Assessment of American shad (*Alosa sapidissima*) in the Cape Fear River at Lock & Dam #1

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Abstract

A study on American shad (*Alosa* sapidissima) was conducted in March and April of 2007 in the Cape Fear River at lock and dam #1 in North Carolina. The purpose of this study was to determine if the population of American shad is increasing in the Cape Fear River after adjustments to the locking procedure were made and regulatory restrictions on catch in the river and ocean were implemented. Of the 591 shad caught by fishermen, 298 were measured, weighed, and sexed. Mean catch per unit effort for the recreational fishery was 2.25 and 4.20 for the commercial fishery. Surface water temperatures ranged from 11.67 ^{o}C to 20 ^{o}C, with the maximum number of shad caught at 12.2 ^{o}C for commercial fishermen and 20 ^{o}C for recreational fishermen. Recreational fishermen caught a higher proportion of males than the commercial fishermen. The total number of shad caught was greater than previous years, however, there was a greater number of interviews in 2007. A non-parametric test showed that there is not a significant trend in abundance of American shad at this time. A 12-year minimum comparative study needs to be implemented with solid data in order to get the best results on the abundance of American shad.

Introduction

The anadromous American shad, *Alosa sapidissima* (Wilson), is the largest Atlantic Coast member of the herring family Clupeidae, ranging from the St. Lawrence River, Canada, to the St. Johns River, Florida (Bailey, 2004; Bigelow, 1953; Facey and Van Den Avyle, 1986; Liem, 1924; McCord, 2005a). The size of sexually mature females, often called roe shad for their highly prized eggs, rarely exceed 600 mm (TL) and a weight of 5.4 kg (Facey and Van Den Avyle, 1986). Mature males (bucks) are generally smaller than females at relatively the same age, rarely exceeding 2 kg (Facey and Van Den Avyle, 1986). Males reach sexual maturity at 3-5 years and females at 4-6 years (Facey and Van Den Avyle, 1986).

The American shad fishery has historically been the most valuable fishery in North Carolina during the late nineteenth and early twentieth centuries (Parker, 1992; Winslow, 1990). Since the late 1800's, North Carolina consistently ranked the highest of commercial landings of American shad along the east coast (Walburg and Nichols, 1967; Winslow, 1990). In the river system, the estimated commercial catch in 1896 was 317,620 lbs, of which the Cape Fear River produced 76 %, the North East Cape Fear River 15%, and the Black River 9% (Nichols and Louder, 1970). In 1897, the overall commercial catch of American shad in North Carolina peaked at over 9 million lbs (4 million kg) (Parker, 1992; Winslow, 1990). By the early 1900's, the landings of American shad had significantly declined due to overfishing, construction of dams, habitat degradation in spawning areas, and pollution (Sholar 1977a; Boremand, 1981; Johnson, 1982; Parker, 1992; Winslow, 1990; Bilkovic, 2000; Bilkovic, Hershiner and Olney, 2002). An increase was noted in 1981-1984, but was not significant, even when compared to the landings of the 1960's (Table 1) (North Carolina Division of Marine Fisheries in Winslow, 1990). Total commercial landings of American shad in North Carolina fell from 468,484 lbs valued at $111,609 in 1972 to 131,621 lbs valued at $108,142 in 1999 (Table 2) (North Carolina Division of Marine Fisheries, 2000). In the Cape Fear River, total commercial landings of American shad in 1972 were 66,968 lbs. By 1999, the commercial landings of American shad fell to 6,804 lbs (Table 2) (NC-DMF, 2000). Since then, commercial landings in the Cape Fear River have slowly increased with landings in 2006 totaling 16,055 lbs valued at $17,343. Gill nets (drift and set) have contributed to the highest percentage of the overall harvest (NC-DMF, 2000). The difference between the two is that set nets are anchored to the bottom and drift nets are not.

In 1985-1986, South Carolina conducted a tagging program of American shad in their coastal waters to monitor stocks and gather information on their migrational patterns (Winslow, 1990). The study revealed that American shad were making a southern spawning migration pattern in nearshore ocean waters off South Carolina, which led to speculation that the North Carolina ocean fishery may be exploiting South Carolina's spawning stock (Winslow, 1990). Intercept fisheries for American shad is discouraged by the Atlantic States Marine Fisheries Commission's (ASMFC) fishery management plan (Atlantic States Marine Fisheries Commission, 1985), which encourages each state to fish on its own stocks in or near natal rivers (Winslow, 1990). The ASMFC (1999) adopted a fishery management plan for American shad and river herring that included a five-year phase-out of the ocean fishery. The ASMFC (1999) required states to develop an approved fishing or recovery plan for each stock under restoration. In 2005, the NCMFC (2000) eliminated fishing for American shad in the Atlantic Ocean. The NCMFC enacted a rule in 1995, which established a closed season for American shad from April 15 through January 1 (NC-DMF, 2000).

Table 1. American shad landings and value in North Carolina, 1880 – 1988 (from Winslow, 1990)

Year	Landings x 1000 kg	Landings x 1000 lbs	Value x 1000 $	Year	Landings x 1000 kg	Landings x 1000 lbs	Value x 1000 $
1880	1,462	3,221	330	1957	379	837	209
1887	2,171	4,783	298	1958	223	493	123
1888	2,599	5,725	295	1959	190	419	105
1889	2,452	5,403	280	1960	230	347	127
1890	2,640	5,815	306	1961	305	673	168
1896	4,014	8,843	417	1962	347	765	191
1897	4,069	8,963	363	1963	314	693	168
1902	2,981	6,567	385	1964	290	640	127
1904	1,466	3,230	313	1965	485	1,069	214
1908	1,781	3,924	373	1966	318	701	170
1918	752	1,657	377	1967	352	777	155
1923	1,075	2,370	583	1968	382	842	128
1927	1,083	2,387	475	1969	326	719	137
1928	1,415	3,118	573	1970	432	953	193
1929	868	1,913	350	1971	308	680	117
1930	532	1,172	210	1972	212	468	112
1931	400	883	139	1973	145	321	85
1932	419	925	126	1974	167	369	106
1934	578	1,274	193	1975	109	241	83
1936	497	1,095	177	1976	75	167	65
1937	316	698	106	1977	54	121	55
1938	468	1,032	165	1978	182	402	145
1939	389	859	137	1979	126	278	122
1940	363	801	120	1980	90	199	88
1945	414	912	199	1981	159	351	190
1950	499	1,100	340	1982	187	412	183
1951	564	1,244	300	1983	202	446	187
1952	671	1,479	377	1984	265	585	241
1953	539	1,188	293	1985	149	330	152
1954	656	1,445	258	1986	169	374	229
1955	294	649	160	1987	148	328	215
1956	350	773	193	1988	118	261	150

Obstruction of migration has also contributed to the decline of several Atlantic Slope anadromous species such as American shad, hickory shad, *Alosa mediocris,* sturgeons, *Acipenser spp*., and striped bass, *Morone saxatilis* (Burdick and Hightower, 2006). According to Burdick and Hightower (2006), dams provide some benefits to society such as flood control and electric power production. However, dams also fragment habitat, convert free-flowing rivers into lentic systems, reorganize trophic cascades, alter thermal regimes, disrupt natural flows, simplify downstream channels, and prevent access to flood plains and suitable spawning habitat (Burdick and Hightower, 2006). Dams limit access to a diversity of habitats, preventing American shad from migrating upstream to their historic spawning areas (Nichols and Louder, 1970; ASMFC, 1985; Moser and Ross, 1993; Moser et al., 1998; ASMFC, 1999; McCord, 2005a: Burdick and Hightower, 2006). Even low-head dams such as lock and dam #1 obstruct upstream migration of adult American shad as well as other anadromous fishes (Nichols and Louder, 1970; Moser and Ross, 1993; Moser et al., 1998; Burdick and Hightower, 2006).

In 1996, Moser and Hall discovered through a sonic telemetry study at lock & dam #1, that 75% of the telemetered shad at the dam base entered the lock chamber, however, only 31% of these shad passed upstream successfully and were re-located above the dam (Moser et al., 1998). Modifications to the fish locking procedure were implemented in March 1997 based on recommendations of Moser and Hall (1996), which included positioning the lower lock gates to retain fish for longer periods of time in the chamber and increasing the lockage (Moser et al., 1998). A steeppass Denil fishway was installed along the southern abutment adjacent to Lock #1 on April 8, 1996 (Moser et al. 1998). The fishway proved to be ineffective at getting the fish past the dam. The change in the lower lock gates and increasing the frequency of lockages were effective. Results indicated that the passage efficiency of American shad increased greater than 50% (Moser et al., 1998).

According to recent studies on the Neuse River in North Carolina, removal of dams has increased the spawning range of anadromous fishes. Burdick and Hightower (2006) reported that the distribution of spawning activity of American shad, hickory shad and striped bass increased after the removal of Quaker Neck Dam, a low-head dam located on the Neuse River. By sampling eggs and larvae after the removal of the Quaker Neck Dam, Burdick and Hightower (2006) discovered that there was a substantial upstream expansion for American shad spawning activity relative to the spawning area before the dam was removed. Prior to the removal of the dam, Beasley and Hightower (2000) implanted sonic transmitters in American shad and striped bass (Burdick and Hightower, 2006). Of 13 striped bass and 8 American shad, only 3 striped

Table 2. Commercial landings and value of American shad in North Carolina, 1972-1999 (from NC-DMF, 2000)
**Closed season April 15-January 1

	Landings							State Total	
Year	Atlantic Ocean	Albemarle Sound Area	Cape Fear River	Neuse River	Pamlico River	Pamlico Sound	Other Areas	Lb	$
1972	--	130,399	66,968	81,715	92,799	92,069	4,534	468,484	111,609
1973	--	80,770	32,120	69,526	30,300	105,237	3,047	321,000	85,491
1974	--	116,502	20,219	61,091	32,167	132,926	5,928	368,833	105,668
1975	--	87,063	22,949	27,764	34,157	69,307	0	241,240	82,815
1976	1,547	78,301	7,288	34,161	32,150	13,743	0	167,190	65,227
1977	--	79,594	16,106	6,144	13,432	3,171	2,575	121,022	54,764
1978	5,000	158,908	32,999	31,726	40,908	124,243	8,233	402,017	144,986
1979	25,064	85,158	52,104	31,611	10,971	69,486	3,676	278,070	121,662
1980	3,943	68,695	45,486	11,615	6,430	44,564	18,473	199,206	88,112
1981	107,415	66,732	52,911	15,549	9,761	97,106	2,026	351,500	189,793
1982	63,979	118,794	78,184	18,129	5,080	122,898	4,788	411,852	183,483
1983	3,788	216,058	65,728	45,378	53,794	58,324	2,809	445,879	187,360
1984	13,511	227,308	69,040	70,305	108,410	85,177	10,552	584,843	241,009
1985	3,159	148,555	17,788	56,620	40,675	52,607	10,235	329,639	152,547
1986	63,085	120,367	37,048	70,880	18,138	49,357	14,919	373,794	228,819
1987	41,162	149,923	14,003	47,117	22,640	50,168	2,633	327,646	215,115
1988	50,088	128,061	5,266	15,110	46,607	33,485	4,433	283,050	171,962
1989	38,548	208,807	12,719	13,452	17,012	27,158	5,700	323,396	214,896
1990	37,064	214,954	26,519	11,543	6,520	14,803	2,147	313,550	170,161
1991	19,217	209,900	30,040	2,860	2,568	9,827	2,095	276,507	221,880
1992	23,956	131,499	44,250	13,808	14,231	8,546	2,872	239,162	194,629
1993	28,122	73,631	62,278	8,538	3,033	3,102	86	178,790	149,739
1994	33,895	49,713	10,871	7,216	4,039	4,944	297	110,975	95,703
1995**	102,984	60,953	11,180	15,311	9,573	5,232	634	205,867	188,541
1996**	58,167	65,953	26,818	24,439	8,672	9,115	5,969	199,133	171,625
1997**	98,312	63,736	15,584	17,154	8,985	12,126	3,633	219,530	149,203
1998**	118,017	168,444	11,144	11,715	11,698	5,008	1,533	327,559	233,761
1999**	32,970	70,071	6,804	7,719	6,920	6,054	1,083	131,621	108,142

bass passed over the dam while it was submerged (Burdick and Hightower, 2006). Bowman and Hightower (2001) studied American shad and striped bass after the removal of the dam and discovered that 12 of 22 American shad and 15 of 23 striped bass with transmitters migrated upstream of the former dam site (Burdick and Hightower, 2006).

American shad migrate several hundred miles from the ocean to freshwater rivers to spawn (McCord, 2005a). Migration begins when water temperatures are between 10^{o}C and 15^{0} C (Facey and Van Den Avyle, 1986; Leggett, 1972). The spawning run begins in January and February; however, American shad generally arrive at lock and dam #1 in late February to early March. American shad require high, stable water flow with a velocity of 30.5 - 91.4 cm/sec of good water quality for spawning and early nursery habitat over substrates of sediment, gravel, and mud (Facey and Van Den Avyle, 1986; McCord, 2005a). According to Carscadden and Leggett (1975) and Glebe and Leggett (1981) as cited in Parker (1992), American shad exhibit a pronounced latitudinal cline in post spawning survival. North Carolina has been reported to be the geographical boundary between semelparous (single spawning per lifetime) and iteroparous (two or more spawning per lifetime) reproductive strategies (Parker, 1992). Populations south of North Carolina tend to be semelparous and populations north of North Carolina more iteroparous (Parker, 1992). Leggett and Carscadden, (1978) and Melvin et al. (1986) supported this idea by using Cating’s (1953) and Judy’s (1961) method for determining age using scales (Parker, 1992). The differences in spawning characteristics were attributed to the higher amount of energy expended to reach southerly spawning grounds (Parker, 1992). American shad in North Carolina tend to spawn only once.

The purpose of this study was to determine if the population of American shad in the Cape Fear River, North Carolina is increasing after the establishment of certain restrictions were implemented on the shad fishery and after the passage efficiency through the lock and dams increased.

Study Area

Lock and Dam #1 is a low elevation dam, located on the Cape Fear River in Bladen County, North Carolina (Figure 1) at Kings Bluff, approximately 39 miles North of Wilmington.

Figure 1. Low elevation Lock and Dam #1 on the Cape Fear River, North Carolina

It was the first of three locks and dams to be built in 1915 to aid waterborne navigation from Navassa to Fayetteville, North Carolina. The lock and dams are not being used for navigation and are being monitored daily by the U.S. Army Corps of Engineers.

Lock and dam #1 has a pair of electrically operated steel gates. Each pair has eight manually operated valves that control the water level in the lock chamber (Nichols and Louder, 1970). During normal river flow, flow through the lock chamber of 0 – 6 ft/s can be produced by opening and closing the gate valves (Nichols and Louder, 1970). Lock & dam #1 is 200 ft long, 40 ft wide, and 32 ft deep (Nichols and Louder, 1970). The entrance is 140 ft downstream from the base of the dam (Nichols and Louder, 1970).

Figure 2. Aerial photograph of Lock & Dam #1

The Cape Fear River is a 202-mile long river, formed in east central North Carolina by the junction of the Deep and Haw rivers, and flowing southeast to enter the Atlantic Ocean south of Wilmington and north of Cape Fear. It is the longest river within North Carolina. The principal tributaries are the North East Cape Fear River, which enters at Wilmington, and the Black River, which enters 15 miles upstream of Wilmington (Nichols and Louder, 1970). The Cape Fear River drains an area of 5,255 mi^2 and has an average discharge of approximately 3,885 ft^3/s ($110 m^3/s$) (United States Geological Survey, 2007).

Methods

Sampling of American shad in the Cape Fear River at Lock & Dam #1 started 6 March 2007 and ended 10 April 2007. Sampling took place 2 – 3 times per week. Commercial and recreational fishermen using gill nets (Net) and hook and line (H&L) were the source of sampled fish. American shad were weighed in kilometers (km) using a Homs, model 10 scale, and measured in millimeters (mm) fork length (FL) and total length (TL). Sex was determined through direct observation of the anal region. Scales were collected for age determination and spawning characteristics from the left side of the fish in the area above the midline and below the dorsal fin. The scales were removed and saved in individually labeled envelopes with date, sample number, length, weight, and sex. Scale removal involved scraping the fish gently from posterior to anterior to obtain approximately 10 – 20 scales. Aging American shad from scales can be difficult and time consuming. In this study, aging was not analyzed due to time restraints; however, they will be analyzed for future studies. Data recorded at the sampling site included date, sample number, interview number, weather, water temperature, type of angler (boat/bank), gear type (H&L/Net), number of drifts for net fishing, time of interview, time party began fishing, number in party, total time fished, net size, bait used (live/artificial), number of fish kept and number of fish released.

Sex ratio was calculated by dividing the total number of males by the total number of females. Sex ratios were tested using a chi-square test.

For drift nets, catch per unit effort (CPUE) was calculated by dividing the total number of shad caught by the number of drifts. For H&L, CPUE was calculated by dividing the total number of shad caught by total hours fished times the number of anglers.

Regression analysis (Proc GLM) was used to determine if there was evidence of a linear trend in the CPUE in the surveys. There were two dependent (Net and H&L) surveys that were combined and then analyzed to determine its trend. A "Z" transformation (normal deviate) was used to standardize the CPUE's (NCDMF, in press). In order to eliminate confounding effects associated with comparing means with different time periods, the standardization was conducted with CPUE's during identical time periods. The standardization was calculated as follows:

Z = [x-mean (survey)] / std (survey)

where x = yearly data point, mean (survey) is the mean calculated for each survey, std (survey) is the standard deviation for each survey (NCDMF, in press). This technique was used to standardize the data sets to zero with a standard deviation of 1 (Zar, 1984). The dependent data included both net and h&l CPUE. The data included 1995, 1996, 1997, 1999, 2000, 2001, 2002, 2004 and 2007. 2005 had a very small sample size and was not applicable in this test. The reliance of the "Z" calculation on a mean is influenced by a change in time analyzed or by the population size. To determine if a linear trend was present, the dependent data was modeled using a Proc GLM (SAS, 1985). The "Z" transformation has an assumption of normality. The Kolmogorov-Smirnov test (SAS Proc Capability) was used to test normality. Normality was violated for the SEAMAP index. The Kolmogorov-Smirnov test is often inaccurate at low samples (NCDMF, in press). The CPUE's for all indices were transformed using log (CPUE + 1). Once the CPUE data was transformed, all indices met the criteria for normality. Additionally, mean scores were analyzed for differences among years using the NPAR1WAY procedure for both net and h&l.

The length-weight relationship was determined by the parameters a (proportionality constant or intercept) and b (exponent) of the length-weight relationship of the form:

$$W = aL^b$$

which was estimated for males and females through a logarithmic transformation as follows:

$$\ln W = \ln a + b \ln L$$

with a and b estimated as least squares regression.

Results

Capture of American shad peaked in mid March for the commercial fishery and early March and April for the recreational fishery (Figure 3). The majority of American shad caught was in March by commercial fishermen. April had the majority of recreational catches.

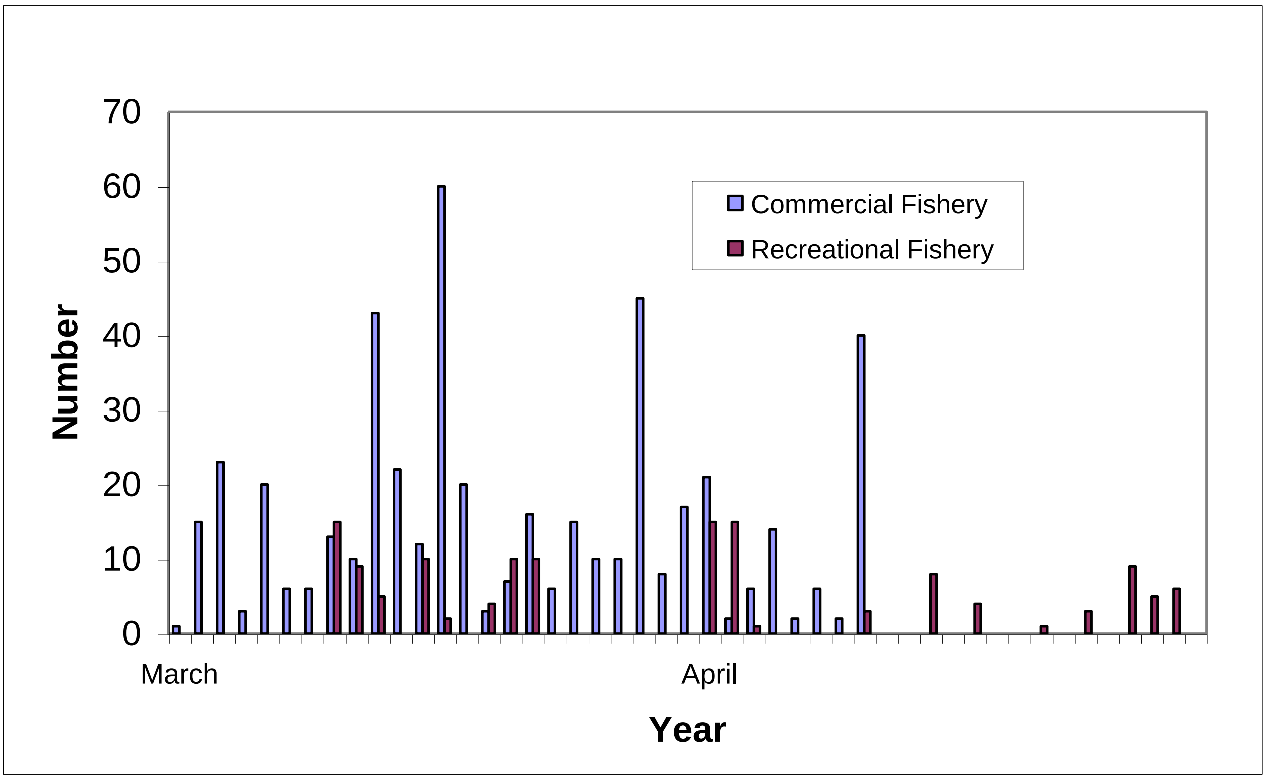


Figure 3. Number of American shad caught by month

Sex Ratio

There was a greater amount of females caught than males in 2007. Comparing with past years, only 1995 and 1996 had a greater amount of males caught than females (Table 3).

To compare all years, a chi-square test was done to find the significance in gear type and sex ratio. There was a significant difference in gear type and year for sex ratio. There were more males caught by recreational fishermen with hook and line than females (Figure 4). There were more females caught by commercial fishermen in drift gill nets than males. The highest amounts of shad caught (248) were males in the recreational fishery in 1995. The lowest amounts of shad caught (0) were both males and females in the recreational fishery in 2005. There was no data taken in 1998, 2003 and 2006. 1996 was not included due to a lack of data recorded for gear type.

Table 3. Comparison of yearly catch of males, females, sex ratio and number of interviews.

Year	# Fish Measured	# Males	# Females	Unknown Gender	Sex Ratio H&L (M:F)	Sex Ratio Net (M:F)	# H&L Interviewed	# Net Interviewed
1995	395	280	115		8.3:1	0.4:1	21	13
1996	162	122	40		15.6:1	1.3:1	14	10
1997	154	69	85		1.8:1	0.3:1	9	10
1999	221	98	123		1.9:1	0.4:1	13	11
2000	461	222	239		3.6:1	0.6:1	12	18
2001	174	41	133		0.8:1	0.2:1	6	13
2002	241	116	123	2	1.3:1	0.4:1	18	17
2004	195	44	150	1	1.8:1	0.2:1	1	16
2005	35	2	33		0.0:1	0.1:1	0	2
2007	297	90	207		1.8:1	0.2:1	43	33

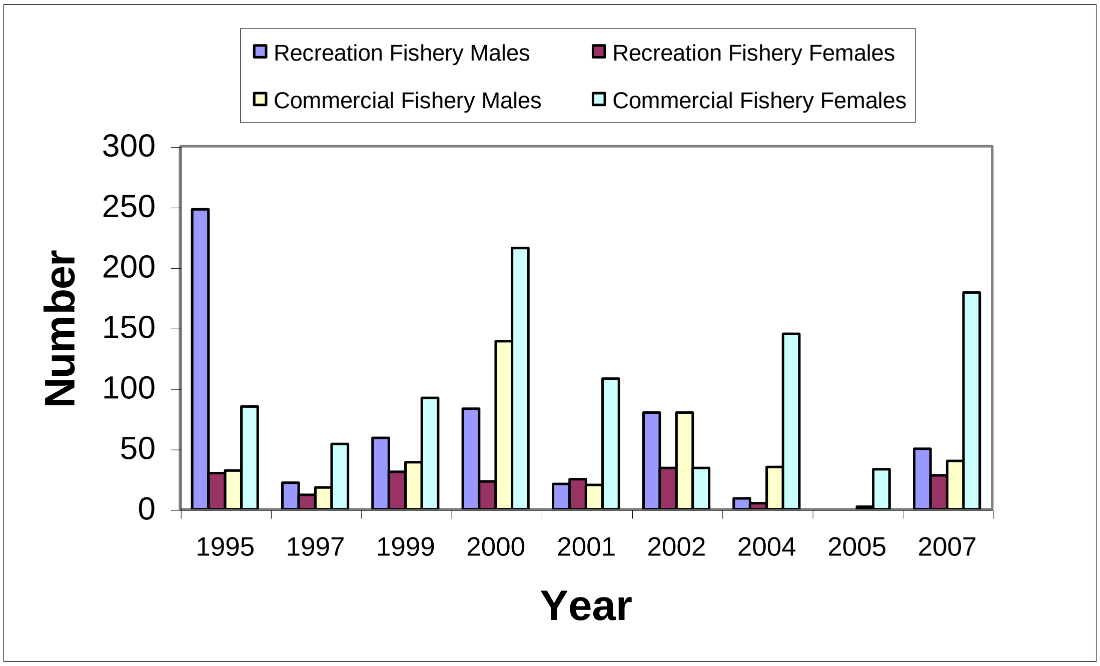


Figure 4. Comparison of sex ratio between recreational and commercial fisheries

Catch Per Unit Effort

The highest CPUE for commercial (net) (19.70) and recreational (h&l) (7.00) was in 2004 (Table 4). The lowest CPUE for commercial (2.30) and recreational (0) was in 2005.

A linear regression was not indicated and there was no significant trend over time. Data from each year was analyzed using a non-parametric test in order to estimate statistical parameters. The nonparametric test identified some years to be lower for recreational fishermen but there was an opposite trend for the commercial data. In 2007, the recreational fishery had a much higher mean score (1.00) than past years and the lowest mean score (0.00) in the commercial fishery than any other year (Table 4 and Figure 5). In the commercial fishery the highest mean score (0.88) occurred in 1996. In the recreational fishery, the lowest mean score (0.14) occurred in 1995 and in 1997. Currently, there is no significant trend present in the abundance indices for American shad. Excluded from this test was 2004 and 2005 due to lacking data and small sample size.

Table 4. Comparison of yearly number of fish measured, mean catch per unit effort, standard deviation and mean scores from a nonparametric test for American shad.

Year	Mean CPUE H&L	Mean CPUE Net	Standard Deviation	Mean Score H&L	Mean Score Net
1995	4.88	2.67	1.56	0.14	0.80
1996	4.56	2.85	1.21	0.33	0.88
1997	1.97	3.36	0.98	0.14	0.80
1999	3.60	2.61	0.70	0.39	0.70
2000	5.46	13.28	5.53	0.46	0.61
2001	4.09	4.76	0.47	0.40	0.80
2002	4.33	3.29	0.74	0.30	0.55
2004	7.00	19.70	8.98		
2005		2.30			
2007	2.25	4.20	1.38	1.00	0.00

CPUE of the commercial fishery using trip ticket data from 1994 – 2006 was analyzed using a linear regression (Figure 6). Both drift gill nets and set nets had their highest CPUE in 2003 and their lowest CPUE in 1999.

Length-Weight Relationship

The highest male mean length (435 mm FL) was in 1999 and the lowest male mean length (384 mm FL) was in 1997 (Table 5). The highest female mean length (467 mm FL) was in 2004 and the lowest female mean length (378 mm FL) in 1999.

The highest male and female mean weight (2.20 kg) was in 2005 (Table 5). The lowest male mean weight (0.70 kg) was in 2002 and the lowest female mean weight (1.40 kg) was in 1997 and 1999.

Table 5. Comparison of yearly mean lengths (FL) and weights of male and female American shad

Year	Male Mean Length (mm)	Female Mean Length (mm)	Male mean Weight (kg)	Female Mean Weight (kg)
1995	**385**	**446**	**0.88**	**1.80**
1996	**390**	**456**	**0.99**	**1.62**
1997	**384**	**438**	**0.90**	**1.40**
1999	**435**	**378**	**0.80**	**1.40**
2000	**407**	**449**	**0.90**	**1.50**
2001	**401**	**461**	**0.86**	**1.58**
2002	**391**	**463**	**0.70**	**1.60**
2004	**403**	**467**	**1.10**	**1.90**
2005	**418**	**436**	**2.20**	**2.20**
2007	**396**	**449**	**0.99**	**1.60**

The PR values were highly significant (t-test; $P < 0.0001$), however, there was no significant trend. $R^2 = 0.88$; df = 7

Data on length and weight each year were analyzed separately in order to get the best comparison results. An analysis of covariance (ANCOVA) was used to quantify statistically significant differences in the length-weight relationship of each year. There was a significant difference in the length-weight relationship. The length-weight relationship has changed over time, and was significant for both regression intercept (Figure 7A) and regression slope (Figure 7B).

Temperature

Temperatures were recorded on the surface of the water close to shore. Temperatures ranged from 11.67 ^{o}C – 20 ^{o}C, with the maximum number of American shad caught by commercial fishermen at 12.2 ^{o}C and 20 ^{o}C by recreational fishermen (Figure 8).

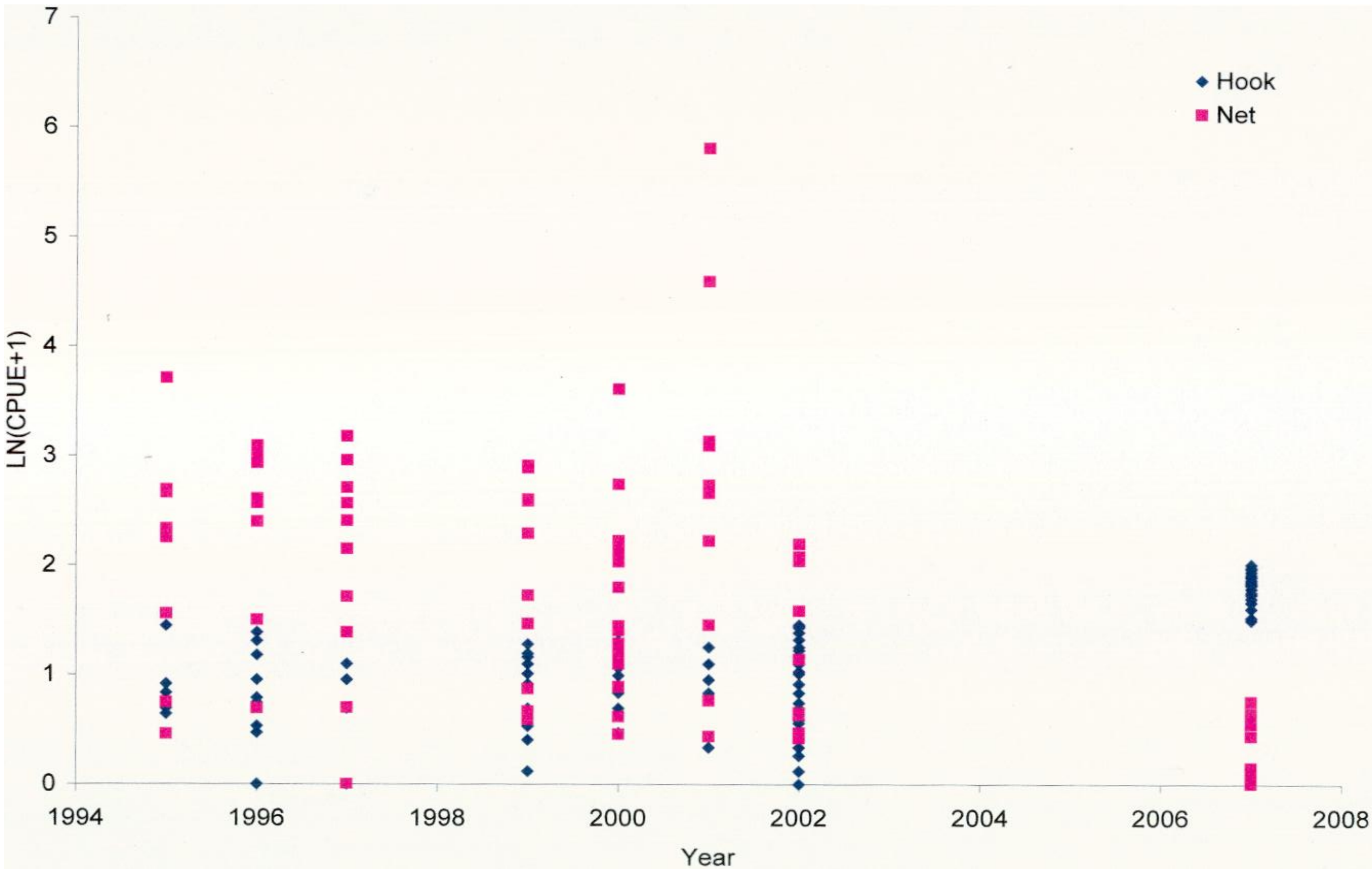


Figure 5. Yearly catch per unit effort (CPUE) of American shad

Figure 6. **C**atch per unit effort (CPUE) of American shad using the commercial fisheries' trip ticket data

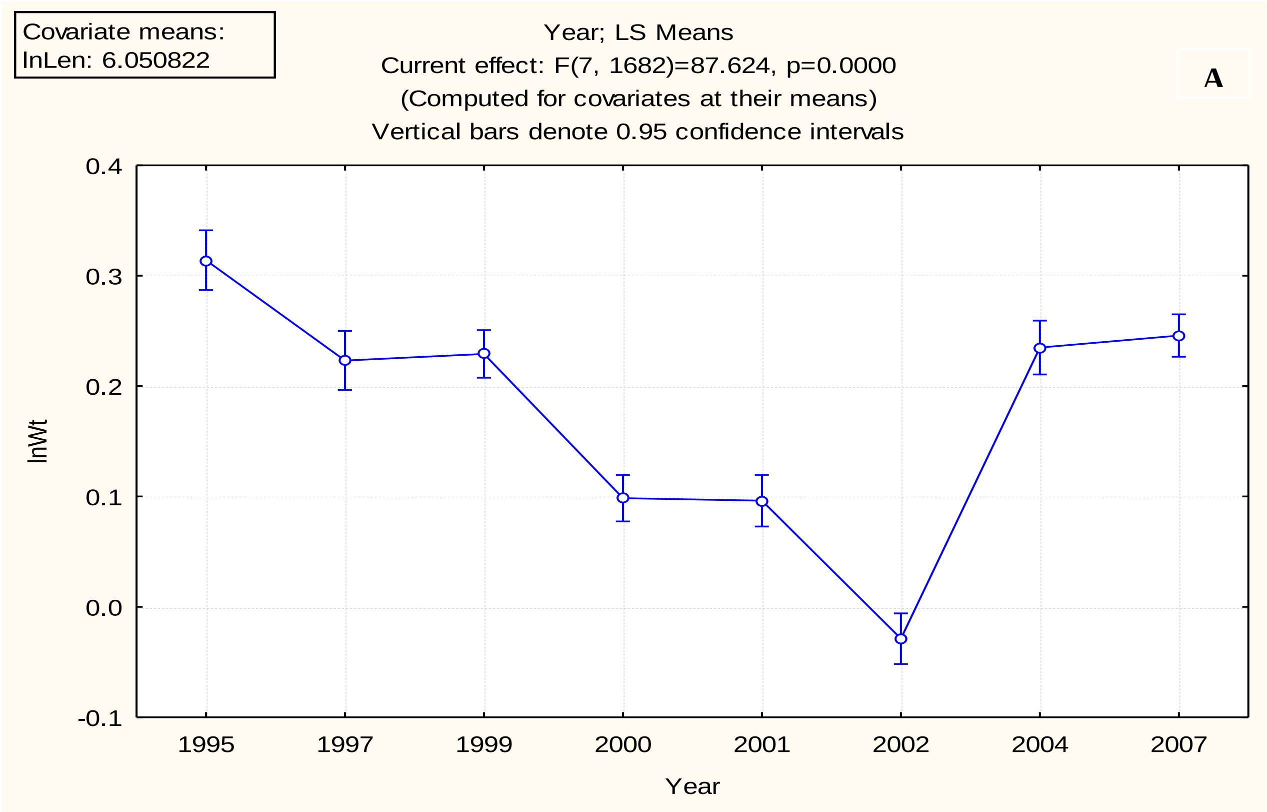
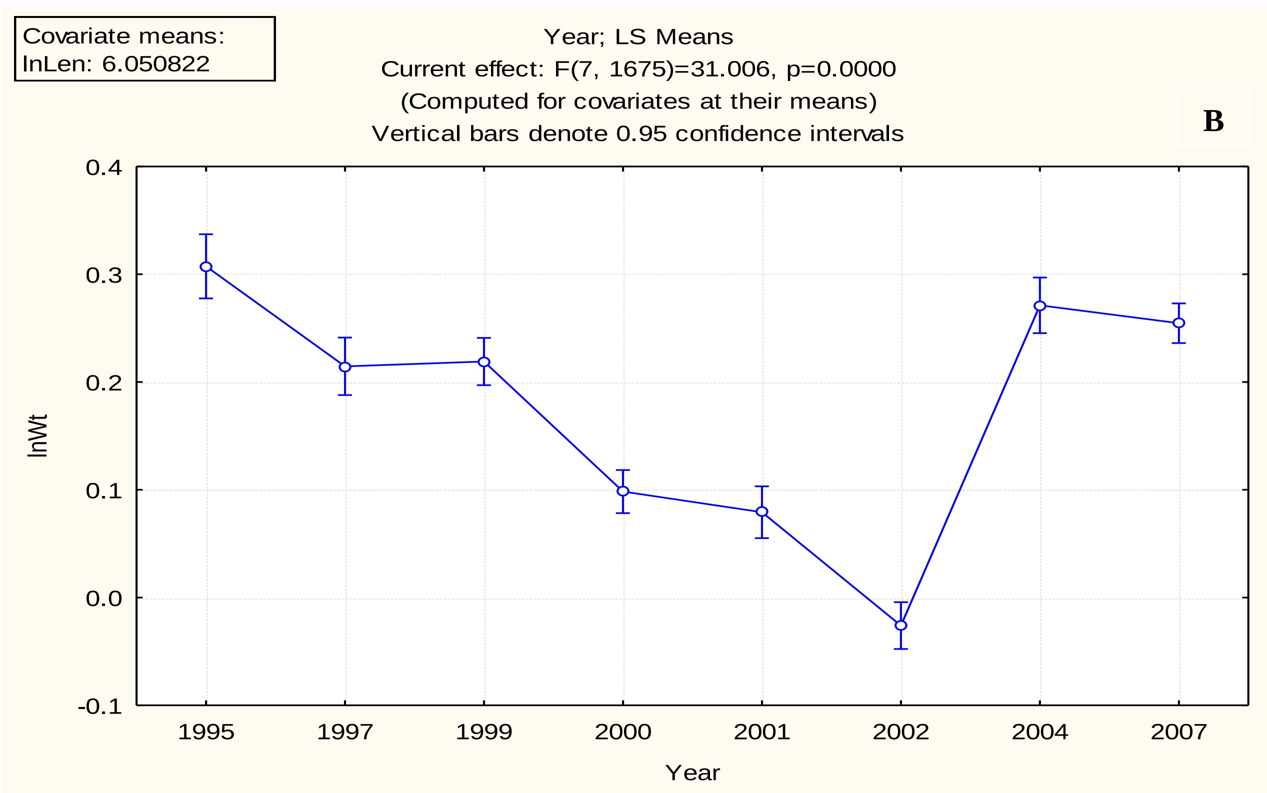


Figure 7. (A) Length-weight intercept (ANCOVA)

(B) Length-weight slope



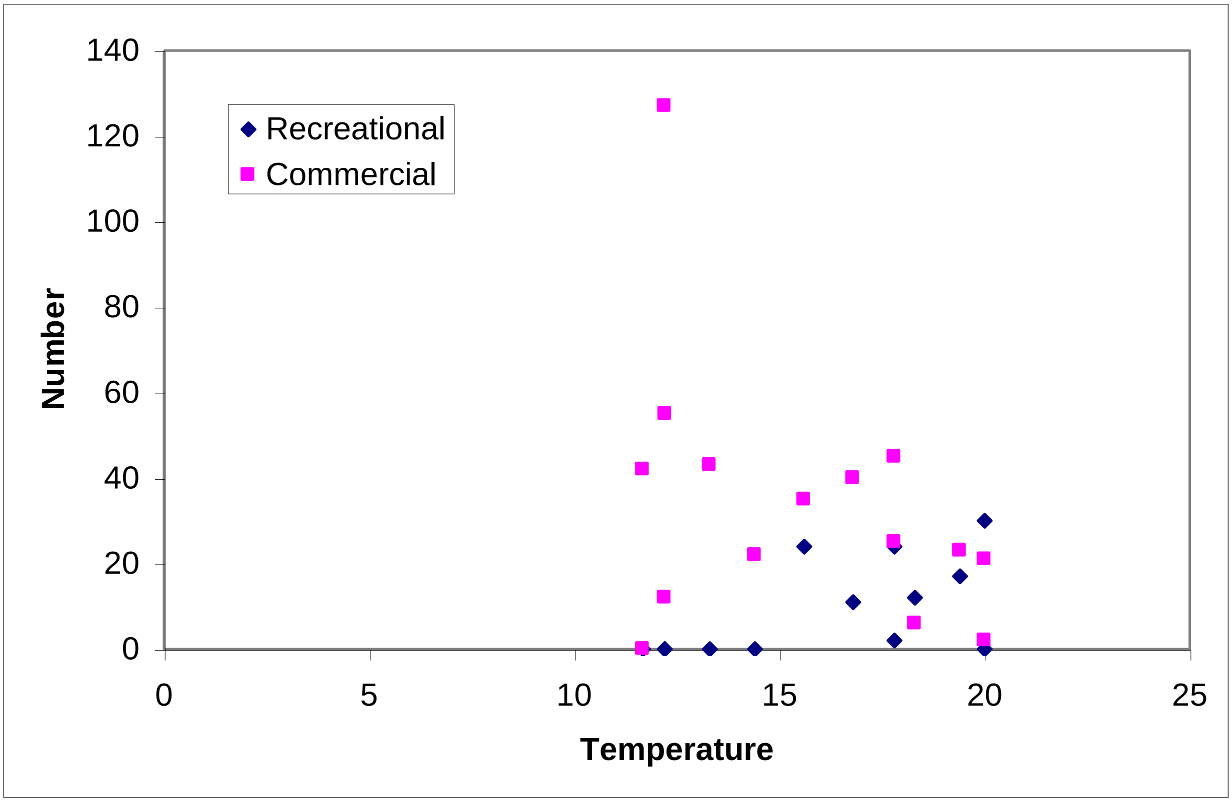


Figure 8. Relationship between the number of American shad caught and surface water temperature.

Discussion

In 2007, the number of females (207) more than doubled that of males (90). Looking at past years, it seemed to be the general trend. Overall, we are seeing a statistical difference in sex ratio by fishing mode. Recreational hook and line fishermen caught a higher proportion of male American shad than did the commercial drift gill net fishermen. In March, because the water clarity was low, most of the fishermen were commercial, catching more females than males. Sometimes, commercial fishermen will bias their catch in favor of the females because they are highly prized for their roe. However, because of the size of the nets (most used 5.5" stretched mesh), and females being larger than males, it made the females more susceptible to capture than males.

Comparing catch per unit effort for commercial fishermen between all years, 2004 had a greater CPUE (19.70) than any other year. The recreational fishermen in 2004 (7.00) also ranked the highest of all the years. Catch per unit effort of the commercial fishermen in 2007 (4.20) ranked the fourth highest of all the years. However, the recreational fishermen in 2007 ranked the third lowest of all the years. Many factors could have contributed to this low CPUE such as temperature, water level, and water clarity. During the month of March, the water level was extremely high and very turbid. This made fishing with drift gill nets easier. However, it also resulted in many days of recreational fishermen with zero catches, which lowered the CPUE. There were also more interviews in March than in April. In April, the water level lowered tremendously and cleared, allowing the recreational fishermen to increase their catch. Though, in 2005, CPUE was zero for recreational fishermen and very low for commercial fishermen. The results were probably due to a small amount of interviews (Table 3). However, there was also a severe drought that year. Analyzing all years, the commercial fishermen had a greater amount of years with higher CPUE than recreational fishermen. This probably had little to do with trends in abundance. Non-parametric test identified that some years were lower for recreational fishermen; however, the commercial data had an opposite trend. This means that currently, there isn't a trend in abundance of American shad. For the overall sample size, the CPUE has reduced, however, data on American shad at lock and dam #1 have not been documented long enough to see any changes in abundances. It can take American shad 3 – 6 years to mature (Winslow, 1990) and migrate back to their natal freshwater rivers to spawn. The second generation takes the same amount of time to migrate to the ocean, mature and migrate back to freshwater. This means that there needs to be at least 12 years (2 generations) of solid data in order to sufficiently analyze and document population abundances in American shad.

Male American shad ranged in length (FL) from 325 mm – 470 mm and in weight from 0.55 kg – 1.70 kg. Males predominated at a length of 370 mm and a weight of 0.75 kg. Females ranged in length (FL) from 367 mm – 500 mm and in weight from 0.65 kg – 2.50 kg. Females predominated at a length of 460 mm and a weight of 1.4 kg. Overall, females were larger than males. Mean length and weight of all years are represented in Table 5. Data on length and weight each year were statistically analyzed separately in order to get the best comparison results. The change in length-weight was significant for both regression slope and regression intercept. This means that shad in some years had differences in the rate of change and in other years, shad either started off heavier or lighter.

Water temperature has been recorded to be the primary factor that triggers American shad migration and spawning. Other factors that trigger migration and spawning include turbidity, water velocity, and photo period (Winslow, 1990; Leggett and Whitney, 1972). Most shad enter rivers at water temperatures between 10 ^{0}C and 15 ^{o}C (Facey and Van Den Avyle, 1986; Ulrich, Chipley, McCord, and Cupka, 1979; Leggett and Whitney, 1972). According to one study, peak spawning occurred at water temperatures near 20 ^{o}C in North Carolina (Winslow, 1990).

American shad began to show up in late February at lock and dam #1. On 6 March 2007, the surface water temperature was recorded at 11.7 ^{o}C. By 10 April 2007, the water temperature increased to 20 ^{o}C. The number of shad caught may be correlated more with turbidity than with temperature. During days of rough, turbid waters, the number of shad caught fell. According to one fisherman (personal communication, 2007), fishing can be very poor when the water is rough, cold and turbid. On 18 March 2007, there were zero catches. The water temperature had dropped from 14.4 ^{o}C to 11.67 ^{o}C and the water was very rough and turbid. Since the number of shad caught initially at 11.7 ^{o}C was 42, the zero catch at 11.67 ^{o}C had little to do with temperature. American shad prefer adequate flow of good water quality, and low sediment loads for spawning and pre nursery habitat (McCord, 2005a; Facey and Van Den Avyle, 1986). Not enough water flow and too much sedimentation will cause the eggs to suffocate (McCord, 2005a). Though, there were a small amount of interviews that day, according to one fisherman (personal communication, 2007), there were approximately 5 boats that had come in earlier with zero catches. The commercial fishermen had their highest catch (127) at 12.2 ^{o}C. Although there was a relatively high number of interviews, one commercial fisherman caught almost half of the total number of shad that day. The recreational fishermen had their highest catch (30) at 20 ^{o}C with a low number of interviews. Currently, there is no trend with number of shad caught and temperature. Regardless of temperature, some days the catch was high with a low number of interviews, and other days the catch was low with a low number of interviews. There is a correlation with the number of shad caught and other environmental factors such as rough, turbulent water, however trends with temperature and catch number requires a longer period of time to accurately analyze.

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