EFFECTS OF STRESS AND FATIGUE ON MIGRATION AND SPAWNING SUCCESS OF AMERICAN SHAD, *Alosa sapidissima*

Darren T. Lerner
Conte Anadromous Fish Research Center
U.S. Geological Survey, Biological Resources Division
One Migratory Way—PO Box 796
Turners Falls, MA. 01376 U.S.A.
413-863-3827/413-863-9810/dlerner@forwild.umass.edu

Michael F. O'Dea, Amy Moeckel and Stephen D. McCormick
Conte Anadromous Fish Research Center
U.S. Geological Survey, Biological Resources Division
One Migratory Way—PO Box 796
Turners Falls, MA. 01376 U.S.A.

EXTENDED ABSTRACT ONLY- DO NOT CITE

The negative impacts of dams on anadromous fish populations are well documented throughout the United States. Two restoration strategies have been in operation: fish ladders or lifts have been added to facilitate upstream passage, and artificial propagation has been utilized in an attempt to improve fish numbers and re-populate upper reaches of the system. Both solutions have been confronted with difficulties and limitations. Passage of American shad, for example, has been low at many ladders (e.g., Cabot Station on the Connecticut River) and artificial propagation of captive stocks has often culminated in low and highly variable results.

Often fish ladders are designed with little knowledge of the physiological and behavioral ability of migrating fish for which they are built, thereby creating stress and fatigue effects that may be a major component resulting in low numbers of fish passing dams. Evidence from many fishes indicates that high levels of stress and fatigue may also have negative impacts on reproductive success (Contreras-Sanchez et al., 1998). The combination of stress associated with dam passage and transport, which is commonly utilized during artificial

propagation, may have severe negative consequences for propagation and rearing of eggs.

Evaluations of the effects of fish ladders and other aids to upstream and downstream fish passage at dams typically focus on monitoring passage time and quantifying fishway-induced mortality in the field and laboratory (Dominy 1971). More rarely, analysis of passage success includes examining physiological indices of stress and anaerobic activity (Maule *et al.* 1988). Such physiological analyses are important because they can establish the reason(s) for poor passage success at ladders. However, when these physiological components have been considered, the focus of many studies has been on the efficacy of fishways and their physiological effect on anadromous salmonids during passage and there is very little known about physiological impacts of upstream passage on non-salmonid species. The objective of this study was to determine the impact of passage through a fish ladder on physiological measures of stress and fatigue in American shad.

Methods

Stress and Fatigue

Adult Shad were collected once during upstream migration (May-June) during 2000 and twice during the same period in 2001 at Cabot Fish ladder in Turners Falls Massachusetts. The Cabot ladder is a modified Ice Harbor fishway with 66 pools and 30 cm height between pools. Fish were sampled for the following physiological indices of stress, fatigue and osmoregulatory homeostasis: plasma cortisol, glucose, lactate, and Na^+, K^+ and Cl^- ions. To assess the effects of ladder passage these parameters were measured from fish (10 males and 10 females) from each of the following ladder components (where possible): the ladder entry, middle, and top of each ladder. Collection methods consisted of fishing (ladder entry), netting from a turn pool (middle), or netting from a mechanical trap (top). Additionally a cohort of fish returning through the downstream bypass ("fallbacks") was sampled as above (2001 only).

Recovery

Animals from the top of Cabot ladder were collected and held for 96 hours (2000) or 48 hours (2001) in a 5-meter flow through circular tank supplied with river water at the S.O. Conte Anadromous Fish Research Center. At the end of the holding period fish were sampled as above.

Results

Plasma cortisol concentrations were three to five times higher in American shad captured at the top of Cabot ladder as compared to fish captured at the ladder entrance. Likewise, plasma glucose was 50% greater and plasma lactate concentrations three to six times greater than ladder-naïve animals (Fig. 1). Plasma lactate was also elevated in fallback American shad. Both plasma cortisol and plasma lactate were reduced following recovery for 48-96 hours.

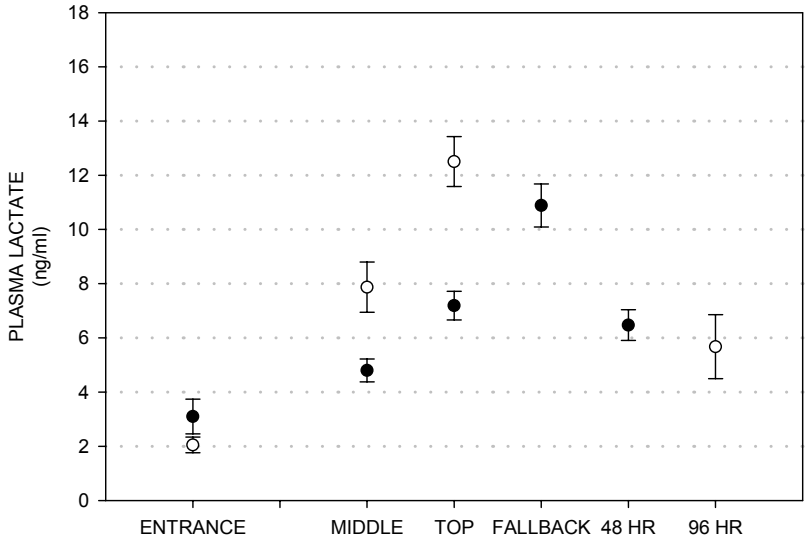

Figure 1. Mean plasma lactate (mM ± SE) sampled on 2-6 June 2000 (open circles) and 1 June 2001 (closed circles) and those held in a 5-meter circular tank for 48 or 96 hours post-capture. Each point represents 10 males and 10 females.

For plasma ions only potassium levels increased significantly as fish progressed up the ladder. Plasma chloride levels exhibited a downward trend, but were not significantly different. No changes were observed in levels of plasma Na^{+}.

Discussion

American shad exiting the top of Cabot ladder had elevated levels of plasma cortisol, indicating that upstream passage was stressful to these animals. Plasma lactate levels progressively increased as fish moved up the ladder and exhibited significant declines upon resting (Fig. 1). Increases in plasma lactate is the result of anaerobic metabolism and indicates that passage through Cabot ladder requires substantial and repeated burst swimming with only limited recovery time. Previous research indicates that extreme exercise demanding high levels of anaerobic performance can lead to mortality 6-24 hours later. However, we did not observe substantial mortality in fish held for 48 to 96 hours. We hypothesize that the high levels of stress and fatigue observed at the top of this ladder contribute to the poor passage success and large number of fallbacks observed at Cabot ladder. Future research will examine whether the stress and fatigue associated with upstream fish passage results in compromised reproductive performance.

Literature cited

Dominy, C. L. 1971. Changes in blood lactic acid concentrations in alewives, *Alosa pseudoharengus,* during passage through a pool and weir fishway. J. Fish Res. Bd. Canada, 28: 1215-1217

Contreras-Sanchez, W. M., C. B. Schreck, M. S. Fitzpatrick, and C. B. Pereira. 1998. Effects of stress on the reproductive performance of rainbow trout (*Oncorhynchus mykiss*). Biological Reproduction. 58:439-447.

Maule, AG; Schreck, CB; Bradford, CS; Barton, BA. 1988. Physiological effects of collecting and transporting emigrating juvenile chinook salmon past dams on the Columbia River. Trans. Am. Fish. Soc., vol. 117, no. 3, pp. 245-261