Anticipated Effects of Allowing Passage of Native Gizzard Shad and, to a Lesser Extent, Naturalized Carp into a Small Freshwater Impoundment on Delaware's Inland Bays with Implications for Management*

-A White Paper-

by:

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Introduction

In 2013, the Delaware Center for the Inland Bays embarked on a feasibility and planning study of opportunities to enhance passage of migratory fishes like alewife (Alosa pseudoharengus) and blueback herring (Alosa aestivalis), collectively known as river herring, in tributaries to the Inland Bays. The DE Department of Natural Resources and Environmental Control (DNREC), as a voting member of the Atlantic States Marine Fisheries Commission (ASMFC), has committed to following the recommendations of the Shad and River Herring Fishery Management Plan (ASMFC 1985) which calls for improvements in fish passage to restore access to historical spawning habitat for these species. Subsequent addenda and reports, like the one prepared by the Atlantic States Marine Fisheries Commission and Shad and River Herring Plan Development Team in 2009, reiterate the need for each state to develop a plan to improve the quality of and restore adequate access to river herring spawning habitat. Methods to do so, including removal of migration barriers and/or installation of fish passage devices past impediments to spawning grounds, are detailed in special ASMFC publication #9 on Atlantic Coast diadromous fish habitat (Greene et al. 2009). As proof of that commitment to provide access to historical spawning grounds, the Delaware Department of Natural Resources and Environmental Control has a nearly 20-year history of approval of and participation in efforts to restore river herring fish passage past a number of dams on Delaware River drainage systems in all three DE counties, using private as well as public funding (Jacobini 2013).

At present there are 11 Alaska Steeppass-type aluminum fish ladders in place at dams on Delaware tidal tributaries. Of these, only one (Waggamons Pond on the Broadkill River) was installed by DNREC themselves. The others were installed by the Delaware Department of Transportation, in the case of Silver Lake Middletown, or, in the case of the other nine ladders, by Public Service Energy Group (PSEG) in a settlement agreement with DNREC as partial mitigation for fishes killed by entrainment and impingement on the intake screens at Salem Nuclear Plant on the Delaware River.

Early on in the process of considering fish passage past migration barriers on tributaries to the Inland Bays, informal discussions with the Department of Natural Resources and Environmental Control's Division of Fish and Wildlife (DF&W) revealed their concerns regarding the inadvertent passage of non-target fishes like gizzard shad (Dorosoma cepedianum) and, to a somewhat lesser extent, common carp (Cyprinus carpio), into impoundments on Inland Bays tributaries where these two species may be absent or scarce. All eleven of the existing fish ladders in Delaware were placed on tidal tributaries where gizzard shad and carp are part of the normal fish fauna, both upstream and downstream of the fish ladders. I believe it is fair to say that the 11 existing ladders in Delaware were installed without regard to whether or not gizzard shad and carp would use the ladder. They were installed primarily to facilitate passage of adult river herring on their spring spawning migrations.

Carp already are present in Millsboro Pond, the lowermost of the impoundments on the Indian River drainage system, probably due to the fact that the Millsboro Pond dam went out in flooding in 1976 and was replaced within a few years (Ken Niblett, City of Millsboro Director of Public Works, personal communication, and Martin 2012). During the time that the dam was out, the site of Millsboro Pond was tidal until the dam was replaced. Therefore, any species previously occurring in the upper tidal portion of Indian River, such as gizzard shad and carp, would have had unrestricted access to the site of Millsboro Pond. Striped bass (Morone saxatilis) apparently also made it into Millsboro Pond during the drawdown (I hooked one myself in the Pond in the early 1980s), but the impounded population probably is gone by now based on their absence in samples taken by Martin (2012) and the relative lack of reliable reports of their recent capture in the Pond by sport fishermen. Carp have been documented in Millsboro Pond since the draw down, and most recently in seine samples taken in 2011 by DNREC in Millsboro Pond (Martin 2012).

Oddly enough, no records of gizzard shad have been documented for Millsboro Pond since the dam was replaced in the late 1970s, even though Wang and Kernehan (1979) were of the opinion that landlocked gizzard shad were spawning in the Pond in the 1970s based on the presence of gizzard shad prolarvae just downstream of the Millsboro Pond dam. They felt that gizzard shad spawning conditions downstream of Millsboro Pond were suboptimal because of the silt load in upper tidal Indian River, and that it was likely that the prolarvae they found originated in the Pond itself. More recently adult gizzard shad have been observed to be abundant in the spillpool below the Millsboro Pond dam (John Clark, DE DF&W, personal communication). Additional information on potential target species like the two species of river herring, hickory shad (Alosa mediocris), American eels (Anguilla rostrata), and striped bass that could benefit from installation of fish passage on Inland Bays tributaries will be provided in a feasibility report entitled "Assessment and Recommendations for Fish Passage Device Installation in Delaware's Inland Bays" that is being prepared by consultants to the Center for the Inland Bays. A draft of this report is expected in May 2014.

Purpose of this Review

The purpose of this White Paper is to summarize what is known about gizzard shad and, to a lesser extent, common carp, especially as it may relate to their introduction into freshwater impoundments, and the anticipated effects such an introduction may have on resident biota in impoundments like Millsboro Pond on Inland Bays tributaries.

Raasch (1997) reviewed available records on gizzard shad in Delaware and concluded that the species is present not only in tidal waters throughout the state, but that landlocked populations also are abundant in many of Delaware's small impoundments in both Kent and Sussex Counties. Gizzard shad are known to occur in tidal and many fresh waters from the St. Lawrence River to Florida (Kells and Carpenter 2011) and the species is naturally abundant in the Chesapeake Bay region (Lippson and Lippson 1984 and Murdy, Musick and Kells, 2013). Lippson and Lippson characterized the species as anadromous, meaning that the species spends most of its life in tidal or marine waters and returns to freshwater as adults to spawn. Gizzard shad have been widely introduced as a forage species into freshwater impoundments where it has established landlocked spawning populations (Noble 1981). It attains a larger size than many other forage fishes and is known to reach lengths of 15 inches plus and weights of two pounds. Such adults would be relatively invulnerable to predation by all but the largest largemouth bass (Micropterus salmoides) and chain pickerel (Esox niger), which are the apex fish predators in Millsboro Pond and other impoundments on the Inland Bays drainage system. Juvenile gizzard shad can be expected to become important prey items in these same impoundments to all species of predatory fishes. Presumably those gizzard shad adults which John Clark observed congregating downstream of Millsboro Dam are subject to predation by sub-adult and adult striped bass which are known to seasonally inhabit the same upper tidal waters of Indian River.

In thinking about why the Division of Fish and Wildlife has concerns about the unintentional introduction of gizzard shad into Millsboro Pond if fish passage is provided for other anadromous species like the two species of river herring and/or hickory shad (Alosa mediocris) and striped bass, these concerns probably stem from long-held beliefs that gizzard shad will compete for food with the naturalized bluegill (Lepomis macrochirus) and largemouth bass populations in these ponds. The genesis of these beliefs date back to studies from the 1940s through 1970s in such papers as those by Swingle (1946), Jenkins (1955), Kutkuhn (1957), Bodola (1965), and Noble (1981), for example. These authors asserted that competition between gizzard shad and sport fishes reduced the growth and survival of sport fishes due to such gizzard shad characteristics as rapid growth that can make them less vulnerable to predation, high gizzard shad fecundity, intensive zooplankton grazing by early life stages of gizzard shad, and the possibility of gizzard shad competing with early life stages of sport fishes for prey items. It has long been known that gizzard shad shift with age from obligate feeding on zooplankton once attaining a size of 30-35 mm in length to a more omnivorous diet of detritus, attached algae, zooplankton, and phytoplankton (Kutkuhn 1957, Bodola 1965 and Cramer and Marzolf 1970). Jenkins (1955) felt that direct interspecific competition occurs between sunfishes and gizzard shad in small-lake populations, but he only studied two small lakes, one of which was treated with rotenone for gizzard shad removal. Other negative impacts that have been attributed to or associated with gizzard shad by these authors and others include increases in turbidity caused by the foraging behavior of adult gizzard shad on bottom and attached detritus, and indirect effects on macrophyte abundance caused by the increased turbidity from their feeding behavior, or because previously sequestered nutrients can be recycled through the gizzard shad's gastrointestinal tract. Kirk et al. (1986) found in Alabama public fishing lakes that there were benefits from removal of gizzard shad on sport fishes, but that the beneficial effects did not last beyond 1-2 years.

As a result of these earlier studies, many fishery managers attempted to reduce gizzard shad populations with varying levels of success in order to benefit sport fish. Much of this earlier work was reviewed in 1990 by DeVries and Stein. According to DeVries and Stein, success in improving sport fish populations by selective removal of gizzard shad proved elusive for a number of reasons, including the difficulty of proving that gizzard shad were completely removed, and the presence of unintended or indirect effects when attempting to remove the gizzard shad. Welker et al. (1994) cited substantial diet overlap between bluegill and gizzard shad for a 3-week period in an Illinois lake. A few years later Dettmers and Stein (1996) concluded that stocking predators decreased gizzard shad and increased crustacean zooplankton, but that this effect was limited to bodies of water with fewer than 10 gizzard shad/m^3 and higher zooplankton densities.

Bremigan and Stein (1999) asserted that production and growth of juvenile gizzard shad can vary greatly in Missouri reservoirs based on the trophic status of the body of water in question. This, in turn, complicated prediction of the effects of gizzard shad on growth of predators such as largemouth bass. Kim and DeVries (2000) confined their studies on early life history stages to avoid the complications of concurrent management techniques used on adult sport fishes in the same water body. They reduced gizzard shad abundance with rotenone in an Alabama lake similar in size to Millsboro Pond (65 ha versus 41 ha). They found that despite a dramatic reduction in gizzard shad biomass, neither abundance nor survival of larval sunfishes increased. Garvey and Stein (1998) found that growth and fall sizes of largemouth bass varied more among lakes studied in which the dominant prey species was gizzard shad as opposed to the dominant prey species being bluegill. Hirst and Devries (1994) concluded that direct feeding competition between larval gizzard shad and larval black bass was of little consequence. Aday et al. (2005), using experiments in 1.6-m circular tanks, concluded that bluegills compete with juvenile largemouth bass for preferred prey items, thus limiting largemouth bass growth, and that the presence of larger gizzard shad did not have the negative implications observed in previous studies that used smaller gizzard shad. That largemouth bass are able to regulate the abundance of age-0 gizzard shad in small ponds was shown by Irwin et al. (2003). Nutt (in an undated, but recent report) and Flickinger et al. (1999) alluded to the often conflicting results on studies where gizzard shad populations were reduced in order to benefit sport fishes and suggested that the use of gizzard shad as a prey species in ponds to benefit the production of trophy-size largemouth bass is an idea that deserves re-examination in light of some more recent studies.

Wang and Kernehan (1979) attributed the presence of gizzard shad prolarvae to a landlocked spawning population in Millsboro Pond. However, assuming that gizzard shad are presently absent in Millsboro Pond, what can we expect in the pond solely from the introduction of gizzard shad? Competition from larval gizzard shad could negatively impact availability of zooplankton to larval bluegill for a few weeks in the summer. But whether this will translate into negative effects on bluegill size structure remains uncertain (Aday et al. 2003). In their study of 10 reservoirs with gizzard shad and 10 reservoirs without gizzard shad, Aday et al. found that the presence of gizzard shad was associated with reduced bluegill growth rates and reduced bluegill adult size structure, but that "mechanisms other than direct competition for food resources may be responsible" for the observed effects on bluegill. When gizzard shad are present, bluegill consumption rates by predators such as largemouth bass may decline because of the preference of largemouth bass for soft-bodied prey like gizzard shad as opposed to spiny prey like bluegills (Wahl and Stein 1988). If bluegill consumption rates decline, this can lead to an over-abundance of prey-size bluegills. However, the indirect effects of gizzard shad may have a greater influence on size structure than does direct competition. If gizzard shad increase turbidity, that can have a confounding effect on both predators and prey (Schaus et al. 2002; Godwin et al. 2011).

Pope and DeVries (1994) found that age-0 white crappies (Pomoxis annularis), were larger in ponds with gizzard shad. Although Millsboro Pond does not have white crappie, Martin (2012) stated that it has a sizeable population of the closely-related black crappie (Pomoxis nigromaculatus). Michaeletz (1998) found positive correlation between age 0 gizzard shad bimass and biomass of ages 1-3 black crappie.

It has been observed that the presence of large quantities of macrophytes may reduce the abundance of gizzard shad to levels lower than expected, thus preventing a negative interaction with bluegill (Michaletz and Bonneau 2005). Millsboro Pond is known to require annual or biannual treatments with herbicides to control overabundant Hydrilla and filamentous algae (Mark Zimmerman, personal communication).

Tisa and Ney (1991) found that landlocked alewife and gizzard shad co-existed well in Smith Mountain Lake, a relatively large VA hydroelectric impoundment, due to differences in the spatial distribution of the two species in that reservoir. Whether this same phenomena would occur in a much smaller impoundment like Millsboro Pond is a matter for conjecture.

Aday et al. (2003) acknowledged that there has been considerable debate about the value of stocking gizzard shad as prey items in reservoirs, but in spite of this uncertainty, they recommended against stocking gizzard shad as forage fish for piscivores. The most important reason they felt was that the presence of gizzard shad results in poor bluegill growth rates and smaller adult bluegill size structure. Once gizzard shad become established in a lake or reservoir, their removal by techniques such as gill netting becomes problematic (Catalano and Allen 2011).

Carp

In regard to the anticipated impact of increasing the population of common carp in Millsboro Pond as a result of providing fish passage devices, any negative effect likely will be masked to some extent by the fact that carp are already present in the pond and have likely been there since at least the late 1970s. It is not known why the carp have apparently not reached nuisance abundance, nor can their direct effect on the water quality and macrophyte levels in Millsboro Pond be readily discerned as one would anticipate, based on the literature reviewed by Weber and Brown (2009). Some of the effects one could expect based on Weber and Brown's review would include destruction of the present macrophyte community in the pond should carp reach abundance levels as high as 200 kg/hectare, increased turbidity, increased phytoplankton, decreases in benthic invertebrates and shifts away from small-bodied prey to larger bodied prey. Since there are no estimates available of the abundance of adult carp in Millsboro Pond nor estimates of the number of adult carp that regularly stage downstream of Millsboro Pond, it is impossible to speculate if a fish ladder would result in an unacceptable number of adult carp taking up residence in the pond.

A Strategy for Moving Forward

Based on the above review, even though there exists considerable uncertainty in predicting the impact of gizzard shad introduction, in an abundance of caution there may be some risks associated with allowing gizzard shad to invade Millsboro Pond from downstream in the upper tidal portion of Indian River, provided they are not already present in the pond. These risks include possible slowing of bluegill growth rates in the pond due to competition for zooplankton between bluegills and early life stages of gizzard shad. As the re-introduced gizzard shad progeny grow beyond 30-35 mm in length and switch over to a diet of primarily detritus (Gido 2003, Yako et al. 1996; Schaus et al. 2002), they have the capability of increasing turbidity by disturbing sediments and of re-cycling sequestered nutrients from sediments, thus increasing phytoplankton populations (Godwin et al. 2011). As stated earlier, these effects may well be masked by the abundant macrophyte populations in the pond which may explain why heretofore gizzard shad have not become abundant in the pond, even though the opportunity to re-invade the pond was certainly available in the late 1970s when the pond's dam was out.

Are these risks acceptable in order to address the goal of re-introducing more desirable native anadromous species like alewife and blueback herring so as to benefit these populations by greatly increasing their access to the freshwaters required for their successful reproduction? I feel that they are acceptable risks for the following reasons:

- Gizzard shad are a native species in the Indian River system. The primary reason they are not present in the impounded freshwater portion of Indian River is that the dams exclude their migration into these impoundments.
- Abundant rooted aquatic vegetation should limit the probability of gizzard shad becoming over-abundant in Millsboro Pond. This vegetation is so thick that fishing often becomes difficult in the summer, thus necessitating periodic treatment by the Division of Fish and Wildlife with herbicides to control over-abundant <u>Hydrilla</u> and filamentous algae.
- Millsboro Pond's population of apex predatory fish like largemouth bass and chain pickerel may actually benefit from the re-establishment of gizzard shad in the pond since juvenile gizzard shad are known to be preferred prey of these species. Adult gizzard shad that have outgrown predation by all but the very largest largemouth bass and chain pickerel will not compete for food with these predators.
- The largemouth bass population in Millsboro Pond has been less than desired, and the Division of Fish and Wildlife felt the need to augment natural reproduction of largemouth bass by stocking juveniles (Delaware's Public Ponds, Division of Fish and Wildlife web site and Martin, 2012). The causes of this less than desirable largemouth bass population have not been determined, but if introduced gizzard shad provide additional forage for largemouth bass with subsequent benefits to largemouth bass growth and maturation rates, then that would be a good thing.

In closing, it is not clear if there will be a discernable impact on Millsboro Pond from the unintentional re-introduction of gizzard shad.

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