question of whether the failure to collect young-of-year sturgeon in 2010 was due to catastrophic mortality of this year class due to hypoxia.

The Delaware River Basin Commission regulates dissolved oxygen levels in the River by requiring wastewater dischargers, such as municipal sewage plants and large industrial facilities, to meet certain criteria in their discharge waters. In 1967, the Commission set the current water quality goal for minimum levels of dissolved oxygen at a twenty-four hour average of 3.5 mg/liter for Zones 4 and the upper half of Zone 5. This includes the stretch of the River from the Philadelphia Naval Base, just upstream from the mouth of the Schuylkill River, downstream to Delaware City, Delaware, just above the mouth of the Chesapeake and Delaware Canal. This reach includes the River from the downstream section of Philadelphia through Wilmington and New Castle, Delaware, encompassing nursery zones, and probably spawning zones, for Atlantic sturgeon. The division between Zones 4 and 5 is the Pennsylvania-Delaware state line, exactly where the Marcus Hook reach lays, so these are the critical zones for this concentration of young-of-year Atlantic sturgeon.

In view of the evidence presented in this paper on the sensitivity of young Atlantic sturgeon to hypoxia, this goal of 3.5 mg/l is inadequate to prevent mortality and reduced growth of young-of-year Atlantic sturgeon. The 1967 goal was a compromise between alternatives that would provide either higher or lower standards and treatment. A report by a fisheries task force formed by the Commission (1979) stated that this compromise target of 3.5 mg/liter was too low to protect fishery resources,

In the first place, the task force labeled as "unacceptable" the fact that the existing standard for oxygen was a 24 hour average. It noted that detrimental effects of low oxygen could occur in "periods much less than twenty-four hours." The task force called for the standard to be set as a minimum at any time, as opposed to a twenty-four hour average.

The standard called for by the Task Force was a minimum level of 4.0 mg/l in the section that now has the goal of 3.5 mg/l (Zones 4 and the upper part of Zone 5, in the Commission's terminology). For the lower half of Zone 5, between Delaware City and Liston Point, the official mouth of the Delaware River and beginning of Delaware Bay, the report called for a minimum of 4.5 mg/l, and for other zones it suggested a minimum of 5 mg/l. In view of the experimental results we now have available (discussed above), the recommendation of 4 mg/l now seems too low for young Atlantic sturgeon.

What can the Commission do to correct the deficiency in this water quality goal of only 3.5 mg/l of dissolved oxygen as a twenty-four hour average? A modeling study conducted for the Commission during the 1990s estimated that dissolved oxygen could be increased by between 1 and 2 mg/liter by significantly reducing the ammonia content of wastewater discharges (also described as reducing the nitrogen-based biological oxygen demand). Though this measure would have a cost, it is economically feasible to increase the dissolved oxygen level by reducing the nitrogen-based biological oxygen demand. This would be accomplished by reducing the large volume of ammonia currently discharged. Ammonia is converted first to nitrite and then to nitrate when exposed to oxygen. By extended aeration prior to discharge, the ammonia concentration can be greatly reduced (E. Sildorff, Delaware River basin Commission, personal communication).

In summary, experimental evidence discussed above demonstrates that young-of-year Atlantic sturgeon suffer reduced growth and increased mortality at reduced levels of dissolved oxygen; they have been compared to rainbow trout in their oxygen requirements. The current hypoxic conditions in the tidal Delaware River in summer are dangerously close to lethal limits for survival and growth of young-of-year Atlantic sturgeon. The Delaware River Basin Commission has the ability to raise dissolved oxygen levels in the Delaware River by requiring dischargers to reduce high levels of ammonia in discharge water. Modeling studies conducted in the late 1990s indicated that removing ammonia pollution could raise dissolved oxygen levels by 1 to 2 mg/liter, which would reduce the likelihood of negative impacts of hypoxia on growth and survival of young-of-year Atlantic sturgeon. The benefit of this improvement in water quality will be enhanced restoration of the Delaware River spawning stock of Atlantic sturgeon, which could eventually join the American shad and striped bass as fully restored stocks of wild fish.

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