Preliminary Assessment of an Alaska Steeppass Fishway on a North Carolina Blackwater Creek

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Abstract: Despite the large number of low-head dams on North Carolina streams and rivers, fishways have rarely been used to restore access to habitat upstream of dams. The goal of this study was to determine the use of a prefabricated Alaska steeppass fishway installed at a low-head dam on Black Creek, a blackwater tributary of the Neuse River near Smithfield, North Carolina. Between 21 February and 2 June 2003 study period, the ladder was used by 949 gizzard shad *(Dorosoma cepedianum)*, 2 American shad *(Alosa sapidissima)*, and 1 golden shiner *(Notemigonus crysoleucas)*. Upstream passage of gizzard shad was marginally correlated ($P = 0.06$) with stage height of a nearby stream. These results illustrate that fish passage should be considered not only for anadromous fishes but also riverine species that undertake a spring spawning migration or that make upstream movements for feeding or other life cycle requirements. Prefabricated fishways are simple to install and could restore access to the considerable habitat upstream of low-head dams.

Key words: fishway, habitat, gizzard, shad, migratory

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Dam construction has provided multiple benefits to society but has also reduced the amount of spawning habitat for migratory fishes and in some cases led to population declines (FAO 2002). In order to reduce these impacts, fish passage facilities are sometimes included in dam construction and in other cases added after a dam has been built. The Alaska steeppass (Denil-type) fishway is a popular design for retrofitting existing dams because it is relatively inexpensive to construct and maintain, can have steep slopes with resulting low space requirements, and can be prefabricated and installed in sections (Haro et al. 1999, FAO 2002). Steeppass sections have even been used to retrofit fish passage systems that were ineffective by mounting on the existing fishway (Harris and Mallen-Cooper 1994). Denil-type fishways are typically used on

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smaller streams and low-head dams, although they have been used on dams with hydraulic heads of up to 15 m (Clay 1995, Haro et al. 1999). Disadvantages of the Denil fishway design include the relatively high discharges required and a tendency to clog with debris (Clay 1995, FAO 2002).

Denil-type fishways were originally designed for adult salmonids but they have proven effective for anadromous clupeids and a wide range of migratory riverine species (Schwalme et al. 1985, Katopodis 1992, Clay 1995, Bunt et al. 1999, Haro et al. 1999, Bunt et al. 2001, FAO 2002). Denil fishways are generally constructed at slopes of 10%–20% but can select for larger, stronger swimming species and individuals (Rajaratnam et al. 1992, Katopodis 1992, FAO 2002). To be effective, the water velocities within the fishway must not exceed the maximum sustained swimming speed of the target species and the distance must not exceed their endurance (Schwalme et al. 1985, Clay 1995).

The purpose of this study was to characterize the use of a prefabricated Alaska steeppass fishway installed on a low-head dam in the coastal plain of North Carolina. Results of this study should be useful in predicting the benefits of fish passage or dam removal on other coastal southeastern streams.

Methods

The steeppass fishway evaluated in this study was located on Holts Lake Dam, a low-head dam (about 2.5 m in height) on Black Creek, a blackwater tributary to the Neuse River near Smithfield, North Carolina (Fig.1). The fishway was installed on one of two concrete spillways separated by a man-made earthen dam (Fig. 1, inset). The spillway with the steeppass fishway was the lower of the two and empties into a shallower and more narrow stream channel. The two stream channels join about 25 m below the dam and the stream flows about 3 km downstream to the confluence with the Neuse River. The fishway has reopened access to 167 km of tributary habitat upstream of Holts Lake Dam (U. S. Fish and Wildlife Service 2004).

The portion of the Neuse River basin where Black Creek is found is almost entirely forested/wetland (50.1%) or cultivated cropland (45.9%) (North Carolina Division of Water Quality [NCDWQ] 2002). Black Creek has a drainage area of 189.8 km^2 (NCDWQ 1998). The creek received a "good" ecological health rating based on a fish community sample, a "fair" rating based on macroinvertebrate data, and an "impaired" rating for water quality (NCDWQ 1998, NCDWQ 2002).

The steeppass fishway was constructed using four 3.04-m prefabricated sections that were 56 cm wide and 69 cm high. It was installed by the dam owner at a slope of 20%, which is greater than the 10%–15% slope generally used for adult freshwater fish (Katopodis 1992). As in prior studies (Schwalme et al. 1985, Bunt et al. 2001), we used a trap installed at the fishway exit in order to determine the number of fish using the fishway. The trap was 1.2 m wide, 1.2 m high, and 2.4 m long, made from a wooden frame and covered with 1.9-cm inch plastic aquaculture netting. A V-shaped funnel extending 1.5 m into the trap and with a 7.6-cm opening allowed fish to enter the trap but limited their ability to move back downstream through the fishway. The

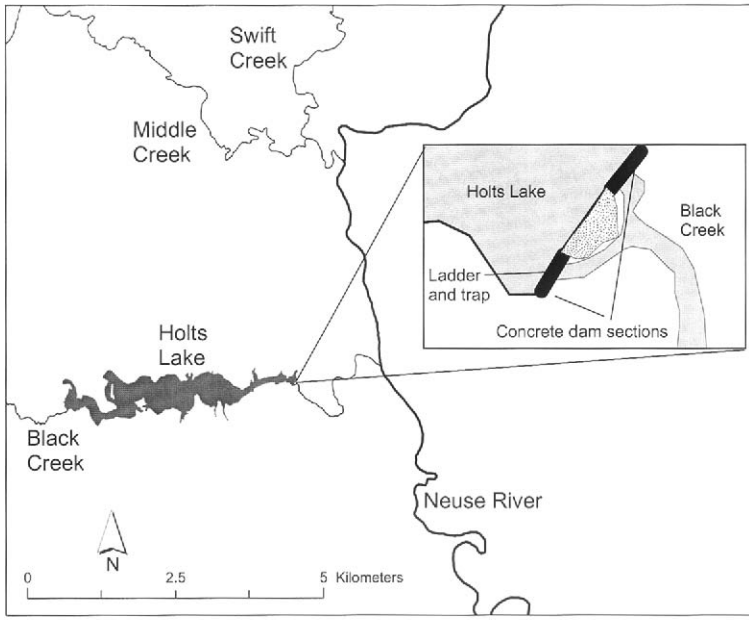

Figure 1. Location of fishway at Holts Lake Dam on Black Creek, a tributary to the Neuse River near Smithfield, North Carolina. The figure inset shows the two concrete dam sections, the central earthen dam, and the fishway location.

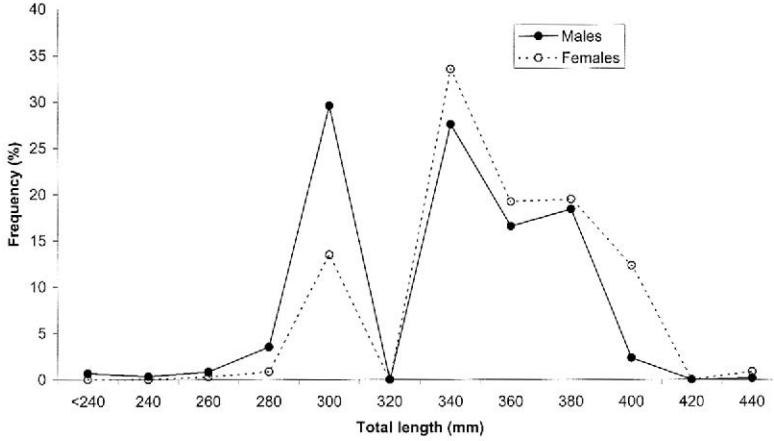

Figure 2. Frequency distributions for total length (mm) of male and female gizzard shad collected in a fishway trap on Holts Lake Dam.

funnel was made from the same aquaculture netting that covered the frame and was secured to the netting on the frame and two pieces of rebar at the upstream opening. The trap was installed during a winter drawdown when the dam gate was open. It was secured in place with rebar, sandbags and cinderblocks. During this period of low flow, rock walls were constructed to help guide fish into the fishway entrance, which is about 12 m from the base of the dam.

The trap was generally checked on Monday, Wednesday, and Friday each week of the study period, 21 February to 2 June 2003. Captured fish were identified and measured (total length, mm), sex was determined if possible, and the right pectoral fin was clipped as a mark in case a fish was recaptured. On a few occasions, we did limited cast netting at the spillway opposite of the fishway in order to get some indication of which species might potentially use the fishway.

A temperature logger secured at the bottom of the trap recorded hourly water temperature throughout the study period. As a measure of flow over the dam and through the fishway, the height of the lake was measured each day from a fixed point on the dam. We also obtained stage and discharge data from the U.S. Geological Survey gauging station on a nearby tributary to the Neuse River, Middle Creek (station 02088000) near Clayton, North Carolina.

Results

During the study period, the fishway was used by 949 gizzard shad *(Dorosoma cepedianum)*, two American shad *(Alosa sapidissima)*, and one golden shiner *(Notemigonus crysoleucas)*. Only one of the captured gizzard shad had been previously marked, suggesting that most fish either remained upstream of the dam after release or, if they went over the spillway, were not likely to return. Many of the gizzard shad and the single golden shiner captured were running ripe, indicating that upstream movement was related to spawning. Average sizes for the gizzard shad we collected were 340.6 mm for males and 357.7 mm for females. Length distributions suggested that at least two age classes were present (Fig. 2).

Gizzard shad were first collected on 24 March, when water temperatures rose above about 15 C (Fig. 3). Based on correlation analysis, there was a marginally significant linear relationship between trap catch rate and Middle Creek stage ($P = 0.06$) but not for water temperature ($P = 0.13$), lake level ($P = 0.36$), or Middle Creek discharge ($P = 0.10$). Two of the three peaks in gizzard shad passage coincided with increases in Middle Creek stage height (Fig. 3).

Limited cast-netting carried out at the spillway opposite of the fishway established that gizzard shad were present in large numbers below the dam. Other species caught below the dam were white perch *(Morone americana)*, black crappie *(Pomoxis nigromaculatus)*, largemouth bass *(Micropterus salmoides)*, warmouth *(Lepomis gulosus)*, green sunfish *(L. cyanellus)*, bluegill *(L. macrochirus)*, redear sunfish *(L. microlophus)*, and redbreast sunfish *(L. auritus)*.

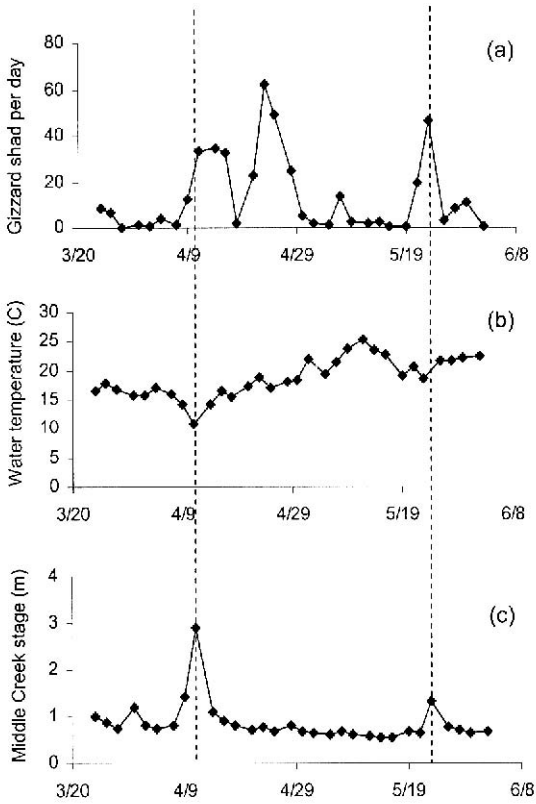

Figure 3. Number of gizzard shad collected per day of monitoring (a), water temperature at the trap (b), and stage height of a nearby stream (c). Vertical lines denote high flow events.

Discussion

Studies regarding fishway use and effectiveness have generally focused on anadromous fishes, especially salmonids, with less attention given to resident species (Bunt et al. 2001). An increased focus on riverine fishes is warranted given that many families including centrarchids, catostomids, cyprinids, and ictalurids have been shown to migrate, particularly in association with spawning (see Bunt et al. 1999). These riverine species may make extensive use of fishways if the design characteristics are suitable (Schwalme et al. 1985, Katopodis 1992, Bunt et al. 1999, Bunt et al. 2001). Katopodis (1992) noted that Denil fishways are successful in passing a wide variety of anadromous and freshwater fishes. Bunt et al. (2001) found that two Denil fishways on the Grand River in Ontario were used by a total of 11,800 fish of 29 species during three spring field seasons. Suckers and shiners occurred most commonly but a wide range of fishes including sunfishes, catfishes and darters used the fishway. Schwalme et al. (1985) found that several resident species including suckers and northern pike *(Esox lucius)* used Denil fishways with slopes of 10% and 20%.

Considerable numbers of spottail shiners *(Notropis hudsonius)* also used the 10% and 20% Denil fishways, although they were too small to be retained by the traps used in that study (Schwalme et al. 1985).

A considerable number of gizzard shad used the Holts Lake fishway to gain access to lake habitat that should be beneficial for spawning. Gizzard shad typically spawn in the type of habitat found throughout the lake; i.e., shallow areas with aquatic vegetation (Miller 1960, Bodola 1966). The lake should also provide a ready supply of phytoplankton and zooplankton for both juveniles and adults (Bodola 1966). The gizzard shad that used the fishway are expected to be about two to four years of age based on their size and published growth information (Bodola 1966). Many of the fish were running ripe, which is consistent with prior work indicating that sexual maturity typically occurs at age two (Bodola 1966).

Water temperature and discharge can be important factors affecting fish migration (Bunt et al. 2001). We first collected gizzard shad in the fishway trap when water temperature reached about 15 C. They occurred sporadically until the monitoring period ended, when water temperatures had reached about 22 C. This temperature range is consistent with the ranges for spawning reported by Miller (1960; 10–21 C) and Bodola (1966; 14–23 C) but lower than the range reported by Downey and Toetz (1983; 21–29 C). We saw some indication that gizzard shad used the fishway in greater numbers during high flow periods, although the relationship was noisy and only marginally significant.

It can be difficult to establish a relationship between flow and fishway use because of the many factors affecting fish passage (Clay 1995, Northcote 1998). When flows are low, fish may be less willing to use a fishway or the attracting flow may be inadequate to allow fish to find the entrance (Gowans et al. 1999, Laine et al. 2002). For example, shad species reportedly use Denil-type fishways more readily when the entrance is submerged by at least 0.8 m (Slatick 1975). One factor in this study that may have aided passage during high flows was the reduced distance from the submerged fishway entrance to the dam crest.

Difficulty in locating the fishway entrance is a particular concern in this study because the entrance was located away from the shoreline. The rock walls constructed to guide fish towards the fishway entrance may have been helpful in that regard. Fish may also have had difficulty locating the fishway entrance during high flows, both because of the location and the relatively low attracting flow. Passage efficiency may also have been reduced during high flows because of turbulence in the fishway. Turbulence is a characteristic of the Denil-type fishways and can reduce passage efficiency (Bunt et al. 1999, Katopodis 1992, Haro et al. 1999). The high slope of the fishway may have exacerbated this condition. Finally, the lack of a fishway on the other spillway would have reduced passage efficiency during periods when water flowed over both spillways.

Our cast-net sampling was not adequate to make inferences about passage efficiency or species selectivity. Cast-netting was done to observe the presence of other species and not in a quantifiable manner. Most fish caught in the cast net and almost every fish in the fishway trap were gizzard shad, a species that often makes up a substantial fraction of the fish utilizing a fishway. For example, 78% of the 589,177 fish

passed in 2003 at the Conowingo East lift on the Susquehanna River were gizzard shad (St. Pierre 2003). Our cast net sampling below the Holts Dam did detect several other species that have utilized Denil fishways elsewhere (black crappie, largemouth bass, bluegill, green sunfish: Bunt et al. 2001). Possible changes in the fishway installation that might increase the passage of other species include positioning the entrance against a shoreline and including a resting pool. A resting pool is recommended every 6–8 m in a Denil fishway to avoid selecting for only the largest and strongest swimming species (FAO 2002).

We did not collect any American shad below the dam, and only two American shad used the fishway. This may indicate that few American shad were present in the stream or that the fishway was inefficient in passing that species. The former explanation is more likely, given that Burdick and Hightower (2004) found American shad spawning activity to be almost entirely confined to the mainstem Neuse River. The relatively high slope of this fishway may have had some effect on American shad passage. Although this species has been observed using fishways with slopes up to 28.7%, passage efficiency decreases as fishway slope increases (Haro et al. 1999). Both American shad that used the Holts Dam fishway were dead when the trap was checked. Hallock et. al. (1975) also observed high mortality of American shad in a trap. This suggests that trap design could be critically important in systems where substantial numbers of American shad are present in order to avoid mortalities due to monitoring.

Our results illustrate that fish passage can be important for riverine migratory fishes in a southeastern stream, regardless of the number of anadromous species present. These prefabricated fishways can restore access to valuable spawning habitat and should result in increased fish populations. In coastal systems, fishways could assist in the restoration of anadromous populations and reestablishment of historic fisheries. When fishways are installed, close attention should be given to design and operational characteristics in order to maximize passage efficiency.

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