American eel population density, growth and behavior in three Virginia mountain streams

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Abstract

American eels (*Anguilla rostrata*) historically occupied waters ranging from large coastal plain rivers to small mountain streams throughout the James River drainage (VA, USA). As their population numbers have declined overall, American eels have become increasingly rare in mountain streams. Little is known about the biology or behavior of American eels in mountain streams, or how to most effectively manage watersheds to protect or restore American eel habitat. In 1999, we used mark-recapture, passive integrated transponder (PIT) tag, and radio telemetry to examine population density, growth rates, and behavior of American eels within three mountain streams in the James River drainage. Our findings include population densities of 0.8 – 5.1 eels/100 m^2, average growth rates of 19 to 69 mm/yr, and limited movement of eels within study sections. In addition, we observed eels using interstitial spaces and undercut banks during periods of decreased activity associated with low water temperatures during winter. Eel population densities and growth rates within the studied streams are within the bounds of previously studied populations in eastern North America. The winter 'burrowing' behavior has implications for watershed management regarding stream bank stabilization and sediment inputs.

Introduction

American eels (*Anguilla rostrata*) historically occupied waters ranging from large coastal plain rivers to small mountain streams along the Atlantic slope, including tributarties to the Chesapeake Bay such as the James River (VA, USA). As population numbers have declined throughout their range (Haro et al. 2000), American eels have become increasingly rare in mountain streams (Jenkins and Burkhead 1993), yet little is known about the biology or behavior of American eels in mountain streams, or how to most effectively manage mountain watersheds to protect or restore American eel habitat.

In 1999, we used mark-recapture, passive integrated transponder (PIT) tag, and radio telemetry to examine population density, growth rates, and behavior (Table 1) of American eels in three mountain streams in the James River drainage (Figure 1). The objectives of our study were to:1) determine population density, 2) determine annual growth rate, 3) determine movement and activity patterns, and 4) compare results with previous American eel studies.

Methods

Population Density

We used mark-recapture to estimate the density of American eels in Shoe Creek, South Fork Piney River, and South Fork Tye River in summer 2000 and summer 2001. We captured eels by making a single pass through a 1000-m long reach with two 700 V AC backpack electrofishing units. All eels that we captured were given a pectoral fin clip and were released at their point of capture. We recaptured eels by making a second pass through the reach 1-2 days after marking was completed. We used Bailey's modification of the Petersen method (Ricker 1975) to estimate population size: N = (M+1)(C+1)/(R+1); where 'N' is the population estimate, 'M' is the number marked and released, 'C' is the total number captured during the recapture event, and 'R' is the number of recaptures during the recapture event. Population estimates were divided by stream area (1000 m reach * average stream width) to calculate population densities.

Growth Rate

All captured eels greater than 200 mm total length (TL) were injected with a PIT tag (11.5 mm x 1.5 mm; 0.06 g). PIT tags contain a unique 10-digit alphanumeric code that identifies fish as individuals upon recapture. We sampled an additional 500 m upstream and downstream of the mark-recapture reach (2 km reach total) to capture additional eels for the growth rate study. We returned to the streams in summer 2002 - 2005 (except South Fork Piney, summer 2002 only) to recapture PIT tagged eels and mark additional fish. We calculated change in length and weight for eels that were marked with a PIT tag and then recaptured the following year as follows: $\Delta size = size_{t2} - size_{t1}$.

Behavior

We used radio telemetry to monitor movement and activity of 13 eels in Shoe Creek, 10 eels in South Fork Piney, and 10 eels in South Fork Tye River from summer 2000 to summer 2001. Radio transmitters (45 mm x 10 mm; 10 g) were surgically implanted into eels larger than 500 mm TL. The location of each eel was recorded at least once per week. In addition we monitored diel movement and activity of individual eels hourly for 24-hour periods. Diel tracking was performed for each eel at least once per season (winter, spring, summer, fall). Activity levels were determined during diel monitoring by listening for signal strength fluctuations during 3-minute periods. Fluctuations in signal strength represented an actively moving eel (Clapp et al. 1990). We used a combination of radio telemetry and direct observation by divers to document American eel behavior during periods of low activity in winter 2000.

Results

Population Density

Population density ranged from a low of 0.79±0.6 eels/100 m^2 in South Fork Piney River 2001 to a high of 5.1±1.5 eels/100 m^2 in the South Fork Tye River 2001. The Tye River had the highest and South Fork Piney River had the lowest population densities in both years (Figure 2).

Growth Rate

We PIT tagged a total of 1,312 eels between 1999 and 2005 and recaptured 2 - 35% the year after tagging (Table 2). On average, American eels captured the year after being marked and released grew 14 - 27 mm/yr (19 - 35 g/yr) in the South Fork Tye River and 22 - 51 mm/yr (29 - 46 g/yr) in Shoe Creek 1999-2001. The lowest growth rates for the South Fork Tye River were in

2005 (Figure 3). We did not recapture enough eels in Shoe Creek 2001-2005 or in South Fork Piney River in any year to estimate growth rates.

Behavior

Radio telemetered eels occupied a mean stream distance (distance between furthest upstream and furthest downstream locations) of 228±114 m, 375±358 m, 28±22 m, 276±267 m, and 36±24 m in summer 2000, fall 2000, winter 2000, spring 2001 and summer 2001, respectively. Only two eels moved among habitat units during diel monitoring; one moved 500 m downstream between 21:00 and 23:00 on 7/30/2000 and one moved 30 m downstream between 03:00 and 13:00 on 10/27/2000. Diel activity levels were lowest in winter 2000 (Figure 4). Telemetry locations suggested and diver observations confirmed that American eels occupied interstitial spaces between boulder and cobble substrates in the stream bed and beneath stream banks during periods of low activity in winter 2000.

Conclusions

The population densities and growth rates we observed were within the bounds of previous studies despite the fact that the majority of these studies focused on eels in larger warm-water rivers or estuaries. When compared with other non-coastal plain rivers in the James River drainage, the eel densities that we observed in the South Fork Tye River are atypically high (Smogor et al. 1995, Virginia Department of Game and Inland Fisheries (VDGIF), unpublished data). The average growth rates we observed were lower than those observed in coastal streams in GA (57-62 mm/yr; Helfman et al. 1984), but were similar to those observed in coastal RI (23-33 mm/yr; Oliveira 1999) and ME streams (18-32 mm/yr; Oliveira and McCleave 2002).

Our telemetry results suggest that eels in Virginia mountain streams occupy relatively small annual ranges (less than 300 m) and our mark-recapture results show that many eels occupy the same stream reach for several consecutive years. Half of the eels marked during the initial PIT tagging event (1999 in Shoe Creek, 2000 in South Fork Tye River) were recaptured at least once by 2004 (Table 2). In addition, telemetry results show that eels in VA mountain streams become less active and occupy interstitial spaces between large substrate particles in the stream bed and beneath stream banks during winter. Decreased activity is likely a physiological response to decreased water temperature in winter. American eels entered a torpid when held in a lab at less than 10 C (Walsh et al. 1983) and water temperature in VA mountain streams falls well below 10 C during winter (Figure 6).

Our results demonstrate that at least some Virginia mountain streams are capable of supporting large numbers of eels. Given that the vast majority of these eels are likely females (Jenkins 1993), and given the thousands of kilometers of mountain streams in the eastern U. S., these streams represent a potentially large source of reproductive power for a population in decline. This begs the question, ‘Why is the population density in South Fork Tye River much higher than other mountain streams?’. Possible explanations include access and habitat quality.

Access to many mountain streams may be limited by the presence of small dams. These dams may not present a complete barrier, but can have a cumulative filter effect (Verdon et al. 2003). A small lowhead dam located is located in the Piney River drainiage, but whether this can explain the differences in population density observed here is unknown. Where access is not limited eel density may be affected by habitat quality. Little is known about the habitat preferences of American eels in mountain streams and behavior when unfavorable conditions are encountered. For example, the effect of the absence or loss of interstitial spaces for overwintering habitat on eel density is unknown. Clearly, further investigation is needed to determine factors affecting use of mountain streams by American eels and the relative importance of these streams to the overall American eel population.

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Table 1. Activity on Shoe Creek, South Fork Piney River, and South Fork Tye River 1999 – 2005.

	1999	2000	2001	2002	2003	2004	2005
Shoe Creek							
population density		x	x				
growth rate	x	x	x	x	x	x	x
behavior		x	x				
South Fork Piney River							
population density		x	x				
growth rate		x	x	x			
behavior		x	x				
South Fork Tye River							
population density		x	x				
growth rate		x	x	x	x	x	x[1]
behavior		x	x				

[1]attempted recapture of previously tagged eels only; no new tags implanted

Table 2. Total American eels captured, number of PIT tags implanted, and percentage of recaptures in Shoe Creek, South Fork Piney River, and South Fork Tye River. Eels less than 200 mm were not tagged. Percentage of recaptures given as percent recaptured the following year (time t+1) and total percentage recaptured in all following years (all times). Multiple electrofishing passes were made through the reaches in 2000 and 2001. Single passes were used 2002 – 2005.

	Eels Captured	PIT implants	% recaps (time t+1)	% recaps (all times)
Shoe Creek				
1999	73	68	32	46
2000	132	93	20	37
2001	87	41	7	24
2002	42	22	9	27
2003	35	16	13	19
2004	67	43	2	2
2005	22	0	--	--
total:	458	283		
South Fork Piney River				
2000	49	40	5	23
2001	39	30	7	7
2002	57	41	--	
total:	145	111		
South Fork Tye River				
2000	334	279	35	56
2001	352	226	25	44
2002	290	149	17	33
2003	180	76	14	25
2004	232	116	18	18
2005	184	72	--	--
total:	1572	918		

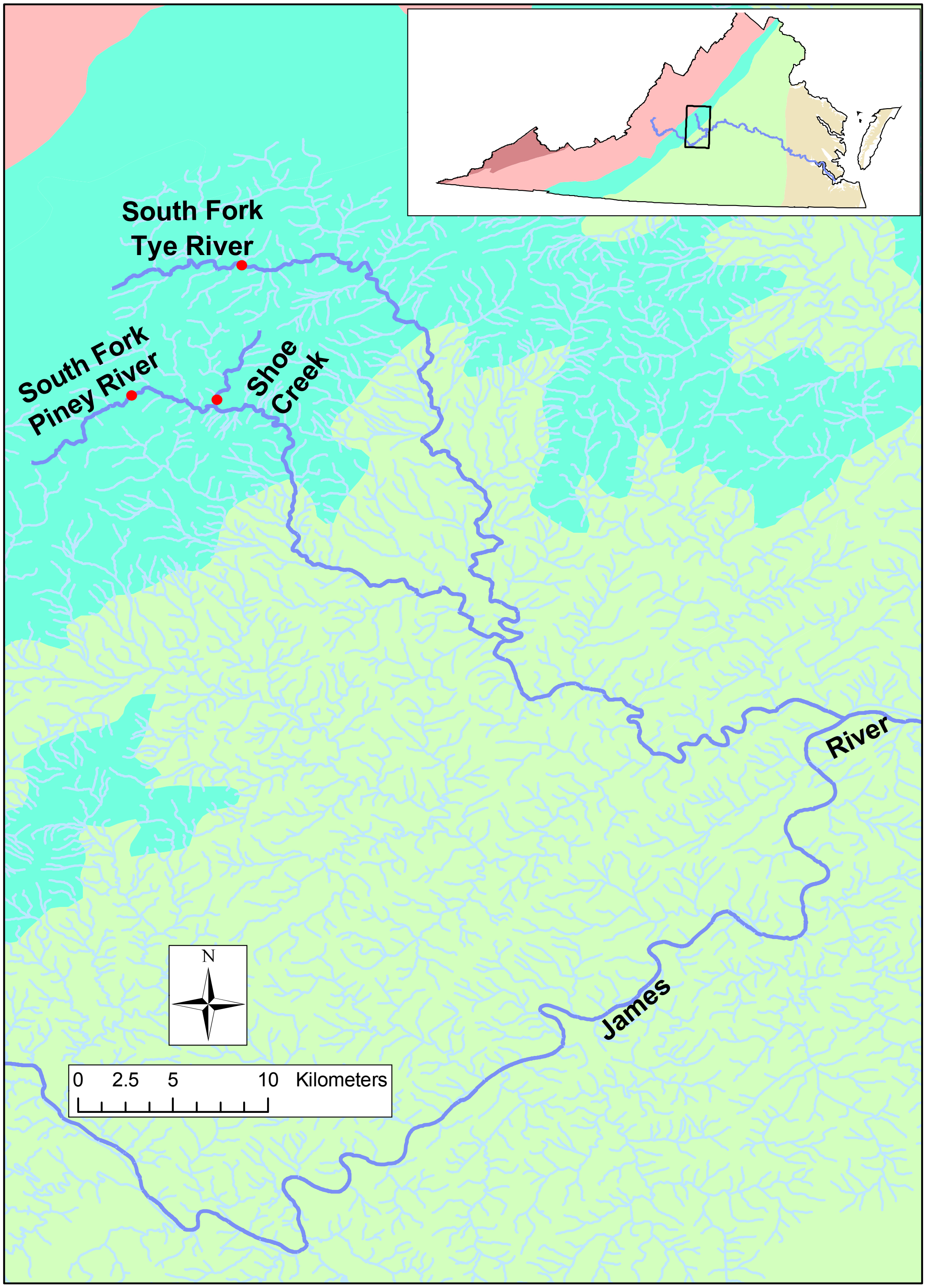

Figure 1. Study areas on Shoe Creek, South Fork Piney River, and South Fork Tye River. Shading indicates physiographic provinces; tan = Coastal Plain light green = Piedmont, dark green = Blue Ridge, pink = Valley and Ridge, red = Appalachian Plateau.

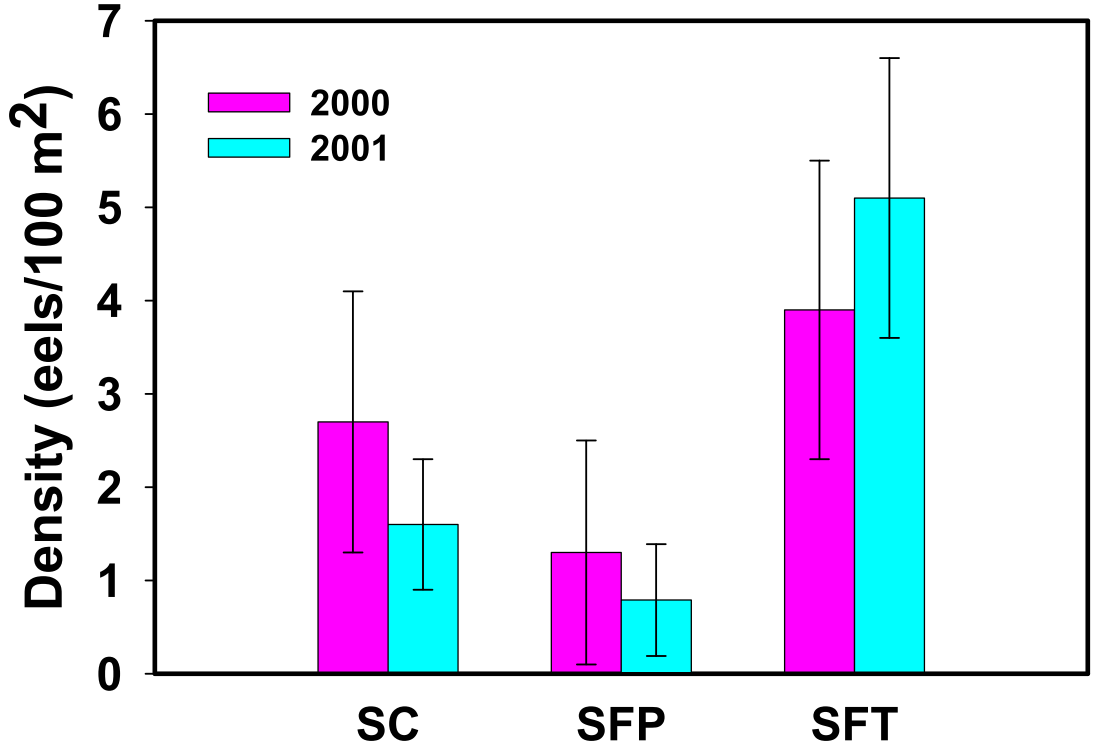

Figure 2. Population density of American eels in Shoe Creek (SC), South Fork Piney River (SFP), and South Fork Tye River (SFT) in 2000 and 2001 as determined by mark-recapture estimates. Error bars show 95% confidence intervals.

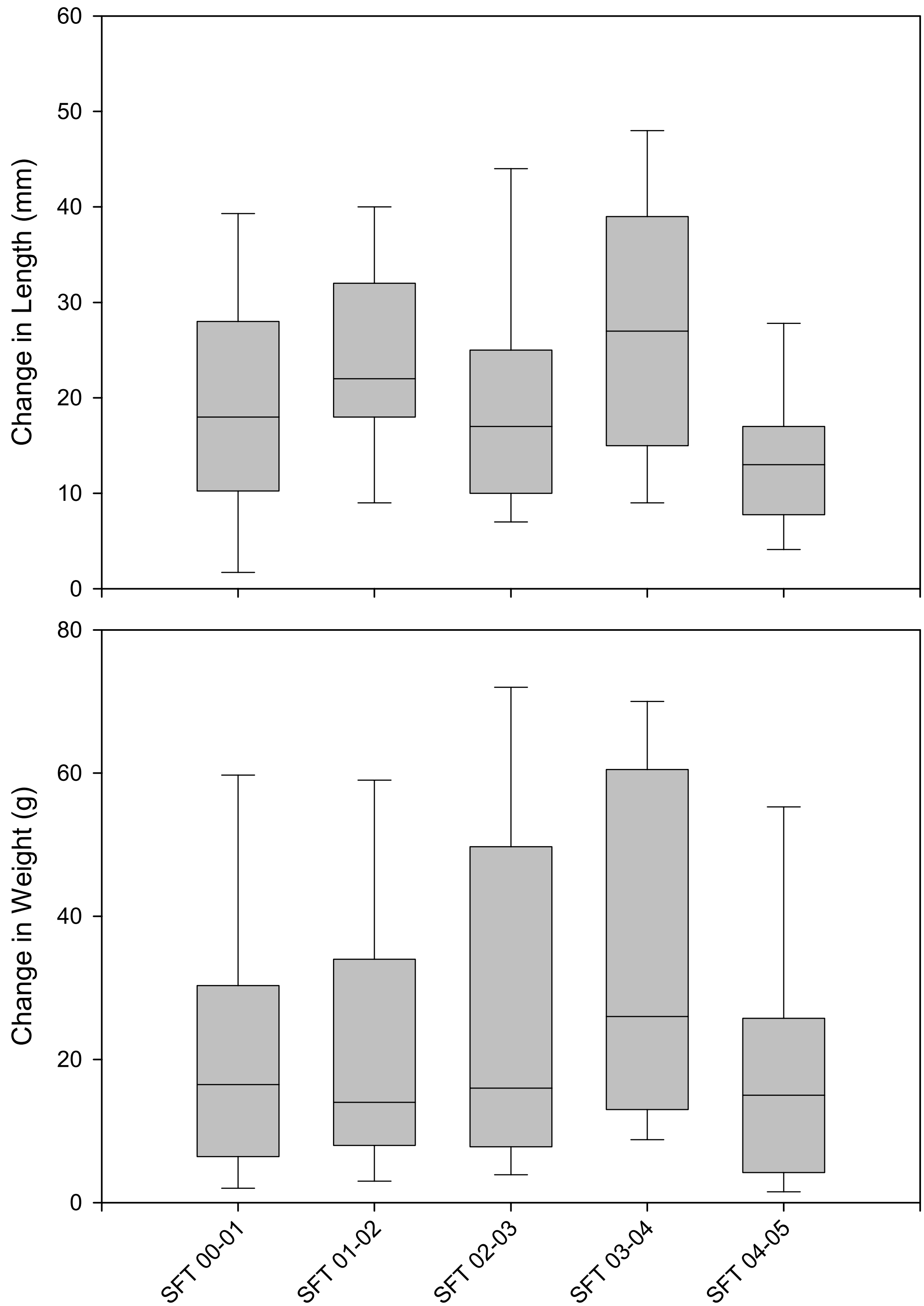

Figure 3. Growth of American eels marked with PIT tags, then recaptured the following year in South Fork Tye River (SFT). Middle line in box plot shows median, bottom and top of box show 25th and 75th percentiles, whiskers show 10th and 90th percentiles.

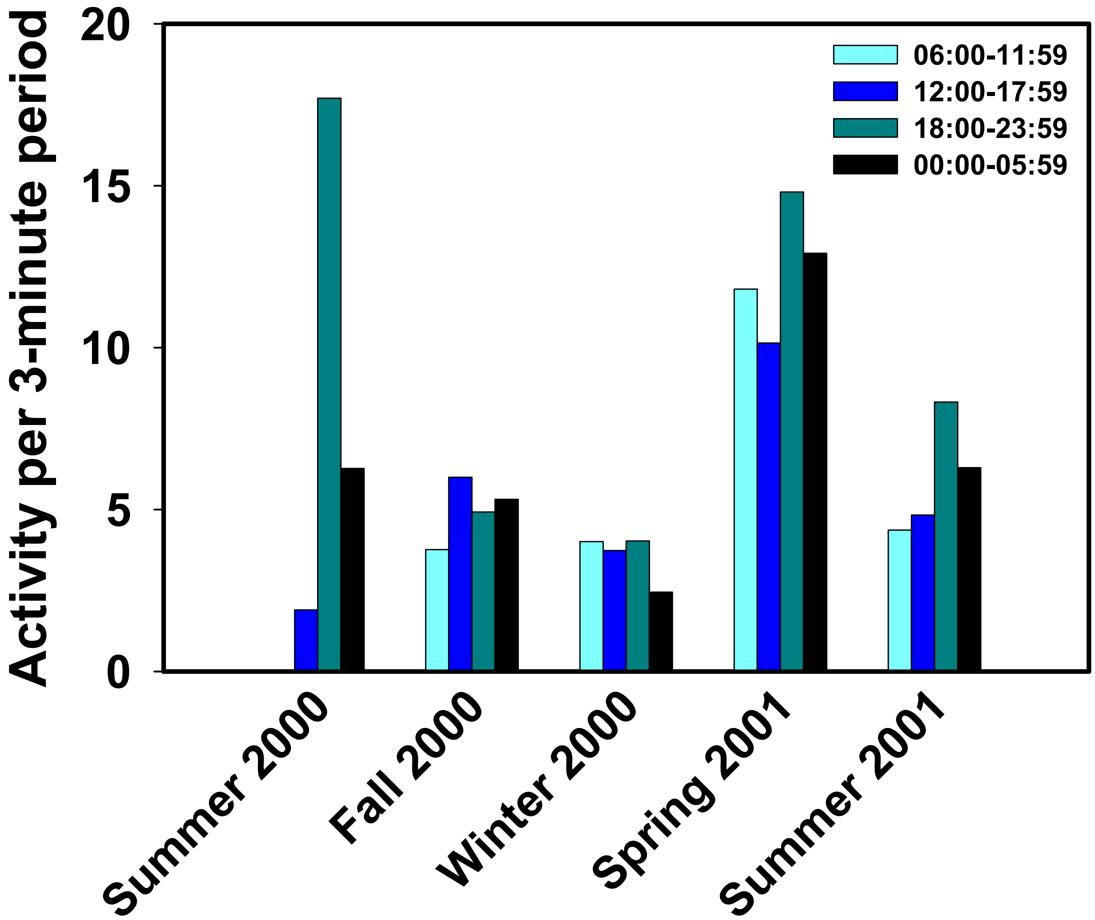

Figure 4. Average activity levels of telemetered American eels over 3-minute periods. Bars represent average of 2-6 eels for each time period.

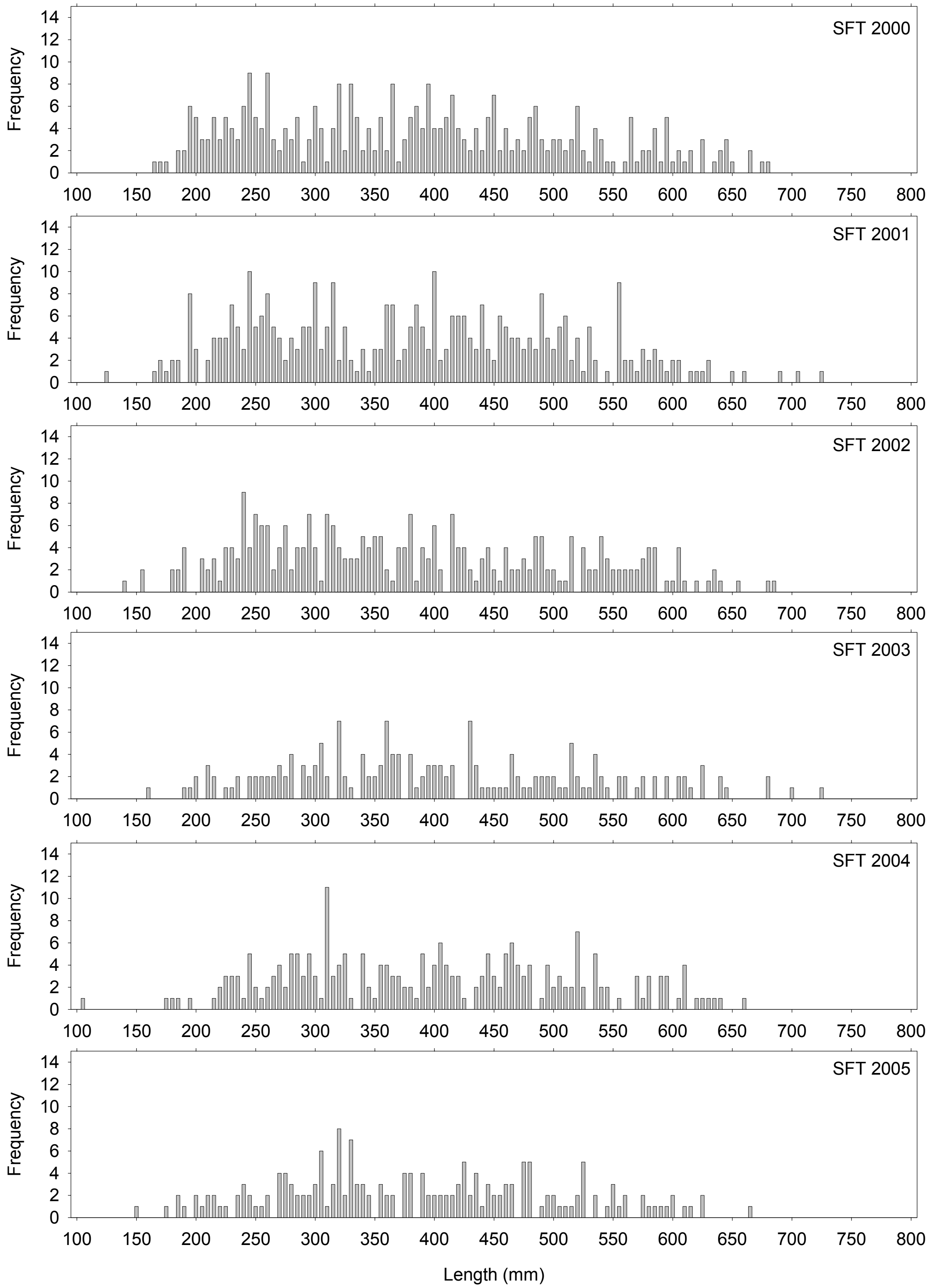

Figure 5. Length-frequency of American eels captured by backpack electrofishing in South Fork Tye River (SFT) 2000-2005. Eels less than 250 mm are sexually undifferentiated and eels greater than 400 mm are rarely males (Smogor et al. 1995). Decreased numbers 2002 - 2005 reflect decreased effort (single vs. multiple pass).

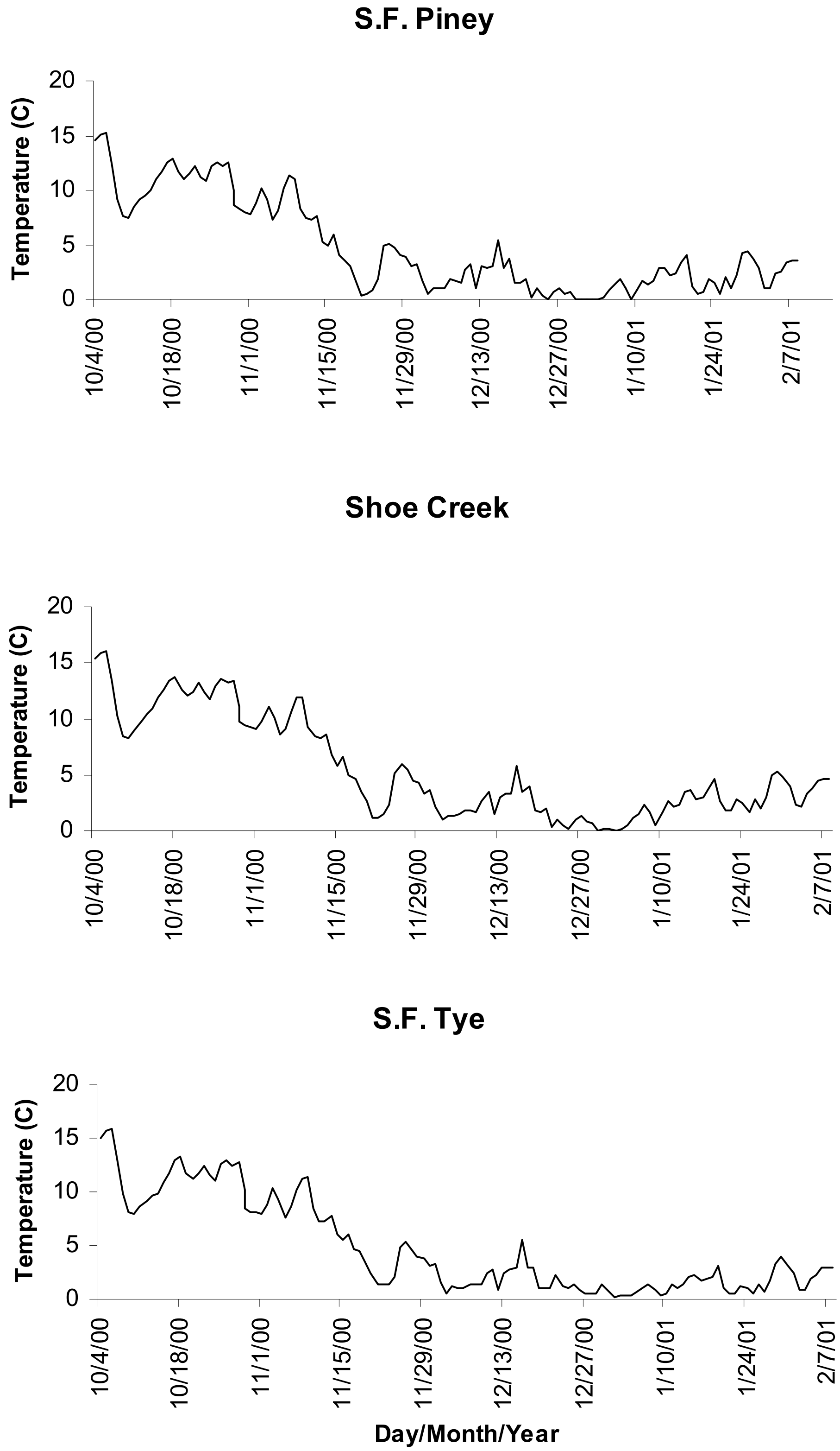

Figure 6. Average daily water temperatures recorded in South Fork Piney River, Shoe Creek and South Fork Tye River between October 2000 and February 2001.