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Population Size and Passage Efficiency of Alabama Shad Reaching Jim Woodruff Lock and Dam

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POPULATION SIZE AND PASSAGE EFFECIENCY OF ALABAMA SHAD REACHING JIM WOODRUFF LOCK AND DAM

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ABSTRACT

In this study, I estimated the population size of migrating Alabama shad below Jim Woodruff Lock and Dam (JWLD) in the Apalachicola River located in the central panhandle of Northwest Florida using mark – recapture and relative abundance techniques. The number of marked fish was adjusted for tag loss, emigration and mortality. The population size of migrating Alabama shad near JWLD was estimated at 26,029 (95% C.I. = 15,174 - 49,040) in 2005 and as 972 (95% C.I. = 270 - 9,720) in 2006. Due to the small sample size, a relative abundance method was used to independently estimate a population size of migrating Alabama shad near JWLD in 2006 at 7,757 (95% C.I. = 5,987 – 11,012). The current population size of Alabama shad reaching Jim Woodruff Lock and Dam is relatively small when compared to both current and historic population estimates of American shad along the Atlantic coast. I also evaluated the effectiveness of the navigational lock at JWLD for upstream passage of Alabama shad using fixed-station telemetry. About 16% of Alabama shad implanted with sonic transmitters either suffered mortality or abandoned their spawning migration. Passage efficiency of the remaining study fish was 59%. I conclude that the navigational lock at JWLD can be effective in passing migrating Alabama shad.

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INTRODUCTION

The Alabama shad *Alosa alabamae* is an anadromous clupeid that lives in the northern Gulf of Mexico and migrates into freshwater rivers to spawn. The historic spawning range of Alabama shad included the Mississippi River and drainages eastward to the Suwannee River in Florida. Although Alabama shad were considered the most abundant anadromous species found along the Gulf coast of Florida (Laurence and Yerger 1967), they are now rare or have been extirpated from much of their range. This decline in abundance has been primarily attributed to the construction of navigational locks and dams (Burkaloo et al. 1993). Although dams and other obstructions serve to concentrate migrating fish making them more readily observable, they likely reduce total shad production (Laurence and Yerger 1967; McBride 2000).

Fishways, fish lifts and navigation locks assist in upstream passage of migrating species (Clay 1995; Moser et al. 2000). Existing navigation locks represent a cost-effective alternative for upstream fish passage; however, the effectiveness of these structures has generally not been assessed (Nichols and Louder 1970; Clay 1995). Passage efficiency of American shad *A. sapidissima* and other migratory clupeids through lock systems is variable (Chappelear and Cooke 1994; Moser et al. 2000; Bailey et al. 2004). Passage may be related to retention time in the vicinity of the passage structure, current velocity, and the seasonal and diel timing of the locking schedule (Barry and Kynard 1986; Moser et al. 2000; Bailey et al. 2004).

Alabama shad populations in Alabama and Florida were identified as a candidate for listing under the Endangered Species Act by the National Marine Fisheries Service in 1997. In 2004, the status of Alabama shad was reclassified as a species of concern due to a lack of available information. Although few studies have been conducted concerning the life history, distribution and historical abundance, research suggests populations of Alabama shad in gulf-coast rivers are relatively small and declining (Laurence and Yerger 1967; Mills 1972; Rulifson et al. 1982; Mettee and O'Neil 2003). Healthy self-sustaining populations still inhabit the Choctawhatchee and Apalachicola river systems in Alabama and Florida (Burkaloo et al. 1993; Mettee and O'Neil 2003). Currently, the Apalachicola River below Jim Woodruff Lock and Dam (JWLD) in northwest Florida supports the largest extant spawning population of Alabama shad (Laurence and Yerger 1967; McBride 2000; Mettee and O'Neil 2003).

Estimations of abundance are essential to understanding and managing fish populations. Mark – recapture techniques have been used to estimate fish abundance for over a century (Ricker 1975), including many populations of American shad along the Atlantic coast (Talbot 1954; Leggett 1976; Crecco and Savoy 1986; Bailey et al. 2004). Mark – recapture techniques have also been used to estimate population size of other anadromous clupeids such as Blueback herring *A. aestivalis* (Isely and Tomasso 1998) and Threadfin shad *Dorosoma petenence* (Van Den Avyle et al. 1995). In some cases, relative abundance estimates have been used as surrogates for population estimates of anadromous species (Walburg 1960; Richkus and DiNardo 1984; Schmidt et al. 2003).

The objectives of this study were to estimate the population size of migrating Alabama shad below JWLD in the Apalachicola River using mark – recapture and relative abundance techniques, and to evaluate the effectiveness of the navigational lock at JWLD for upstream passage.

STUDY AREA

Jim Woodruff Lock and Dam is located in the central panhandle of Northwest Florida near the Georgia border, and impounds the waters of the Chattahoochee and Flint rivers forming Lake Seminole. The Apalachicola River originates below JWLD and flows without obstruction for 171 km to Apalachicola Bay, an inlet of the Gulf of Mexico (Figure 1). Jim Woodruff Lock and Dam was completed in 1957 to aid navigation and generate hydroelectric power. The Dam consists of a power house, 16 independent 12.2 m wide gates, and a connected navigational lock on the west end (Figure 2). The lock measures 25 m wide by 137.2 m long with a lift capacity of 10.1 m. Elevation change between the river and the lake averages about 10 m. All of the Alabama shad collected for the study were captured and released in the Apalachicola River within 2 km of JWLD.

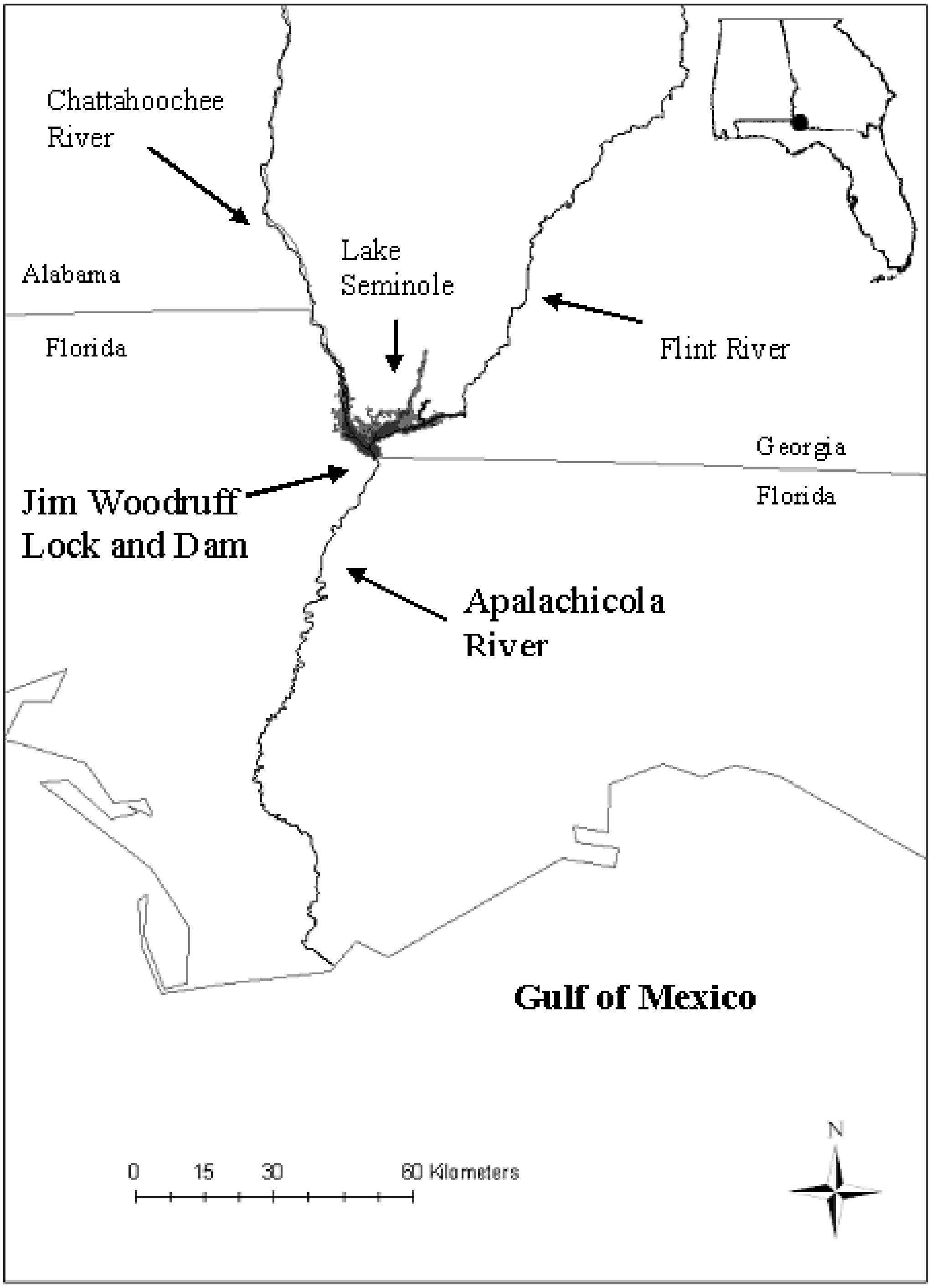

Figure 1.—Location of study area on the Apalachicola River, Florida, below JWLD.

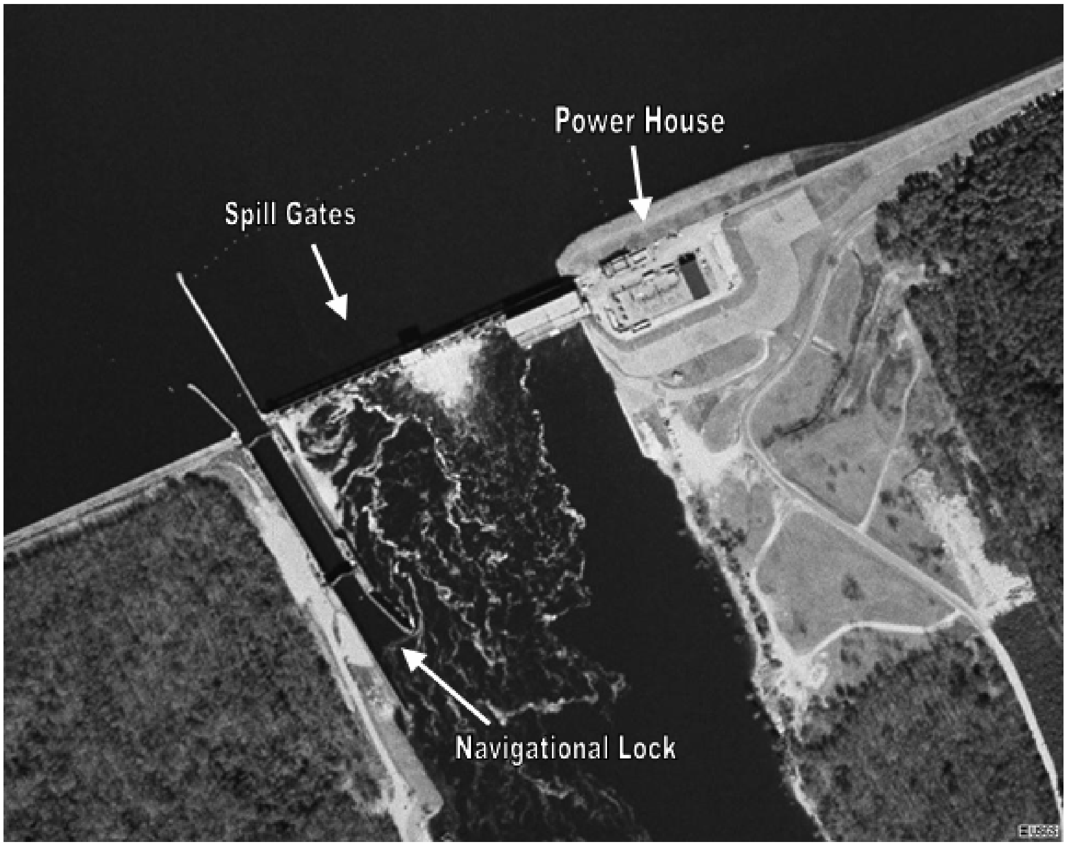

Figure 2.— Aerial photograph of Jim Woodruff Lock and Dam, Florida.

METHODS

I estimated the population size of migrating Alabama shad reaching Jim Woodruff Lock and Dam using mark – recapture. Mark – recapture estimates were accomplished using the Petersen method for a randomly mixed population as modified by Chapman (Ricker 1975) from the equation:

$$N = (M+1)(C+1)/(R+1)$$

where N is the population estimate, M is the number of fish marked and released (adjusted for tag loss, emigration, and mortality), C is the number of fish in the recapture sample, and R is the number of previously marked fish recaptured.

During the peak in Alabama shad spawning migration in 2005 between February 22 and March 25, and in 2006 between March 22 and April 28, adult migrating Alabama shad were marked with either one or two T-bar internal anchor tags (Floy Tag, Seattle, WA, USA) and released. All tagging was conducted between 0800 and 1700 hours using standard boat electrofishing techniques. After capture, fish were immediately tagged without anesthesia and released within 2 minutes of capture. Tags imprinted with a unique identification number were inserted just below the dorsal fin perpendicular to the pterygiophores. Standard boat electrofishing was used to collect Alabama shad for the recapture sample during a 3-week period in 2005 and a 2-week period in 2006 following marking.

The number of marked fish (M) was adjusted for tag loss, emigration and mortality. Tag loss was based on returns of double-tagged fish; where 10 out of 497 doubled tagged fish were recaptured with 0% tag loss. Emigration and mortality were estimated from the proportion of Alabama shad implanted with sonic transmitters that died or migrated downstream and did not return to the study area. Emigration was estimated at 7% and mortality was estimated as 9%, for a cumulative loss of 16%. Because the number of fish examined for tags was small with respect to the population size, confidence intervals (C.I. 95%) were estimated according to Ricker (1975) for large samples based on a Poisson distribution of recaptures.

Due to the small sample size in 2006, a relative abundance method was used to independently estimate the population size of migrating Alabama shad reaching JWLD. The method was based on the direct proportion of catch per unit effort and the population estimate from 2005. I accomplished this using the following equation:

$$N = N_a C / C_a$$

where N is the unknown population size for 2006, N_a is the population size from 2005, C is the catch per unit effort (computed as total catch/total sampling time) from 2006, and C_a is the catch per unit effort from 2005. Confidence intervals (C.I. 95%) were estimated for N using the equation:

$$N\ (C.I.\ 95\%) = N_a * C / [C_a \pm (C_{Stdev} * 1.96)]$$

where C_{Stdev} is the standard deviation of C. In 2005, the catch rate of Alabama shad per hour was recorded weekly over the 11-week study period (Table 1). In 2006, the catch rate of Alabama shad per hour was recorded weekly over the 8-week study period (Table 2)

Table 1.---Weekly catch rate of Alabama shad from the Apalachicola River below JWLD, 2005, using standard boat electrofishing techniques.

Sample week (2005)	Total shad collected	Total sample time (h)	Catch per hour
2/21-2/27	149	6.64	22.4
2/28-3/6	216	12.46	17.3
3/7-3/13	217	11.37	19.1
3/14-3/20	450	9.10	49.5
3/21-3/27	97	12.95	7.5
3/28-4/3*	0	0	
4/4-4/10*	0	0	
4/11-4/17*	0	0	
4/18-4/24	54	2.16	25.0
4/25-5/1	222	12.33	18.0
5/2-5/8	92	6.11	15.1

*Due to flood conditions, sampling was not conducted during this 3-week period.

Table 2.---Weekly catch rate of Alabama shad from the Apalachicola River below JWLD, 2006, using standard boat electrofishing techniques.

Sample week (2006)	Total shad collected	Total sample time (h)	Catch per hour
3/7-3/16	9	4.16	2.2
3/19-3/25	70	8.17	8.6
3/26-4/1	17	5.77	2.9
4/2-4/8	69	6.91	10.0
4/9-4/15	9	2.08	4.3
4/16-4/22	16	1.99	8.0
4/23-4/29	7	2.70	2.6
4/30-5/6	4	1.66	2.4
5/7-5/13	19	2.61	7.3

In 2005, 45 Alabama shad were fitted with sonic transmitters (Hydroacoustic Technology Inc., Seattle, WA, USA). The transmitters measured 6.8 mm in diameter by 21 mm in length, weighing 0.8 g in water, and possessed a minimum battery life of 25 days. Each transmitter was uniquely coded by frequency and inserted into the fish's gastric cavity. To facilitate gastric implantation, transmitters were affixed to a hollow flexible tube and orally inserted into the stomach. Transmitters were coated in a water-soluble, non-toxic lubricant to minimize trauma during insertion. Once implanted, the tube was removed leaving the transmitter in the gastric cavity of the fish. Transmitters were only inserted into fish that appeared to be in excellent condition. Handling required less than 2 min per fish.

Study fish were collected within 2 km below JWLD using standardized boat electrofishing techniques. After capture, Alabama shad were placed in a live-well and transported inside the navigational lock. Once inside, the lower lock gates were closed. Following transmitter insertion, study fish were released into the lock. The lock level was then raised to lake level over the course of about 20 min and the upper gates were then opened. After 30 min, the upper gates were closed and the lock was drained to the downstream elevation.

Alabama shad were detected using a fixed station sonic telemetry system (HTI 290; Hydroacoustic Technology Inc., Seattle, WA, USA). Study fish were continuously monitored over a 55-d period following release. Hydrophones were placed above, within and below the lock. When a transmitter was detected at a hydrophone, pulse frequency, time and date were recorded. Direction of movement, emigration from the system, time spent in the lock, transmitter failure, and mortality were then determined.

RESULTS

In 2005, 1,091 Alabama shad were tagged over a 5-week period (Table 3). During the 3-week recapture period in 2005, 12 out of 368 shad captured were previously tagged. In 2006, 95 Alabama shad were tagged over a 6-week period. During the 2-week recapture period in 2006, 1 out of 23 shad captured was previously tagged. The population size of migrating Alabama shad near JWLD was estimated at 26,029 (95% C.I. = 15,174 - 49,040) in 2005 and as 972 (95% C.I. = 270 - 9,720) in 2006. The total catch rate averaged 20.47 Alabama shad per hour in 2005 and 6.10 Alabama shad per hour in 2006 (Table 4). Using a direct proportion method, the population size of migrating Alabama shad near JWLD in 2006 was estimated at 7,757 (95% C.I. = 5,987 – 11,012) (Table 5).

Four Alabama shad died within 2 d of implantation as a result of tagging and/or handling, and two transmitters experienced battery failure within the lock. Sixteen Alabama shad (41%; 95% C.I. = 26% - 56%) exited the lock downstream following transmitter implantation. Of those, three emigrated out of the study area and never returned. One fish stayed in the study area for about 8 hours before emigrating and never returning. Two fish emigrated out of the study area but returned approximately 20 d later. Ten shad that exited downstream remained in study area an average of 17.3 d (range = between 6-27 d). All of the shad that remained in the area were located at least once in the vicinity of the lock entrance. One of the fish that exited downstream was recaptured in good condition within 1 km of the dam 33 d after transmitter implantation.

Twenty-three of 39 Alabama shad with working transmitters successfully passed from the lock into the reservoir for a passage efficiency of 59% (95% C.I. = 44% - 74%). Two of the 23 shad initially exited downstream but later re-entered the lock and successfully passed; one exited and re-entered the lock the same day and then passed the following day, while the other re-entered the lock 3 d after exiting and passed within an hour. Of the remaining 21 shad; six passed during initial release, eight passed the day after release, two passed within 2-3 d, two passed within 4-5 d, and three passed within 6-7 d. Three fish that initially passed were later detected below the dam indicating that they passed back down through the spill gates; one was detected below the day after passage and the other two were detected within 3-4 d. No fish that passed upstream re-entered the lock from the reservoir and exited downstream.

Table 3.--- Study year, unadjusted number of fish marked (M), number of fish marked adjusted for tag loss, emigration, and mortality (M_1), number of fish examined for marks (C), number of fish captured that were previously marked (R), population estimate (N), and 95% confidence intervals for migrating Alabama shad reaching JWLD.

Year	M	M_1	C	R	Estimated N	95% C.I. of N
2005	1,092	917	369	13	26,029	15,174 – 49,040
2006	96	81	24	2	972	270 - 9,720

Table 4.---Total catch rate of Alabama shad for 2005 and 2006 from the Apalachicola River below JWLD using standardized boat electrofishing techniques.

Year	Total catch	Effort (h)	CPUE
2005	1497	73.12	20.47
2006	220	36.06	6.10

Table 5.---Adjusted population estimate from 2005 (N_a), total catch per unit effort from 2006 (C), total catch per unit effort from 2005 (C_a), population estimate for 2006 (N), and 95% confidence intervals for migrating Alabama shad reaching JWLD.

N_a	C	C_a	N	95% C.I. of N
26,029	6.10	20.47	7,757	5,987 - 11,012

DISCUSSION

The current population size of Alabama shad reaching Jim Woodruff Lock and Dam is relatively small when compared to both current and historic population estimates of its sister species the American shad (Berry 1964), found along the Atlantic coast. For example, the population size of American shad in the Hudson River was estimated to be between 1.5 and 1.6 million in 1951 (Talbot 1954). In 1989, the population size of American shad in the Delaware River was approximately 1 million (Allen 1996). More recently, the population size of American shad in the Savannah River reaching the first barrier to migration was estimated at nearly 190,000 (Bailey et al. 2004) and 147,000 in the Altamaha River system (GA-DNR 2004). Given the similarities in discharge and drainage area and latitude, it would be reasonable to expect abundances of Alabama shad in the Apalachicola River to have the potential to reach abundances observed for American shad in other Southeastern U.S. rivers.

The number of Alabama shad reaching JWLD was notably less in 2006 than it was for 2005. Even though this drop in abundance may be a cause for concern, it has been well documented that population sizes of American shad widely fluctuate over time. In 1980, the population size of American shad in the Hudson River was an estimated 3.3 million but declined to about 1.7 million the following year (Hattala 1996; ASFMC 1998). In the Connecticut River, American shad numbers varied from >1.5 million in 1992 to < 300,000 in 1995 to over 650,000 from 1996 to 1998 (ASFMC 1998; Moring 2005). The variation in year-class strength typically observed in this genus suggests that populations of Alabama shad could increase substantially under favorable environmental conditions.

Unfortunately, information regarding the historic abundance of Alabama shad is limited. The U.S. Fish Commission reported commercial landings of Alabama shad of 3,165 kg in 1889, and 48 kg in 1902; no commercial landings have been reported since (Hildenbrand 1963). Laurence and Yerger (1967) collected 141 Alabama shad in the Apalachicola river system in 1966 over the course of 17 sampling days using gill nets and dip nets. Of those 141 shad, 72 were collected specifically below JWLD over the course of 8 days using dip nets. Mills (1972) collected 251 Alabama shad in the same drainage in 1969-1970 using gill nets, dip nets and hook and line fishing techniques. Of the 251 Alabama shad collected, 133 were collected in 32 hours using hook and line fishing techniques, averaging one fish caught every 29.72 minutes per individual rod used. Mettee and O'Neil (2003) collected 400 Alabama shad in the Choctawhatchee River using boat electrofishing gear and floating gills nets from 1994 to 2000. They reported a weekly average catch rate in 1999-2000 that varied from 0.89 to 7.79 fish per hour. Although none of these studies directly estimate abundance, the relatively low catch rates suggest low abundances of Alabama shad in these systems in previous years.

About 7% of Alabama shad implanted with sonic transmitters apparently abandoned their spawning migration. This response is referred to as fallback (Moser and Ross 1993), and is a common result of stress caused by handling or transmitter implantation as well as unfavorable environmental conditions. Fallback responses of Alabama shad in this study are less than previous estimates for American shad. In 1996, 23% of American shad in the Cape Fear River never returned to the dam after transmitter implantation (Moser et al. 2000). In 2001, American shad in the

Savannah River were fitted with similar transmitters and 25% never returned to the study area (Bailey et al. 2004).

Passage efficiency of Alabama shad at JWLD (59%) is comparable to other studies in which the passage efficiency for American shad was estimated using navigational locks (Moser et al. 2000; Bailey et al. 2004). However, studies for American shad have shown a wide fluctuation in passage efficiency between years. In 1996-1997, passage efficiency for American shad in the Cape Fear River was 33% but improved to 61% in 1998 (Moser et al. 2000). Passage efficiency for American shad in the Savannah River was 53% in 2001 but significantly decreased to 9% in 2002 (Bailey et al. 2004). Decreases in passage efficiency could be related to unfavorable environmental conditions such as a decrease in attraction flow near the lock entrance and extreme water temperatures. It is likely that passage efficiency at JWLD will vary similarly.

During my study, the lock was in operation seven days per week between 0800-1600 hours. Therefore, all Alabama shad were passed during these operation hours. Analogous studies of American shad illustrate the diel timing of fish lockages is critical for successful passage, and that highest passage efficiency has been observed during the daytime (Moser et. al. 2000; Bailey et al. 2004). It is also apparent that passage efficiency of Alabama shad was positively correlated to the number of lockages per day. Based on our results, it can be concluded that the navigational lock at JWLD can be effective in passing migrating Alabama shad. Increasing passage efficiency could be achieved by maximizing the number of lockages per day. Future research should focus on attracting migrating Alabama shad into the navigational lock.

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