Movement and Growth of Wild Brown Trout in the Chattahoochee River below Lake Lanier, Georgia

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Abstract: The Georgia Wildlife Resources Division (WRD) conducted a tagging study from April 2011 to May 2012 to study growth of wild brown trout (*Salmo trutta*) in the Lake Lanier Tailwater section of the Chattahoochee River. Sampling occurred monthly at four sites and fish were tagged with VI-Alpha tags on nine occasions between April 2011 and March 2012 for subsequent recapture. Follow-up samples in June and December 2012 confirmed a lack of movement between sites by any tagged brown trout that was seen in the previous samples. Growth increments between tagging and recapture events were calculated and used to estimate average length at age. More than 80% of brown trout collected measured between 17.5 and 27.5 cm TL. Brown trout appeared to initially grow rapidly, likely reaching quality size (23 cm total length [TL]) within two years. Growth rapidly slowed, however, as fish approached 30 cm. A few individuals exhibited faster growth rates and attained larger sizes, which was most likely due to transition to piscivory. Accordingly, the general strong decline observed in growth rate among larger fish is potentially a result of limited forage in a relatively unproductive river.

Key words: Salmo trutta, tagging, tailwater

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The Lanier Tailwater section of the Chattahoochee River in northern Georgia has supported coldwater salmonid fisheries since 1960 (Hess 1980). The tailwater was originally managed exclusively as a put-and-take fishery for brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), and brook trout (*Salvelinus fontinalis*) (Martin 1985). In 2005, the Georgia Department of Natural Resources (GADNR) ceased stocking brown trout and subsequently determined that stocking brown trout was unnecessary to sustain the fishery based on evidence of natural reproduction (Long and Martin 2008, O'Rouke and Martin 2011). Rainbow trout are still stocked in the Lanier Tailwater section for put-and-take purposes, but not brook trout.

Tailwater trout fisheries often provide a high-profile fishery resource for state agencies, particularly from an economic impact standpoint, and the Lanier Tailwater was recently named one of the "50 Best Tailwaters to Fly Fish" (Gunn and Gunn 2013). Located in the Metropolitan Atlanta suburbs, this section of the Chattahoochee River is located adjacent to three of Georgia's four most populous counties. O'Rouke and Martin (2011) reported more than 100,000 angler trips during a 2007–2008 creel survey (approximately 77,197 annual angler trips estimated in 2007, unpublished data, GADNR). Of the total effort, 99.6% of anglers indicated they were fishing for trout. The upper (5 km) and lower (29 km) ends of the Lanier Tailwater are managed under Georgia's statewide trout regulations, but anglers may only use artificial lures in the 25 km middle section. Anglers may keep up to eight trout per day of any size under both of these regulations. While O'Rouke and Martin (2011) did not report sizes of brown trout in the creel survey, the majority of the brown trout caught by anglers is usually less than 275 mm total length (TL) (GADNR, unpublished data). However, larger fish do inhabit the system. In July 2014, a new state record brown trout weighing 9.5 kg was caught from the Lanier Tailwater, besting the previous record of 8.3 kg, also from the Lanier Tailwater. Obviously, such catches perpetuate angler interest in the "trophy" component of this fishery.

Additional data are necessary to describe brown trout population dynamics factors such as movement and annual/seasonal growth. Stable annual water temperatures, common for tailwaters, including the Lanier Tailwater, can make otoliths and other hard parts unreliable for age determination (Quist et al. 2012). As a result, prior efforts to collect age and growth information on this population via otolith analysis proved difficult (C. Martin, personal communication). Anglers often inquire about the potential for new regulations, which require a better understanding of these two factors. Therefore, the objective of this study was to tag individual brown trout for the purpose of measuring growth rates and tracking movement in the Lanier Tailwater.

Methods

Study Area

The Lanier Tailwater section of the Chattahoochee River measures approximately 58 km between Buford Dam and Morgan Falls Dam. Average daily water temperature ranged from 8.5° to 12.9° C

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during this study (O'Rouke 2013) and discharge can range from 17 m^3 sec^{-1} to 340 m^3 sec^{-1} (O'Rouke and Martin 2011) directly below Buford Dam. Downstream of Buford Dam, tributary input can strongly impact temperature and flow, especially during floods (Runge et al. 2008). Alkalinity is relatively low, typically ranging from 20–25 mg L^{-1} $CaCO_3$ (O'Rouke 2013). Substrate is dominated by bedrock and gravel at the upstream end of the Lanier Tailwater and transitions to shifting sand interspersed with rocky shoals downstream. Large woody debris are prevalent along the bank throughout the entire tailwater section.

Monthly Electrofishing

The sampling locations for this study were located near Buford Dam (river km 560), Settles Bridge (river km 552), Abbotts Bridge (river km 538) and Jones Bridge (river km 528) and are long-term GADNR sampling stations (Figure 1). Sampling for adult trout occurred monthly at all four sites from April 2011–May 2012 using a boom-mounted Smith-Root 2.5 GPP electrofishing unit from a 17-foot aluminum tunnel-hull jet boat. Per standard methods set forth in O'Rouke and Martin (2011), sites were sampled using 3–4 amps of current for 20 min pedal time at Buford Dam and 30 min pedal time at Settles Bridge, Abbotts Bridge, and Jones Bridge. Net handlers were instructed to capture all trout regardless of size or species. Fish were then placed in a live well to be processed for data collection and tagging. Following standardized electrofishing, if time and conditions allowed, adjacent areas were often sampled for brown trout to obtain greater sample sizes for tagging and recapture. Standardized/non-standardized status was noted in the data for all captured fish, though only to allow future comparison against the long-term standardized data set, as catch per unit effort was not used in this study. Effort was only limited in this study by sampling conditions (e.g., weather or generation) and available time (i.e., work day length). The overall goal of each trip was to tag as many brown trout within the vicinity of each station as feasible.

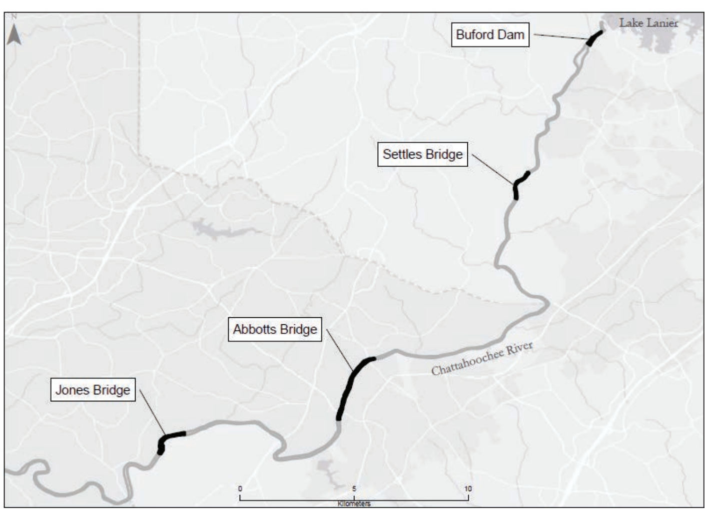

Figure 1. Map of Lanier Tailwater sampling stations. Shaded areas represent sampling reaches where brown trout were collected and tagged from April 2011–May 2012.

Tagging

Brown trout ≥15.0 cm TL were tagged in April, May, June, August, September, November, and December 2011 and February and March 2012 using VI-Alpha tags produced by Northwest Marine Technologies (Shaw Island, Washington). These colored tags contained a three-digit, alpha-numeric code that identified individual fish and tagging location by one of four colors. Fish were not tagged in July and October 2011 and January and April 2012 because of diet analysis (O'Rouke 2013) of captured fish. In all months from April 2011 through May 2012, brown trout were measured (TL, mm), weighed (g), and inspected for a previously-inserted tag. Untagged brown trout were anesthetized with a low-voltage electric charge (Jennings and Looney 1998), and tags were inserted under translucent skin behind one eye using a VI-Alpha injector. Fish were placed in a holding cage in the river adjacent to the boat to recover from handling stress before release. Once all fish had been processed, fish from the holding cage were inspected for any evidence of tagging mortality and released; all but four brown trout, identified as mortalities, were subsequently released.

Following the monthly sampling, an effort was made in June and December 2012 to explore finer-scale movement among original capture sites, which were all separated from each other by 8–14 km. The Chattahoochee River National Recreation Area maintains 1.6-km (i.e., mile) markers along the river that were used to delineate sampling sections. Electrofishing was conducted for 10 min below each marker beginning right below Buford Dam to 35.4 km downstream, immediately upstream of Holcomb Bridge Road. All brown trout collected were counted and inspected for tags.

Growth Analysis

For analysis, lengths of brown trout were rounded to the nearest cm to minimize small measurement errors, as many of these data were collected by volunteers. Monthly growth rate (GR) of individual fish was estimated from:

$$GR = \frac{\left(\frac{lf-lt}{d}\right)365}{12},$$

where l_f was the length at final recapture, l_t was the length at initial tagging, and d was the number of days between these two events.

Brown trout growth among sites was examined using ANOVA followed up with a Tukey's HSD Test in Microsoft Excel to identify differences among sites. Growth of brown trout that had been tagged and recaptured within a specific season (Winter: December–

February; Spring: March–May; Summer: June–August; Fall, September–November) was examined using similar methods. Finally, an ANOVA was used to determine whether growth rates differed significantly by size using 2-cm length groups (classified by length at initial tagging). A significance level of $P < 0.05$ was used for all statistical tests.

Results

A total of 3147 individual fish (4287 captures) was examined between April 2011 and May 2012, with 2386 of these fish receiving tags. Tagged brown trout were recaptured a total of 836 times (563 individual fish), with individual recaptures ranging between 1–6 times. The size of brown trout captured during this study ranged from 8.8 to 69.2 cm TL. Half (50.0%) of the fish captured were between 20.0 and 25.0 cm TL, while 80.1% were between 17.5 and 27.5 cm TL. More than 90% of brown trout collected measured <29 cm across all seasons (Figure 2).

Movement

Recaptures of tagged brown trout ranged from 126–272 across sites, comprising 84–182 individual fish among sites, over the 14 months of the study (Table 1). All fish were recaptured within their original tagging location and were never recaptured in another site. All tagged fish recaptured during intensive sampling in June and December 2012 were likewise found in their original tagging location. No tagged fish were recaptured in areas outside the original four tagging sites. In June 2012, 18 of 82 brown trout examined within the four tagging sites had tags, while zero of 215 in other locations had tags. By the end of the study (December 2012), tagged fish were recaptured in three of four tagging locations (excluding Abbotts Bridge), approximately nine months after the final tagging event, accounting for five of the 100 fish examined in the four sites. No tagged fish were found among the non-tagging locations (221 fish observed).

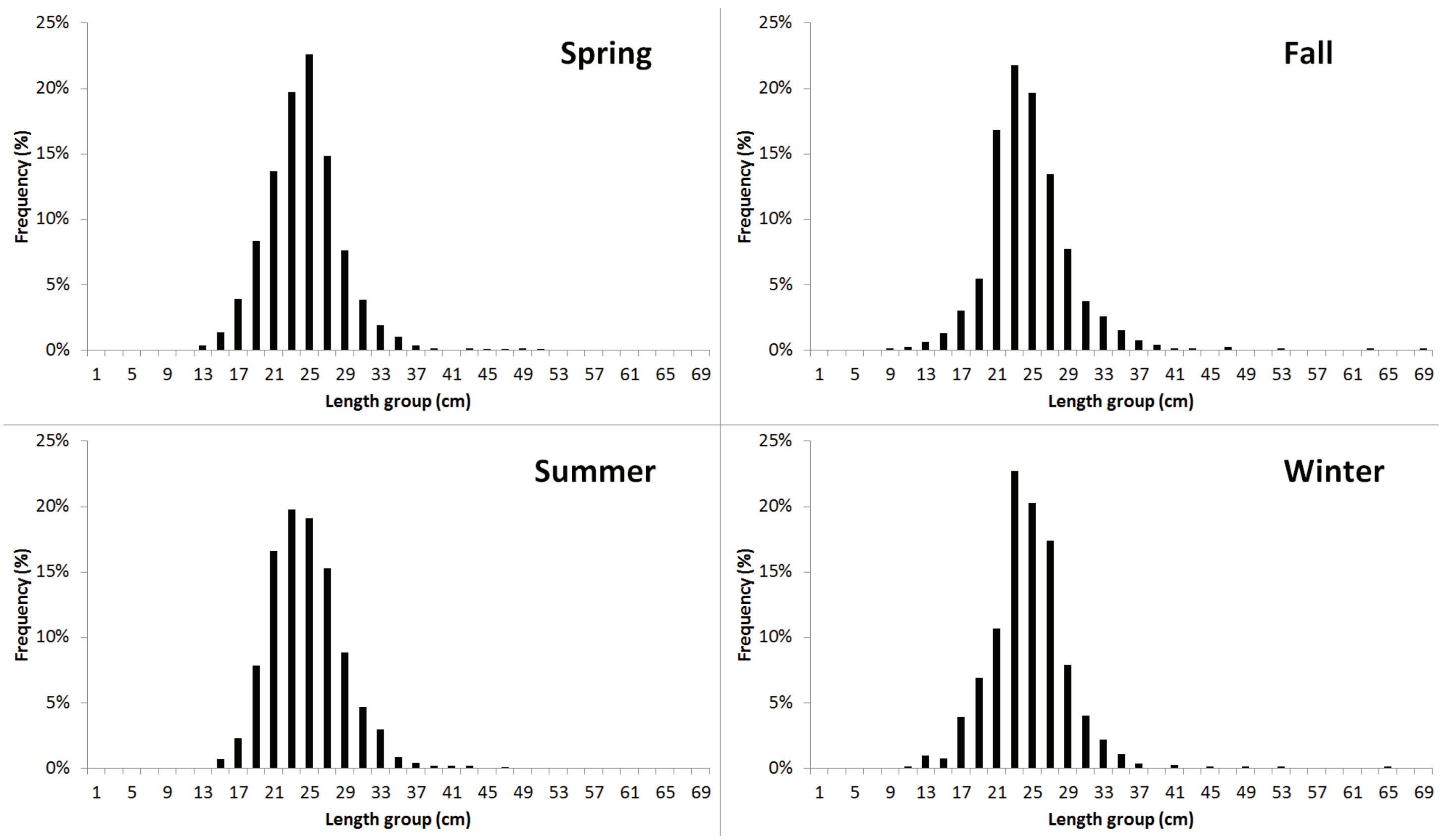

Figure 2. Length-frequency of all brown trout caught by electrofishing from in Spring (April–May 2011 and March–May 2012, $n = 1491$), Summer (June–August 2011, $n = 1042$), Fall (September–November 2011, $n = 931$), and Winter (December 2011 and January–February 2012, $n = 823$) in the Lanier Tailwater, organized by 2-cm length groups.

Table 1. Number of brown trout with tags at-large (AL) and recaptured (RC) in each month at four sites on the Lanier Tailwater of the Chattahoochee River from April 2011–May 2012.

	Buford Dam		Settles Bridge		Abbotts Bridge		Jones Bridge	
Month	**AL**	**RC**	**AL**	**RC**	**AL**	**RC**	**AL**	**RC**
Apr	0	0	0	0	0	0	0	0
May	132	6	125	10	124	4	108	17
Jun	300	19	276	26	186	13	149	14
Jul	400	19	367	14	227	10	222	30
Aug	400	21	367	18	227	7	222	14
Sep	497	20	439	16	277	6	274	18
Oct	584	22	513	43	302	28	295	19
Nov	584	22	513	26	302	10	295	8
Dec	674	20	584	18	330	5	321	17
Jan	716	24	639	34	344	6	360	14
Feb	716	18	639	19	344	17	360	20
Mar	781	6	726	16	371	8	416	12
Apr	804	9	753	19	392	5	437	10
May	804	15	753	13	392	7	437	24

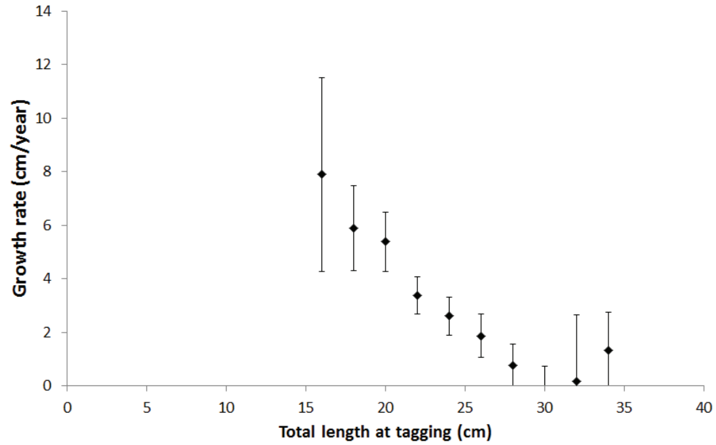

Figure 3. Growth rate of average brown trout in the Lanier Tailwater per 2-cm length group (at time of tagging). Error bars represent 95% upper and lower confidence intervals for each length group.

Growth

Growth of brown trout was generally similar among sites (Table 2), excepting Jones Bridge, where growth was higher than at Settles Bridge and Abbotts Bridge ($F = 5.93$, df = 3, 559, $P < 0.01$). Mean growth rate by season (Table 3) was highest in spring and lowest in fall, with winter and summer growth intermediate and similar to the other seasons ($F = 3.41$, df = 3, 252, $P = 0.02$). Brown trout showed declining growth rates based on length at initial tagging until approximately 30 cm, at which point the growth rate appeared to slightly increase (Figure 3).

Table 2. Mean growth rate (cm mo^{-1}) and standard error of brown trout at four sites on the Lanier Tailwater of the Chattahoochee River from April 2011–May 2012. Means followed by the same letter were similar (Tukey HSD Test, $P > 0.05$).

Site	***n***	***Mean***	***SE***
Buford Dam	157	0.22ab	0.03
Settles Bridge	182	0.17b	0.03
Abbotts Bridge	84	0.11b	0.04
Jones Bridge	140	0.32a	0.03

Table 3. Mean growth rate (cm mo^{-1}) and standard error of brown trout during Winter (December–February), Spring (March–May), Summer (June–August) and Fall (September–November) on the Lanier Tailwater of the Chattahoochee River from April 2011–May 2012. Means followed by the same letter were similar (Tukey HSD Test, $P > 0.05$).

Season	***n***	***Mean***	***SE***
Winter	29	0.28ab	0.08
Spring	113	0.31a	0.04
Summer	60	0.21ab	0.06
Fall	54	0.09b	0.06

Discussion

Movement of brown trout within the Lanier Tailwater was not observed during this study. Tagged fish were never found outside of the study areas during monthly samples, nor in the two subsequent, more comprehensive samples. Some studies have also shown extremely small home ranges for brown trout (Bachman 1984, Young 1994, Burrell et al. 2000), but greater movement for brown trout during the fall spawning season has also been reported (Bettinger and Bettoli 2004, Bunnell et al. 1998, Burrell et al. 2000). No evidence of a spawning migration was observed for brown trout in the Lanier Tailwater. November and December are peak spawning months for these fish, and numerous ripe male and female brown trout were observed throughout the study area during these months in this study. The lack of movement suggests that spawning may occur throughout the Lanier Tailwater and long-range spawning runs are not necessary. However, Quinn and Kwak (2011) found that brown trout movement was positively correlated with size, while Bunnell et al. (1998) observed greater movement in brown trout >375 mm TL, and it is possible that this study did not observe long-range migrations simply due to small sample sizes of larger fish. Only five fish over 375 mm TL were tagged in this study, and only two of these were subsequently recaptured. Additionally, more mobile individual fish can be difficult to detect in these types of studies, biasing estimates of overall movement (Gowan and Fausch 1996). Regardless, the general lack of movement observed in this study may provide managers with the opportunity for finer-scale (i.e., shorter stream lengths for special regulation zones than are currently used) zoning of the fishery should management goals require this approach.

Brown trout in the Lanier Tailwater grew quickly at smaller sizes, but growth slowed sharply as most fish approached approximately 25 cm TL. Although growth appears to essentially cease in most fish prior to 30 cm TL, occasional larger fish were observed during this study. The presence of fish up to nearly 70 cm TL in this study indicated that individual fish may have quite different growth trajectories (e.g., Bacon et al. 2005).

Diets of brown trout in the Lanier Tailwater was composed mostly of small midges (Diptera), with larger aquatic macroinvertebrates, such as caddisflies, stoneflies, and mayflies, only infrequently consumed (O'Rouke 2013). Availability of intermediate- and large-sized prey items can be growth-limiting for individual fishes (Hayward and Margraf 1987), which could delay an ontogenetic diet shift to piscivory. This shift may be critical for a brown trout to achieve faster growth and larger sizes in the Lanier Tailwater. In support of this, growth of brown trout was highest in the spring and lowest in the fall, corresponding to considerably fewer large macroinvertebrates in brown trout diets in fall compared to spring reported by O'Rouke (2013). Relatively few brown trout (<1.7%) had fish in their stomachs, but most trout showing evidence of piscivory measured greater than 25 cm TL. While only 7.9% of brown trout <25 cm TL had empty stomachs, 31.3% of brown trout >30 cm TL had empty stomachs (O'Rouke 2013), further indicating higher rates of piscivory, as piscivorous fish are more likely to have empty stomachs (Arrington et al. 2002). Johnson et al. (2006) reported that fish made up 20% of the diets of brown trout between 25–35 cm TL in an Arkansas tailwater; whereas, fish comprised more than 90% of the diets of trout >40 cm TL.

The information obtained from this study will be vital for future management of the Lanier Tailwater. The rapid growth rate of smaller brown trout likely provides a large capacity for angler harvest while maintaining high proportions of quality size category (23 cm TL, Neumann et al. [2012]) fish in the system. Given the 3% harvest rate for brown trout reported by O'Rouke and Martin (2011), growth overfishing for stock size fish is not likely a concern in this fishery; this may be a case of natural recruitment exceeding the ecosystem's capacity to support better growth rates. However, the relative small proportion of fish that appear to exceed average growth for the population may limit the potential for common brown trout catches of preferred size or greater (Neumann et al. 2012). Trophy fish are occasionally caught by anglers in this fishery, but due to diet and growth limitations, there may only be a small subset that are capable of transitioning to piscivory and reaching trophy sizes. Forage availability may be the main factor influencing growth rates, therefore any management plan aimed at increasing the trophy component of the fishery will need to address this concern. Future work should focus on the potential to increase the proportion of brown trout in the fishery that make a successful transition to piscivory. Factors governing this transition are unknown, but could be due to limited habitat or forage, or genetics of individual fish. Rainbow trout stocking likely already provides a foraging opportunity for trophy-sized brown trout, and an adjustment in size at stocking below the current minimum of 230 mm TL could provide an opportunity to transition additional brown trout to piscivory. Potential forage species (e.g. sculpins *Cottoidea*) appear sparsely populated in this river section (personal observation) and do not likely contribute significantly to the diets of most brown trout. If brown trout genetics are not a factor, regulations that encourage harvest of smaller fish while protecting larger fish more likely to transition to piscivory could potentially increase the quality of this fishery.

Acknowledgments

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Literature Cited

Arrington, D. A., K. O. Winemiller, W. F. Loftus, and S. Akin. 2002. How often do fishes "run on empty"? Ecology 83:2145–2151.

Bachman, R. A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society 113:1–32.

Bacon, P. J., W. S. C. Gurney, W. Jones, I. S. McLaren, and A. F. Youngson. 2005. Seasonal growth patterns of wild juvenile fish: partitioning variation among explanatory variables, based on individual growth trajectories of Atlantic salmon (*Salmo salar*) parr. Journal of Animal Ecology 74:1–11.

Bettinger, J. M. and P. W. Bettoli. 2004. Seasonal movement of brown trout in the Clinch River, Tennessee. North American Journal of Fisheries Management 24:1480–1485.

Bunnell, D.B., J.J. Isely, K.H. Burrell, and D.H. Van Lear. 1998. Diel movement of brown trout in a southern Appalachian river. Transactions of the American Fisheries Society 127:630–636.

Burrell, K.H., J.J. Isely, D.B. Bunnell, Jr., D.H. Van Lear, and C.A. Dolloff. 2000. Seasonal movement of brown trout in a southern Appalachian river. Transactions of the American Fisheries Society 129:1373–1379.

Gowan, C. and K.D. Fausch. 1996. Mobile brook trout in two high-elevation Colorado streams: re-evaluating the concept of restricted movement. Canadian Journal of Fisheries and Aquatic Sciences 53(6):1370–1381.

Gunn, T. and W. Gunn. 2013. 50 Best Tailwaters to Fly Fish. Stonefly Press, Bloomington, Indiana. Pages 148–151.

Hayward, R.S. and F.J. Margraf. 1987. Eutrophication effects on prey size and food availability to yellow perch in Lake Erie. Transactions of the American Fisheries Society 116:210–223.

Hess, T.B. 1980. An evaluation of the fishery resources of the Chattahoochee River below Buford Dam. Georgia Department of Natural Resources, Federal Aid in Sportfish Restoration Project F-26-7.

Jennings, C.A. and G.L. Looney. 1998. Evaluation of two types of anesthesia for performing surgery on striped bass. North American Journal of Fisheries Management 18:187–190

Johnson, R.L., S.C. Blumenshine, and S.M. Coghlan. 2006. A bioenergetics analysis of factors limiting brown trout growth in an Ozark tailwater river. Environmental Biology of Fishes 77:121–132.

Long, J.M. and C.R. Martin. 2008. Fisheries management in the Upper Chattahoochee River basin in response to water demands. Pages 21–35 *in* M.S. Allen, S. Sammons, and M.J. Maceina, editors. Balancing Fisheries Management and Water Uses for Impounded River Systems. American Fisheries Society, Bethesda, Maryland.

Martin, C.R. 1985. Hatchery and field performance of six trout strains stocked as catchables in the Chattahoochee River, Georgia. Georgia Department of Natural Resources, Game and Fish Division. Final Report. Federal Aid Project F-26.

Neumann, R.L., C.S. Guy, and D.W. Willis. 2012. Length, weight, and associated indices. Pages 637–676 *in* A.V. Zale, D.L. Parrish, and T.M. Sutton, editors. Fisheries Techniques, Third Edition. American Fisheries Society, Bethesda, Maryland.

O'Rouke, P.M. 2013. Diet composition of wild brown trout and stocked rainbow trout in a coldwater Tailwater fishery in North Georgia. Journal of the Southeastern Association of Fish and Wildlife Agencies 1:83–88.

——— and C.R. Martin. 2011. Fishery viability of a wild brown trout population in the Chattahoochee River near Atlanta, Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 65:131–135.

Quinn, J.W. and T.J. Kwak. 2011. Movement and survival of brown trout and rainbow trout in an Ozark tailwater river. North American Journal of Fisheries Management. 31:299–304.

Quist, M.C., M.A. Pegg, and D.R. Devries. 2012. Age and Growth. Pages 677–731 *in* A.V. Zale, D.L. Parrish, and T.M. Sutton, editors. Fisheries Techniques, Third Edition. American Fisheries Society, Bethesda, Maryland.

Runge, J.P., J.T. Peterson, and C.R. Martin. 2008. Survival and dispersal of hatchery-raised rainbow trout in a river basin undergoing urbanization. North American Journal of Fisheries Management 28:745–757.

Young, M.K. 1994. Mobility of brown trout in south-central Wyoming streams. Canadian Journal of Zoology 72:2078–2083.