Diet Composition of Wild Brown Trout and Stocked Rainbow Trout in a Coldwater Tailwater Fishery in North Georgia

Patrick M. O'Rouke, *Georgia Department of Natural Resources, 2150 Dawsonville Highway, Gainesville, GA 30501*

Abstract: The Lanier Tailwater section of the Chattahoochee River, Georgia, below Buford Dam has populations of wild brown trout (*Salmo trutta)* and stocked rainbow trout (*Oncorhynchus mykiss)*. To better understand the ability of wild brown trout to recruit to the fishery, stomach contents of brown trout and rainbow trout were examined in summer and fall 2011 and winter and spring 2012 at four locations along the river. Midges (Diptera) were the most common category observed in the diets of both species throughout the study. Other common items included caddisflies (Trichoptera), stoneflies (Plecoptera), ants/termites (Formicidae/Termitoidae), worms (Annelida), and scuds (Isopoda). While rainbow trout were more likely than brown trout to have empty stomachs, their diets were otherwise similar. Midges were consumed more often by brown trout and rainbow trout than any other diet category at all sites and in all seasons. Some categories were less prevalent at the most upstream site. Stoneflies were most common and caddisflies were least common in diets of both species in winter compared to the other seasons. Terrestrial insects were most commonly consumed in summer. Although diet composition of brown trout showed little ontogenetic shifts, size of brown trout appeared to have an influence on feeding habits as larger fish were more likely to have empty stomachs. There may have been a greater occurrence of piscivory, particularly in larger brown trout, than the results of this study indicated.

Key words: electrofishing, midge, piscivory, interspecific competition

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Coldwater trout fisheries exist across the southeastern United States as a result of hypolimnetic releases from large hydropower project reservoirs. While reservoir hypolimnetic reserves provide the cold water needed to sustain trout year-round, the effects of hydropeaking operations can reduce a river's productivity (Cushman 1985), species richness, and abundance of macroinvertebrates and fish (Garcia de Jalon et al. 1994). Therefore, many tailwaters do not provide the food base for trout that comparable large rivers might, and this can have an effect on growth and trophy potential of trout species.

The Chattahoochee River has approximately 77 km of coldwater habitat in the Georgia counties of Gwinnett, Forsyth, Fulton, Dekalb, and Cobb, created when Buford Dam was completed in 1957 (U.S. Army Corps of Engineers 1973). The 58-km reach beginning below Buford Dam downstream to Morgan Falls Dam is known as the Lanier Tailwater, and provides suitable water temperatures for salmonid populations. This section has been stocked with multiple trout species by the Georgia Department of Natural Resources (GADNR) since 1960 (Hess 1980) and was originally managed primarily as a put-and-take fishery (Martin 1985). Following the discovery of brown trout (*Salmo trutta*) natural reproduction in the 1990s, the GADNR experimentally ceased stocking brown trout in this section in 2005 (Long and Martin 2008). O'Rouke and Martin (2011) determined that natural reproduction was capable of sustaining the brown trout population, therefore, the agency has maintained the brown trout stocking moratorium since that time. There is likely minimal natural reproduction of rainbow trout (*Oncorhynchus mykiss*) also occurring (Long et al. 2007, Long et al. 2008), but the GADNR stocks approximately 170,000 catchable (i.e., 230 mm TL or greater, J. Thompson, GADNR, personal communication) rainbow trout annually to maintain acceptable angler catch rates (O'Rouke and Martin 2012). Stocking occurs from mid-March through December, with the heaviest densities being stocked from mid-March through August. Fishing effort is considerable, as there are more than 75,000 angler-trips per year on the Lanier Tailwater (GADNR, unpublished data).

The discovery of this wild brown trout population created data needs for managers, as it created an opportunity to shift the management philosophy from exclusively put-and-take management to co-managing with wild fish. Type and size of prey are important factors influencing trout growth (Bowen et al. 1995), and wild brown trout must consume adequate food to reach a size comparable to hatchery trout. Additionally, stocked trout can potentially impact growth (Bohlin et al. 2002), biomass (Vincent 1987), and survival of existing wild salmonids (Einum and Fleming 2001). Thus, the objectives of this study were to (1) determine the diet items consumed by rainbow trout and brown trout, (2) describe variation in trout diets by river location and season, and (3) describe ontogenetic differences in brown trout diets. Overall, a better understanding of the food these fish consume may help direct complementary research on other factors affecting population dynamics for this brown trout population such as growth or seasonal movement.

Methods

Study Area

Sampling sites were located exclusively within the Lanier Tailwater section of the Chattahoochee River. Water temperatures of Buford Dam releases between 1 May 2011 and 30 April 2012 ranged from 8.0 to 17.6 C, though mean daily temperature of these releases only ranged from 8.5 to 12.9 C; higher temperatures typically only occur during peak power generation. Discharge from Buford Dam typically ranges from $17 m^3 sec^{-1}$ to $340 m^3 sec^{-1}$ depending on power generation (O'Rouke and Martin 2012); however, tributary input influences both flow and temperature downstream of Buford Dam (Runge et al. 2008). Alkalinity in the river below Buford Dam is approximately 20–25 mg L^{-1} $CaCO_3$ (GADNR, unpublished data), and substrate is characterized by a mix of bedrock, loose gravel, and shifting sand. Large woody debris can be found along riverbanks throughout this section, though the scouring effects of hydropeaking flows prevent much from accumulating in the channel.

Fish Collection and Data Analysis

Adult trout were collected using a boom-mounted Smith-Root 2.5 GPP electrofishing unit on a 5.2-m aluminum tunnel-hull jet boat. Four standardized locations were sampled, including (upstream to downstream): Buford Dam (river km 560), Settles Bridge (river km 552), Abbotts Bridge (river km 538), and Jones Bridge (river km 528). Each site was sampled once in July 2011, October 2011, January 2012, and April 2012, representing summer, fall, winter, and spring seasons, respectively. Electrofishing samples first ran for a specified time (20 minutes pedal time at Buford Dam, 30 minutes pedal time at all other sites) and in a specific location per standardized sampling protocol described in O'Rouke and Martin (2012). Following this standardized portion, additional electrofishing was then employed in adjacent areas to supplement sample sizes. Sampling concluded when: a) time was limiting or increased flows prohibited more sampling, b) a representative sample of vulnerable size classes of brown trout and rainbow trout was obtained, or c) all known habitat within the sampling site had been electrofished exhaustively. All brown trout and rainbow trout were measured (mm, TL) and weighed (g). Fulton's Condition Factor ($K_n = 10^5 * (W/L^3)$) was used to calculate condition of each fish. Fish stomachs were flushed (Bowen 1996) using a 500-mL plastic squirt bottle with a 90° elbow nipple filled with water until five samples of each species were collected within each 20-mm length group (to provide samples from all vulnerable size classes) per site. If more than five fish were collected in a given length group, subsequent fish were released after being measured and weighed. Stomach contents were identified in the field into broad, easily-identifiable categories (Table 1). Presence of each category was recorded for individual fish. The amount (in terms of number or weight) of each category present was not quantified due to time and labor constraints, therefore these data only described fish diets as frequency of occurrence as described in Bowen (1996). Percent resource overlap index (PROI) (Schoener 1970) was used to determine the significance of diet overlap between brown trout and rainbow trout and between different sizes of brown trout. The value for PROI falls between 0 and 100, and values >60 can be considered significant (Zaret et al. 1971, Soupir et al. 2000, Shepherd and Maceina 2009, Sammons 2012). One-way ANOVA was used to test for differences in length and condition of brown trout between sites and seasons, and Tukey's HSD was used to test for post-hoc differences between groups (P=0.05). These tests were not performed for rainbow trout condition because the majority of these fish were assumed to be stocked and therefore would have reached catchable size before entering the river. Additionally, time at large since stocking could have influenced the condition of rainbow trout as individual fish transitioned to a natural diet.

Table 1. Categories of common diet items collected in the Lanier Tailwater section of the Chattahoochee River, Georgia, in 2011 and 2012. Diet items were grouped based on distinguishable morphometric characteristics, and, where possible, taxonomic relationship.

Items (order, family, genus, species)	Category
Diptera	Midges
Trichoptera	Caddis
Plecoptera	Stoneflies
Hymenoptera (Formicidae, (Epifamily) Termitoidae)	Ants/termites
(Phylum) Annaelida	Worms
Isopoda	Scuds
Ephemeroptera	Mayflies
Orthoptera, Hymenoptera (Vespidae, (superfamily) Apoidea)	Terrestrial invertebrates
(Class) Gastropoda	Snails
Diptera (Culicidae)	Mosquitoes
Hemiptera	True bugs
Anura	Frogs
Decapoda ((superfamily) Astocoidea)	Crayfish
Salmo trutta, Oncorhynchus mykiss, (Superfamily) Cottoidea, unidentified fish	Fish
Unidentified origin	Fish eggs

Results

A total of 1,069 brown trout and 429 rainbow trout were collected during electrofishing. Of these, 605 brown trout and 322 rainbow trout stomachs were lavaged over the course of this study (Table 2). Brown trout ranged from 88 to 462 mm and rainbow trout ranged from 138 to 410 mm.

Table 2. Sample size and percent empty stomachs found in brown and rainbow trout collected for diet analysis in the Lanier Tailwater section of the Chattahoochee River, Georgia, in 2011 and 2012. The four sites represented are Buford Dam (BD), Settles Bridge (SB), Abbotts Bridge (AB), and Jones Bridge (JB).

	July 2011		October 2011		January 2012		April 2012	
Location	*n*	% empty	*n*	% empty	*n*	% empty	*n*	% empty
				Brown trout				
BD	49	10.2	51	25.5	54	0.0	29	0.0
SB	30	16.7	36	50.0	40	10.0	30	0.0
AB	42	7.1	32	31.3	41	17.1	26	3.8
JB	42	7.1	28	7.1	50	2.0	25	8.0
Total	163	9.8	147	29.3	185	6.5	110	2.7
				Rainbow trout				
BD	24	83.3	15	73.3	20	0.0	31	12.9
SB	8	37.5	12	75.0	6	0.0	8	12.5
AB	41	39.0	27	66.7	19	10.5	24	12.5
JB	39	15.4	22	27.3	14	0.0	12	25.0
Total	112	40.2	76	57.9	59	3.4	75	14.7

Midges (Diptera) were the most commonly-encountered diet category across all sites and seasons for both species, present in 68.6% of all brown trout and in 54.3% of all rainbow trout sampled; of these, 76.9% of fish containing midges had only subadults (i.e., larval or pupal form), 10.0% of fish had only adult midges, and 13.1% had a combination of both. Other common prey categories encountered were caddisflies Trichoptera; (63.5% subadults, 5.4% adults, 18.2% both), stoneflies (Plecoptera; 100% subadults), ants and termites (Formicidae and Termitoidae), worms (Annelida), and scuds (Isopoda) (Table 3). Less-common diet items (combined presence in 10.6% of brown trout and 6.2% of rainbow trout) encountered are listed in Table 1. Fish species (present in 1.7% of brown trout and 0.0% of rainbow trout) found included brown trout, rainbow trout, sculpins (Cottoidea), and other unidentified, partially-digested fish.

Brown trout stomachs were empty in 12.2% of samples. Rainbow trout stomachs were empty in 31.7% of samples. An especially high percentage of rainbow trout had empty stomachs in summer and fall but empty stomachs were very rare for rainbow trout in winter (Table 2). There was a clear trend of increasing empty stomachs as brown trout size increased (Table 4). Correspondingly, 80% of brown trout that had consumed other fish were >250 mm TL.

Rainbow trout consistently exhibited a lower percent occurrence for most diet categories. However, PROI values between brown trout and rainbow trout indicated that diet overlap was nearly identical in all four seasons (Table 3). Stoneflies were far more common diet items in winter, occurring in approximately half of the stomachs, compared to other seasons (Table 3). Caddisflies were rarely consumed in winter. Ants and termites were consumed most commonly in summer. While midges were the most common diet category in all seasons, they were encountered most often in winter and spring. Trout stomachs were more likely to contain items included in the "other" (largely terrestrial insects, mayflies, and fish eggs) category in summer and spring than in fall and winter. Sample sizes for brown trout remained high throughout the year, but fewer rainbow trout were collected in the winter ($n = 64$) than in the summer ($n = 188$).

Over all seasons, diets of brown trout differed little among size classes, with PROI values approaching 100 in all length group comparisons (Table 4). Likewise, there were very few apparent differences in diet occurrence among sites. Caddisflies, stoneflies, and scuds were less-common diet items at Buford Dam than at other sites. Scuds were most common at Jones Bridge.

The mean length of all brown trout collected was 238.5 mm TL (SD = 43.0) and mean condition (K_n) was 0.87 (SD = 0.11). The mean length of rainbow trout was 264.1 mm TL (SD = 34.1) and mean condition was 0.86 (SD = 0.11). Table 5 summarizes these values for brown trout among site and season. Mean length of brown trout was greater at Buford Dam than at Settles Bridge; mean lengths at the other two sites were similar to both sites

Table 3. Frequency of occurrence (%) by season of selected categories of diet items (described in Table 1) in brown trout (BNT) and rainbow trout (RBT) and percent resource overlap index (PROI) between the two species for each season. Fish were collected in the Lanier Tailwater Section of the Chattahoochee River, Georgia, in 2011 and 2012.

	July 2011		October 2011		January 2012		April 2012	
Diet category	BNT	RBT	BNT	RBT	BNT	RBT	BNT	RBT
Midges	52.1	41.1	57.1	35.5	82.7	79.7	84.5	73.3
Caddis	27.0	8.0	11.6	9.2	3.8	5.1	40.0	22.7
Stoneflies	6.0	18.0	0.7	0.0	45.9	55.9	10.9	2.7
Ants/Termites	27.6	22.3	2.7	1.3	0.5	0.0	8.2	5.3
Worms	14.7	10.7	10.9	2.6	4.3	3.4	6.4	1.3
Scuds	4.9	4.5	2.7	1.3	10.3	6.8	13.6	1.3
Other	16.0	8.0	3.4	0.0	4.9	1.7	21.8	13.3
PROI	99.8		99.8		99.5		99.7	

Table 4. Frequency of occurrence (%) of empty stomachs and for common brown trout diet categories in three ontogenetic groups and percent resource overlap index (PROI) among groups. Fish were collected in the Lanier Tailwater section of the Chattahoochee River, Georgia, in 2011 and 2012.

	<200 mm TL		200–299 mm TL		300+ mm TL	
Diet category	***n***	**% occurrence**	***n***	**% occurrence**	***n***	**% occurrence**
Empty	7	3.3	41	10.3	26	31.3
Midges	99	46.3	275	68.8	41	49.4
Caddis	26	12.1	76	19.0	10	12.0
Stoneflies	22	10.3	74	18.5	3	3.6
Ants/Termites	8	3.7	47	11.8	4	4.8
Worms	10	4.7	42	10.5	3	3.6
Scuds	12	5.6	29	7.3	5	6.0
Other	10	4.7	50	12.5	11	13.3
PROI: <200:200–299				99.7		
PROI: <200:300+				99.9		
PROI: 200–299:300+				99.7		

Table 5. Mean length and condition (with associated standard deviations) of brown trout by site and season in the Chattahoochee River, Georgia, in 2011 and 2012. Superscripts indicate significant statistical differences ($P < 0.05$) between groups.

Site/Season	Mean total length (mm)	SD TL	Mean condition (K_n)	SD K_n
Buford Dam	241.4^{a}	46.5	0.91^{a}	0.12
Settles Bridge	232.5^{b}	38.2	0.84^{c}	0.09
Abbotts Bridge	239.3^{ab}	47.3	0.85^{bc}	0.09
Jones Bridge	241.1^{ab}	40.1	0.87^{b}	0.09
Summer	240.9^{a}	42.9	0.84^{c}	0.08
Fall	237.3^{a}	44.0	0.86^{c}	0.08
Winter	236.7^{a}	46.0	0.88^{b}	0.12
Spring	237.9^{a}	37.0	0.93^{a}	0.12

($F = 3.02$, df = 3, 1065, $P = 0.03$). Brown trout condition was highest at Buford Dam, next highest at Jones Bridge, and lowest at Settles Bridge ($F = 33.93$, df = 3, 1056, $P < 0.01$). Mean lengths of brown trout were similar among seasons ($F = 0.53$, df = 3, 1056, $P = 0.66$), but condition was highest in the spring and lowest in summer and fall ($F = 34.62$, df = 3, 1056, $P < 0.01$).

Discussion

Invertebrate samples were collected using Hester-Dendy sampling plates by the Chattahoochee Coldwater Fishery Foundation (CCWFF) from 2000–2011 in the vicinity of all my electrofishing sites except for Abbotts Bridge (CCWFF, unpublished data). These data showed that midge larvae dominated the invertebrate community in the river. Midge species (virtually all *Simulium* spp.) comprised 70.0% of the invertebrates collected by number, though this varied among sites (96.3% at Bowman's Island, 64.7% at Settles Bridge, and 20.2% at Jones Bridge) and seasons (79.6% in winter, 77.6% in spring, 51.6% in summer, and 49.1% in fall). The high midge density reported by the CCWFF study generally matched their frequency of occurrence in the diets of both trout species in my study. Midges were the most commonly-found item by site and season. Similarly, Johnson et al. (2006) found a high abundance of a single order of macroinvertebrates (Isopoda) in brown trout diets from an Arkansas tailwater.

One limiting factor of these data is that I did not attempt to quantify the number or weight of individual prey items, only percent occurrence in individual trout. This research was initiated as a side project tied to a tagging study exploring growth and movement of brown trout, and the time allotted for sampling and data processing was limited for the diet portion of the research. Typically, previous studies using PROI to measure diet overlap in fishes have used an index of importance that employs total mass of each category (e.g. Soupir et al. 2000, Shepherd and Maceina 2009, Sammons 2012) and assumes that mass is generally proportional to caloric values (Wallace 1981). Use of percent abundance in overlap indices may over-represent the dietary importance of smaller prey (Wallace 1981). The high PROI values (>99) found in this study almost certainly would have been lower if the mass of each diet category was used to estimate its relative importance. However, brown and rainbow trout often had dozens or even hundreds of midges in their stomach at one time; therefore, I do not believe that the importance of these small invertebrates was grossly overrepresented. It is apparent from this study and from the CCWFF invertebrate sampling that midges are an important part of the invertebrate community that is available to trout in the Lanier Tailwater.

Overlap values for brown trout greater than 300 mm TL (Table 4) could be considerably biased as a result of study limitations. With some exceptions, larger brown trout that did have midges in their stomachs tended to only have a small number (i.e, <10) present compared to the large numbers seen in smaller brown trout. Also, larger fish were more likely in this study to have fish in their stomachs. The >300 mm TL group was approximately three times as likely as brown trout 200–299 mm TL and approximately ten times as likely as brown trout <200 mm TL to be classified as empty in this study. Piscivorous fishes are more likely than insectivorous fishes to exhibit empty stomachs due to different foraging strategies (Arrington et al. 2002). Also, the gastric lavage technique may not have been effective at dislodging large items (e.g., fish) from trout stomachs, and an efficiency estimate (Chipps and Garvey 2007) might have found that fish were less likely to be discovered than other diet categories in this study. If many of these larger brown trout had transitioned to high levels of piscivory, the fish category might have been under-represented on a percent frequency basis, which would have only compounded the limitations noted above.

Piscivory can be an important factor in the growth and survival of larger trout (Aass et al. 1989, Mittelbach and Persson 1998, Jonsson et al. 1999, Grey 2001, L'Abée-Lund et al. 2002). A literature review by Johnson et al. (2006) found that fishes comprised an average of 20% of the diets of stream-dwelling salmonids 250–350 mm TL and 90% of salmonids >400 mm TL. The lack of an ontogentic shift in diet composition in this study may have simply been due to a lack of piscivory, such as that found by Johnson et al. (2006) in an Arkansas tailwater. However, if detection efficiency of fish was poor in this study, piscivory may still be significant, particularly for brown trout >300 mm TL (e.g., Grey 2001).

The timing and rate of rainbow trout stocking likely influenced their presence in these samples. Klein (2003) reported a 68% annual mortality rate for stocked rainbow trout on the Lanier Tailwater, and Bettinger and Bettoli (2002) described poor persistence of stocked rainbow trout in another southeastern U.S. tailwater fishery. Accordingly, the smallest sample sizes of rainbow trout were collected during winter in this study, when rainbow trout were not being actively stocked. Settles Bridge, located in an area not stocked since 1997, produced the lowest numbers of rainbow trout in all seasons, thus, the impacts of stocking catchable rainbow trout in tailwaters may represent a localized phenomenon (Bettinger and Bettoli 2002). In contrast, the other three sites received regular (often weekly) rainbow trout stockings (P. Markey, GADNR, personal communication). Rainbow trout had fewer empty stomachs in the winter (when fish had not been recently stocked) than in the summer or fall. Stocked trout can exhibit suboptimal foraging behavior that differs from wild trout (Teixeira and Cortes 2006), and Bachman (1984) observed that stocked brown trout fed less and moved more than wild brown trout, likely leading to high natural mortality rates such as those seen by Klein (2003). Despite seeing obvious overlap in diet contents, there was no clear evidence of negative competitive impacts on brown trout due to rainbow trout stocking. The average length and condition of brown trout were lower at Settles Bridge than at the three stocked sites. Interspecific competition may be mostly limited to holdover or wild rainbow trout that persist in the fishery for months or years. While there were likely a small number of wild rainbow trout represented among these samples, the size of fish collected in this study suggests that the population is still overwhelmingly of hatchery origin. O'Rouke and Martin (2012) reported that 38% of brown trout collected in electrofishing samples were <178 mm TL before the brown trout stocking moratorium and subsequent verification of a robust wild brown trout population. Only 11% of rainbow trout collected in this study measured <230 mm TL (i.e., smaller than target stocking size) and only 3% measured <200 mm TL. Therefore, the level of competition between rainbow trout and brown trout is likely relatively low.

There were several differences in occurrence of prey categories in trout diets between sites and seasons. There were fewer instances of stoneflies, caddisflies, and scuds at Buford Dam than at sites farther downstream. This may be a result of increased downstream tributary inputs (e.g., Vannote et al. 1980) and/or reduced scouring flows with increased distances from Buford Dam. There were more stoneflies and fewer caddisflies found in the winter, and ants/termites were mostly found in diets during summer, perhaps indicating seasonal availability of these categories. However, large numbers of brown trout and rainbow trout consumed midges regardless of river location or season, and PROI values did not suggest significant differences between the two species in diet across seasons.

Growth rates and length-frequencies observed at the Lanier Tailwater suggest that most brown trout grow very slowly beyond ~300 mm TL, and over 80% of brown trout collected in these four sites during a concurrent tagging study measured between 181–280 mm TL (GADNR, unpublished data). However, trophy potential still exists in this fishery, as numerous brown trout >500 mm TL are caught by anglers each year and the state record brown trout (>8 kg) came from the Lanier Tailwater in 2001. These findings should help managers understand the potential for both the catchable and trophy brown trout fisheries in the Lanier Tailwater and similar tailwater fisheries. They may also help guide future rainbow trout stocking rates and strategies relative to their impacts on brown trout.

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