

Dispersal, Mortality, and Predation on Recently-stocked Rainbow Trout in Dale Hollow Lake, Tennessee

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Abstract: Forty-four hatchery-raised rainbow trout (*Oncorhynchus mykiss*) were implanted with ultrasonic tags and stocked into Dale Hollow Lake, Tennessee, and tracked at least once per week for eight weeks to describe post-stocking dispersal rates, movements, and habitat use. Dispersal followed a three-stage pattern characterized by rapid movement away from each stocking site during the first week, relatively little dispersal during the next three weeks, and further dispersion during the final four weeks that fish were tracked. Rainbow trout exhibited a strong affinity for coves and were rarely encountered in the main channel. Tagged fish stocked in March exhibited lower mortality ($Z_{\text{weekly}} = 0.027$) than those stocked in January ($Z_{\text{weekly}} = 0.062$) during the first eight weeks post-stocking. Diets of potential predators in Dale Hollow Lake were examined. Walleye (*Sander vitreus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), and holdover rainbow trout all preyed on recently stocked trout. Larger walleye were more likely to prey on stocked rainbow trout, and walleye of all sizes tended to prey on the smaller trout in each stocked cohort. Walleye were more likely to feed on rainbow trout during January than March. Effective stocking strategies should focus on reducing predation by stocking larger rainbow trout or by stocking when predation risk is minimized (i.e., March).

Key words: movement, telemetry, survival, predators

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To diversify the angling experience in Tennessee, the Tennessee Wildlife Resources Agency (TWRA) routinely stocks rainbow trout (*Oncorhynchus mykiss*) in tailwaters, free-flowing streams, urban ponds, and large reservoirs. The management goals for each of these programs are distinct and are largely dictated by the biology of the species and the associated challenges presented by the receiving habitats (Fiss and Habera 2006). Approximately 190,000 rainbow trout are stocked annually into seven large reservoirs in Tennessee. These reservoirs provide a year-round supply of well-oxygenated cold water, thereby permitting over-summer survival. Natural reproduction is negligible and stocking is conducted during the winter.

Dispersal and movement patterns of rainbow trout vary greatly according to habitat. Rainbow trout in small lotic systems often exhibit little movement (Cargill 1980, Mellina et al. 2005, Simpson 2006), whereas trout tend to move greater distances in larger lotic systems (Bettinger and Bettoli 2002, Runge et al. 2008) and lentic systems (James and Kelso 1995, Warner and Quinn 1995, Lindberg et al. 2009). In lentic systems, rainbow trout are most commonly found in littoral areas when temperatures in the epilimnion do not exceed their thermal preferences (James and Kelso 1995, Warner and Quinn 1995). Tabor and Wurtsbaugh (1991) observed that

rainbow trout in lentic ecosystems were cover-oriented. Higher electrofishing catch rates of rainbow trout in coves compared to the main-channel indicated differential use of off-channel areas in Tennessee reservoirs (Bergthold and Bettoli 2009).

Rainbow trout mortality due to stocking stress reportedly is minimal (Barwick 1985); however, predation has been implicated as an important source of mortality for stocked trout in reservoirs (Talley 1976, McMahon and Bennett 1996, Hyvarinen and Vehanen 2004). Rainbow trout are an ideal prey item for piscivores because of their soft rays and fusiform body shape, physical features that result in prey-selectivity in some piscivorous fishes (Wahl and Stein 1988). As a general rule, predation on stocked fish is most intense soon after stocking (e.g., Buckmeier and Betsill 2002). Talley (1976) found that predation on fingerling rainbow trout stocked in a reservoir was greatest during the first 10 d after stocking. Upon introduction to a structurally complex reservoir habitat (compared with hatchery raceways or rearing ponds), stocked fish are naive of its intricacies and may exhibit behavior that increases the risk of predation (Brown and Smith 1998, Schlechte et al. 2005). Fish are usually stocked in high densities from relatively few points and the resulting aggregation may increase feeding efficiency of predators (Jepsen et al. 1998, Johnson and Ringler 1998). Additionally, the

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abundance of other prey species during winter may be low and the availability of other prey has been found to buffer predation on trout (Talley 1976, Johnson and Rakoczy 2004).

Stocked rainbow trout can represent a notable portion of walleye (*Sander vitreus*) diets in systems where they coexist (Baldwin et al. 2003). Walleye in Tennessee reservoirs stocked with rainbow trout generally exhibited higher relative weights than walleye in systems without trout (Vandergoot 2001). In Wyoming reservoirs, there was a positive correlation between walleye relative weights and fingerling rainbow trout stocking densities (Marwitz and Hubert 1997). During the 1970s, the introduction of nonnative walleye to impoundments on the North Platte River system, Wyoming, had a detrimental effect on what was once considered a blue-ribbon trout fishery supported through fingerling stocking (McMillan 1984).

The objectives of this study were to (1) describe post-stocking movements and dispersal by rainbow trout in Dale Hollow Lake; (2) describe the use of main-channel and off-channel (i.e., cove and embayment) areas during the first two months post-stocking; (3) utilize telemetry data to estimate mortality of recently stocked rainbow trout in Dale Hollow Lake; and (4) assess temporal and size-based trends in predation on rainbow trout by walleye in Dale Hollow Lake.

Study Area

Dale Hollow Lake is an impoundment on the Obey River and lies mainly in northern Tennessee extending northward into Kentucky. Constructed in 1943, the 11,210-ha tributary storage impoundment is operated for hydroelectric power and flood control by the Army Corps of Engineers and has a maximum depth of 42m. Dale Hollow Lake is stocked annually with approximately 76,500 rainbow trout, representing about 7 fish/ha. It was stocked twice during the winters of both 2007–2008 and 2008–2009. During 2007, some fish were stocked inshore at boat ramps and some were transported offshore using a barge; during 2008, fish were only stocked from boat ramps. The study area for the telemetry study ranged from the dam up-reservoir about 15km (measured along the Obey River channel) to First Island and encompassed about 1550 ha; 1085 ha were deemed main-channel area and 465 ha were deemed off-channel area (Figure 1). Mitchell Creek is a large sinuous embayment encompassing about 820 ha and was omitted from this study, along with all areas upstream of First Island, due to personnel limitations. Rainbow trout were stocked in two locations: Horse Creek Marina, located at the head of Horse Creek, a 2.1-km long 69-ha embayment near the dam, and Pleasant Grove Recreation Area, located on the main channel approximately 3.75km

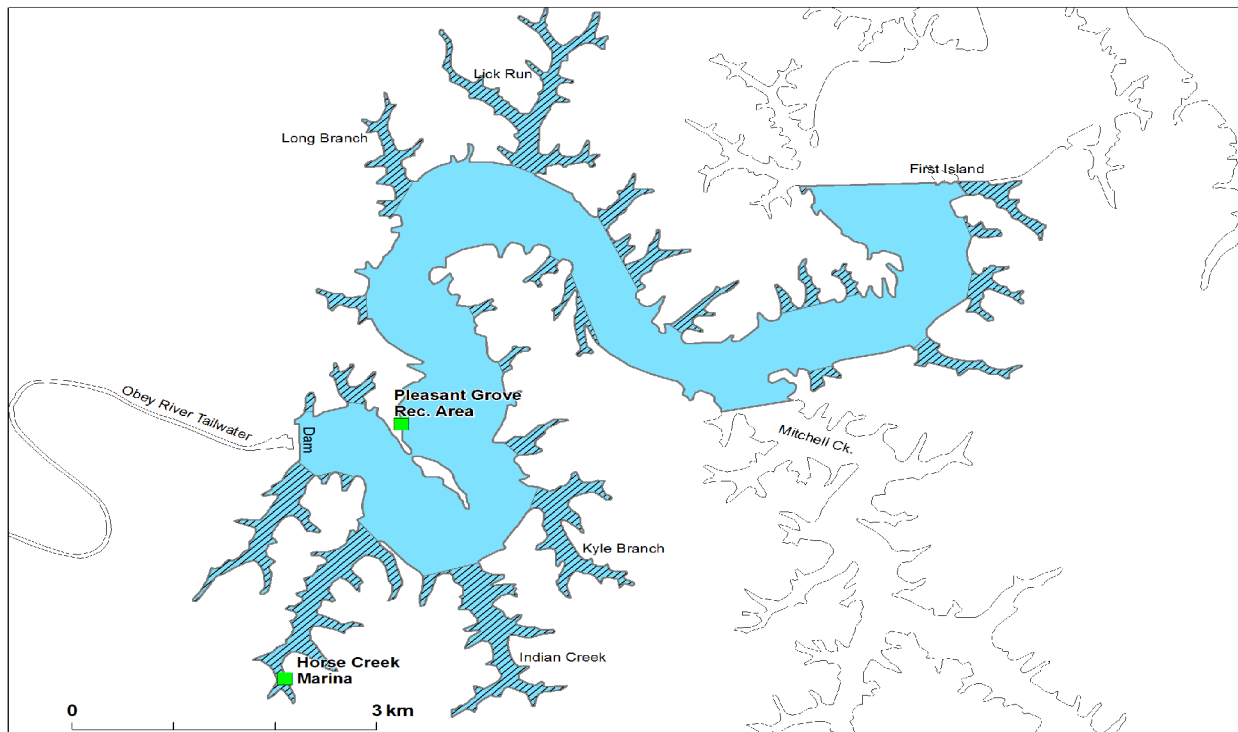


Figure 1. The study area for the trout dispersal study (shaded region) encompassed 1,550 ha of Dale Hollow Lake. Crosshatching indicates cove areas. Tagged rainbow trout were stocked at Horse Creek Marina and Pleasant Grove Recreation Area.

upstream of the dam (Figure 1). Predatory fishes in Dale Hollow Lake include holdover (large) rainbow trout, walleye (maintained through stocking), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), spotted bass (*M. punctulatus*), channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), and muskellunge (*Esox masquinongy*).

Methods

Movement and Dispersal

Hatchery-raised rainbow trout were internally implanted with Sonotronics² IBT-96-2 ultrasonic transmitter tags (dimensions: 23x7 mm, weight in air: 4.4 g, guaranteed battery life: 2 mo, range: ≥ 650 m) at Dale Hollow National Fish Hatchery, Celina, Tennessee. Tags were implanted according to the methods of Ivasauskas and Bettoli (*in press*). Monocryl sutures were used on all fish. Tagged fish ranged in length from 210 to 280 mm and averaged 235 mm (SE=2.57). Tag burdens ranged from 1.9%–4.4% of bodyweight and averaged 2.9% of bodyweight. Although this is greater than the generally accepted “2% rule” (Winter 1983), a number of laboratory studies have imposed burdens greater than 2% with no significant adverse effects (see Jepsen et al. 2004). Immediately following surgery, fish were transferred to one of two 580-L transport tanks equipped with aerators; water in the tanks was treated with a commercial “bait saver” formulation and ice was added as needed. Tagged fish spent no longer than 20 h in the tanks and transport to stocking sites took less than 15 min.

Tags were implanted in 24 rainbow trout on 6 January 2009. On 7 January 2009, half of these fish were stocked at Horse Creek Marina in Dale Hollow Lake and the other half were stocked at Pleasant Grove Recreation Area. Similarly, tags were implanted in an additional 20 rainbow trout on 5 March 2009; the next day, half were stocked at Horse Creek Marina and the other half were stocked at Pleasant Grove Recreation Area. All tagged fish were released along with at least 1,500 untagged rainbow trout used in normal stocking operations.

Tagged fish were manually tracked from a boat during daylight hours by following a transect around the perimeter of the study area and stopping to detect transmitters at least every 500 m. The boat was stopped more frequently in structurally complex areas where lake contours may have limited tag detection. A Sonotronics directional hydrophone (DH-4) and Sonotronics receivers (USR-5W and USR-96) were used to detect tag transmissions. Fish were tracked to location, considered to be when signal strength

was equal in a 360-degree arc. The precise location (within 5 m) of each fish was mapped using a handheld Global Positioning System (GPS). Fish stocked in January and March were tracked 5 and 7 times, respectively, during the first 7 d post-stocking; thereafter, they were tracked once every 6 to 8 d for an additional seven weeks. Dale Hollow Lake was isothermal during both stockings and exhibited weak stratification by the conclusion of tracking at the end of April 2009. However, surface water temperature (measured at a depth of 1.5 m) was suitable for rainbow trout (i.e., <21 C, Rowe and Chisnall 1995) throughout the duration of the study.

Tracking data were examined using ESRI Arcsoft Geographic Information System (ArcGIS) software. The Dale Hollow Lake polygon was acquired from the Tennessee Federal GIS Data Server (www.tngis.org 2009). All distances were measured as the minimum within-reservoir distance between two points. Tags that were relocated at the same location for at least two weeks and exhibited no further movement were considered “stationary.” Stationary tags were considered indicative of a dead fish during the first week that they ceased movement, and observations of movement during the preceding week were excluded from analyses.

Dispersal distances (km) were determined by measuring the minimum distances from stocking sites to each fish. If a fish was not located during a given tracking event, but was located during the immediately preceding and subsequent tracking events, the dispersal distance for the interval that the fish was not found was estimated as the average of the two distances. If the fish was not located during two or more subsequent events, movement was not estimated.

Minimum weekly movement (km/wk) was determined by measuring the distances between individual fish locations during subsequent weeks. If a fish was not located during a given week, but was located during the immediately preceding and subsequent weeks, the traversed distance was equally divided between the two one-week timeframes. If the fish was not located on two or more subsequent weeks, no movement estimate was made for that fish until two more subsequent locations were obtained.

Dispersal distances during the first week post-stocking were compared between fish stocked at Pleasant Grove and Horse Creek Marina using a mixed-model ANOVA and specifying individual fish as the sampling unit to avoid pseudoreplication (Rogers and White 2007). If differences were not apparent, behavior of fish stocked from the two locations was deemed similar and data were pooled. Fish dispersal and movement were compared between tracking events using a mixed-model ANOVA with fish as the sampling unit (Rogers and White 2007). Where differences were apparent, the Bonferroni procedure was used to compare least-squared means.

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Differential use of main-channel and off-channel areas was assessed using a 2x2 contingency table and the chi-square test statistic. The number of observations of fish located in each area was compared to the expected number of observations in those areas based on an equal distribution according to availability (i.e., surface area). Designations of main-channel and off-channel areas are depicted in Figure 1.

Mortality Estimates

Estimates of rainbow trout mortality in Dale Hollow Lake during the first two months post-stocking were derived from observations of movement for the 44 telemetered rainbow trout. Stationary tags (per the definition above) were considered indicative of mortality (Bettoli and Osborne 1998, Hightower et al. 2001). Any tag that was not detected during an individual tracking event but was later relocated in a different location was assumed to be non-stationary (i.e., “alive”) during that interim period. No inference was made for any tag that was not later relocated (i.e., the fish was censored when it ceased to be located; Table 1).

Survival curves for the first eight weeks post-stocking were computed using the Kaplan-Meier product limit estimator (Kaplan and Meier 1958). The Kaplan-Meier estimator relies on the central limit theorem to provide a robust estimate of survival, given a dataset where some subjects are censored before the end of the study (White and Garrott 1990, Stute 1995). A stationary transmitter may also be indicative of a tag that has been expelled, which is a well-documented phenomenon in several fish species including rainbow trout (Ivasauskas and Bettoli *in press*). To account for this possible bias, the Kaplan-Meier survival estimate for those weeks

Table 1. Weekly sample sizes based on observations of 44 telemetered trout stocked in Dale Hollow Lake on 7 January and 6 March 2009. Fish were censored from the study when they could not be relocated.

Week	0	1	2	3	4	5	6	7	8
January stocking									
Alive	24	20	15	13	11	9	7	7	7
Dead/expelled	0	4	7	7	8	9	9	9	9
Censored	0	0	2	4	5	6	8	8	8
March stocking									
Alive	20	20	19	18	16	13	9	8	8
Dead/expelled	0	0	0	0	1	2	3	4	4
Censored	0	0	1	2	3	5	8	8	8

Table 2. Adjustment factors applied to observations of stationary transmitters observed during a given week. Values are adopted from laboratory findings reported by Ivasauskas and Bettoli (*in press*) and represent the expected proportion of trout that expelled transmitters through eight weeks.

Week	1	2	3	4	5	6	7	8
Adjustment factor	0.0	0.0	0.0	0.05	0.05	0.10	0.15	0.2

when a stationary transmitter was detected was adjusted by adding the expected cumulative probability of transmitter expulsion for that week (Table 2), adopted from laboratory findings described by Ivasauskas and Bettoli (*in press*).

Instantaneous weekly mortality rates over the first eight-weeks post-stocking were calculated for each of the two tagged cohorts stocked early- and late-winter using the equation:

$$Z = \frac{(\log_e(N_0) - \log_e(N_8))}{\Delta t}$$

where N_0 is the initial number of rainbow trout at week 0, N_8 is the number of trout alive at eight weeks (estimated from the Kaplan-Meier procedure and adjusted for expulsion), and Δt is the interval in weeks (8).

Predation on Recently-Stocked Rainbow Trout

Stocking of rainbow trout in Dale Hollow Lake took place in two phases (early- and late-winter) during both years. In 2008, the first stocking of rainbow trout occurred on 2 January 2008 and predators were sampled 8 January 2008. The second stocking occurred on 2–3 April 2008 and predators were sampled 3 April and 8 April 2008. In 2009, rainbow trout were stocked on 9 January 2009 and predators were sampled on nine dates between 9 January and 6 February 2009. Rainbow trout were again stocked on 6 March 2009 and predators were sampled on 9 March and 10 March 2009.

Potential predators of rainbow trout were sampled using experimental sinking gillnets measuring 30x2.4 m with mesh sizes 25-, 38-, 51-, and 64-mm bar measure, fished perpendicular to the shore. Nets were deployed during the afternoon and recovered the following morning. All potential predators (i.e., walleye, largemouth bass, smallmouth bass, spotted bass, channel catfish, flat-head catfish, and holdover rainbow trout) were weighed (g) and measured (TL, mm), euthanized with an overdose of MS-222, and stomachs were removed. Stomach contents were categorized to the lowest identifiable taxonomic order, enumerated, and any rainbow trout were measured (standard length [SL], mm). When rainbow trout remains were too digested to accurately measure, the predigested SL was visually estimated; if this was not possible, the mean length of all ingested fish (170 mm) was used as the predigested length estimate. Measurements taken from a random sample of 210 rainbow trout destined for stocking into Dale Hollow Lake and two other Tennessee reservoirs were used to build a SL:TL linear regression model and to create a length-frequency distribution for stocked fish.

Logistic regression models were constructed using data from walleye with non-empty stomachs to relate the probability of a rainbow trout being in a walleye’s diet to walleye total length. The Hosmer-Lemeshow goodness-of-fit test was used to assess the fit

of the model to the data. The Kolmogorov-Smirnov test was used to compare the length-frequencies of rainbow trout ingested by walleye and all trout stocked. Simple linear regression was used to relate the TL of consumed rainbow trout to the TL of the walleye that ingested it (Poe et al. 1991, Zimmerman 1999). To estimate feeding frequency, the proportions of non-empty walleye stomachs following early- and late-winter stocking events in Dale Hollow Lake were compared using a chi-square test. The proportions of diets containing rainbow trout were also compared between early- and late-winter samples using the chi-square test statistic. Statistical significance for all tests was set at $\alpha=0.05$.

Results

Movement and Dispersal

The distances rainbow trout dispersed during the first week did not differ between stocking sites (mixed-model ANOVA, $F_{1,218} = 1.58, P=0.2102$). Therefore, movement of fish stocked at each site was considered similar and data were pooled for further analyses.

Differences in dispersal distances were apparent (mixed-model ANOVA, $F_{13,334} = 11.8; P<0.0001$) and dispersal took place in three stages (Table 3). The first stage (approximately 0–7 d post-stocking) was categorized by rapid dispersal of fish away from each stocking site. During the second stage (1–4 weeks), dispersal was minimal. During the third stage (4–8 weeks), fish dispersed further away from their respective stocking sites. Minimum weekly movement differed slightly from week-to-week (mixed-model ANOVA, $F_{7,121} = 2.14; P=0.0440$), but the Bonferroni procedure failed to detect any specific differences between weeks (Table 4).

Rainbow trout exhibited a strong affinity for coves and embayments ($\chi^2=176.3; df=1; P<0.0001$). Cove area represented 30% of the study area’s surface area, whereas 63% of trout observations were in coves. Rainbow trout were infrequently encountered in pelagic, offshore habitats; most (69%) observations of rainbow trout in the main channel were along the shoreline.

Mortality Estimates

Rainbow trout stocked in March 2009 exhibited better survival than those stocked in January 2009 (Figure 2). Weekly instantaneous mortality (Z_{weekly}) during the first eight weeks post-stocking was 0.062 for rainbow trout stocked in January 2009; whereas, Z_{weekly} for trout stocked in March 2009 was only 0.027. These estimates of Z correspond to eight-week survival rates of 61% (January stocking) and 81% (March stocking).

Predation on Recently-Stocked Rainbow Trout

Walleye, smallmouth bass, largemouth bass, and holdover rainbow trout all preyed on recently-stocked rainbow trout (Table 5).

Table 3. Mean dispersal of tagged rainbow trout stocked in Dale Hollow Lake on 7 January and 6 March 2009. Periods where the Bonferroni post-hoc procedure (Bonf.) failed to detect differences in least-squares (L.S.) mean dispersal distances are indicated by shared groupings.

Post-stocking period	n ^a	Mean dispersal distance (km)	Minimum (km)	Maximum (km)	L.S. means	S.E. of L.S. means	Bonf. grouping
Day 1	42	0.70	0.07	3.90	0.780	0.256	A
Day 2	41	1.04	0.08	6.11	1.109	0.258	A, B
Day 3	38	1.07	0.06	6.36	1.157	0.264	A, B
Day 4	35	1.17	0.05	6.60	1.250	0.269	A, B, C
Day 5	37	1.53	0.06	8.35	1.56	0.265	A, B, C
Day 6	34	1.56	0.07	10.06	1.62	0.271	A, B, C
Day 7	34	1.77	0.08	11.76	1.79	0.271	B, C
Week 2	30	1.71	0.08	4.82	1.94	0.280	B, C, D
Week 3	29	1.84	0.04	5.23	2.111	0.283	C, D
Week 4	24	1.75	0.09	4.40	2.095	0.298	C, D
Week 5	16	2.86	0.14	5.50	3.045	0.339	D, E
Week 6	14	2.87	0.09	7.40	2.974	0.355	D, E
Week 7	12	3.90	0.07	12.50	4.054	0.375	E
Week 8	7	1.99	0.09	3.70	2.274	0.465	B, C, D, E

a. n = number of trout

Table 4. Weekly minimum distances traversed by tagged rainbow trout stocked in Dale Hollow Lake on 7 January and 6 March 2009, including least-squares (L.S.) means and standard errors (S.E.).

Post-stocking period	n ^a	Mean distance traversed (km/wk)	Minimum	Maximum	LS means	S.E. of L.S. means
Week 1	36	1.73	0.08	11.76	1.731	0.298
Week 2	31	0.95	0.00	4.20	1.136	0.320
Week 3	27	0.62	0.00	3.10	0.855	0.333
Week 4	24	1.30	0.00	4.60	1.503	0.347
Week 5	16	1.59	0.05	5.00	1.791	0.403
Week 6	14	1.63	0.05	5.70	1.755	0.424
Week 7	13	2.10	0.00	9.70	2.288	0.450
Week 8	7	1.13	0.20	1.90	1.852	0.650

a. n = number of trout

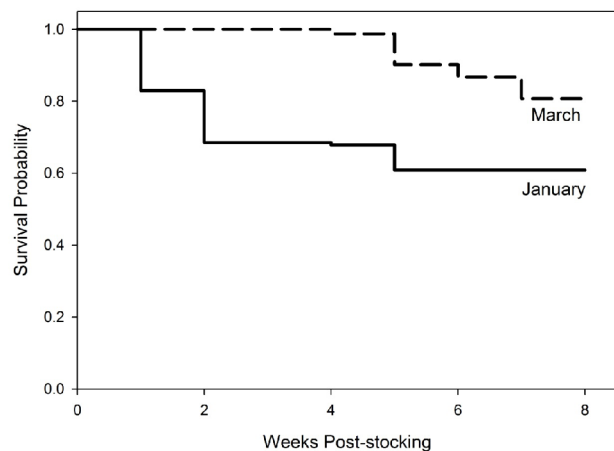


Figure 2. Kaplan-Meier survivorship curves constructed from observations of tagged trout stocked in January and March 2009 into Dale Hollow Lake, adjusted for expulsion.

Table 5. Summary of sample sizes for the diet analysis of predatory species caught in gillnets set in Dale Hollow Lake following rainbow trout stocking events occurring December 2007 through March 2009. A "holdover" rainbow trout refers to a trout stocked during previous years.

Species	N _{total} ^a	N _{non-empty} ^b	N _{with trout} ^c
January and February			
Walleye	155	66	7
Smallmouth bass	20	13	3
Largemouth bass	1	0	0
Rainbow trout (holdover)	6	4	1
March and April			
Walleye	127	18	3
Smallmouth bass	17	12	1
Largemouth bass	4	3	1
Spotted bass	3	2	0

a. N_{total} is the total number of fish collected.

b. N_{non-empty} is the number of fish non-empty stomachs.

c. N_{withtrout} is the number of fish with the diets containing at least one trout.

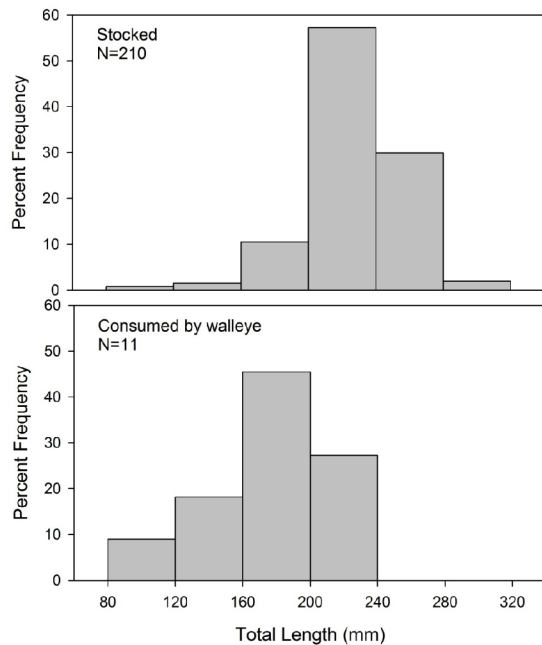


Figure 3. Length-frequency distributions of rainbow trout that were stocked and that were consumed by walleye. N is the number of measured trout.

The probability that a walleye recently preyed on at least one rainbow trout was positively related to walleye total length (logistic regression, $X^2=13.58$, $df=1$, $P=0.0002$; Hosmer-Lemeshow Goodness-of-fit test $P=0.6325$). The model was:

$$P(\text{rainbow trout in diet}) = \frac{\exp(-20.2794 + 0.0343(\text{TL}))}{1 + \exp(-20.2794 + 0.0343(\text{TL}))}$$

The smallest walleye that consumed a rainbow trout was 521 mm TL, and one walleye (593 mm TL) consumed two trout. Relative to all rainbow trout stocked, the trout consumed by walleyes tended

to be small (Figure 3, Kolmogorov-Smirnov test, $P < 0.0001$). There was no relationship between the total lengths of walleye and the lengths of rainbow trout they consumed ($r^2=0.0875$, $P=0.377$). A larger proportion of walleyes collected from Dale Hollow Lake had non-empty stomachs during early-winter (41%) than during late-winter (14%) in 2008 and 2009 ($X^2=26.93$, $df=1$, $P < 0.0001$), but the proportion of non-empty stomachs that contained rainbow trout remained constant between the two time periods ($X^2=0.4953$, $df=1$, $P=0.4816$).

Discussion

When rainbow trout are stocked in systems where they tend to disperse slowly, catch rates near the stocking sites are high, especially during the first several weeks post-stocking; thus, fishing mortality and return to creel are high (Helfrich and Kendall 1982, Fay and Pardue 1986, Baird et al. 2006). The rapid dispersal from both main-channel (Pleasant Grove Recreation Area) and cove stocking sites (Horse Creek Marina) indicated that rainbow trout stocked in Dale Hollow Lake quickly become less vulnerable to anglers fishing near stocking sites.

Bergthold and Bettoli (2009) reported that electrofishing catch rates in coves were up to 237% greater than along the main-channel of the reservoir. Similarly, tagged rainbow trout in this study were observed 241% more frequently in off-channel areas than in the main-channel (taking into account the total availabilities of the two areas). Thus, both studies suggest that recently stocked rainbow trout select coves over main-lake areas in Dale Hollow Lake. Furthermore, most rainbow trout found in the main channel were highly mobile, especially those in the pelagic zone; whereas tagged trout located in coves were typically stationary under docks, amongst large woody debris, or associated with benthic morphometric features (e.g., drop offs, channel points). Coves in Dale Hollow Lake tend to have greater shoreline development indices than the main channel; as such, coves provide a more structurally complex habitat and receive more allochthonous inputs. Habitat complexity and structure provide protection from predation (Tabor and Wurtsbaugh 1991, Walters et al. 1991). The influx of allochthonous material (coupled with the more complex habitat structure) may also promote greater abundances of invertebrate food resources in coves.

The observed behaviors of recently stocked rainbow trout in Dale Hollow Lake may reflect their vulnerability to a variety of predators inhabiting a variety of habitats. Most (78%) of the transmitters that became stationary from the group stocked in January did so within three weeks of implantation. In a laboratory experiment, no rainbow trout sutured with Monocryl (the suture material used in the current study) expelled tags during the first three weeks (Ivasauskas and Bettoli, *in press*). It was therefore unlikely that these stationary trans-

mitters resulted from expulsion but rather to mortality. In March, we did not observe any stationary transmitters during the first three weeks. Although the rate of tag encapsulation and expulsion has been shown to increase with higher water temperature (Bunnell and Isely 1999), water temperatures at 1.5 m in Dale Hollow Lake differed by only 1.3 C between 22 January and 19 March 2009. Thus, initial mortality appeared to be lower in March than January.

There is a delay in detecting mortality resulting from predation because telemetry tags implanted into ingested prey must pass through the predator's gastrointestinal tract and be excreted before becoming stationary. Hyvarinen and Vehanen (2004) reported that when northern pike (*Esox lucius*) consumed tagged brown trout (*Salmo trutta*), the implanted tags were passed within nine days. Similarly, Jepsen et al. (1998) reported that tags were passed within 3–6 d when northern pike ate tagged smolts. An experiment conducted in a hatchery setting in March 2008 confirmed that walleye can excrete ingested tags identical to those used in the present study (Ivasauskas and Bettoli 2010). Empirical evidence obtained from monitoring tagged rainbow trout stocked in Dale Hollow Lake suggested that tags were excreted by some predators in less than a week.

This study confirmed that stocked rainbow trout are readily consumed by piscivorous fishes in Dale Hollow Lake. Larger walleye were more likely to consume stocked rainbow trout than smaller walleye. Such a relationship was expected because physical constraints of the predator, such as mouth gape (Hambright 1991), limit the maximum size of prey it can consume. Other studies have identified an inverse relationship between rainbow trout size at stocking and mortality due to predation (Cunningham and Anderson 1992, Walters et al. 1997, Flinders and Bonar 2008). Yule et al. (2000) found that as length of stocked rainbow trout increased, they became less vulnerable to predation by the majority of the piscivorous fish community. In Dale Hollow Lake, the size of consumed rainbow trout was not linked to predator size, although walleye of all sizes tended to prey on the smaller trout in each stocked cohort. These results suggest that stocking larger rainbow trout could reduce predation by preventing smaller walleye from eating trout and also limit predation by larger walleye.

Survival can also be increased by stocking fish later in the winter. Tracking and gillnetting data both indicated that the weekly mortality rate over two-months was higher for rainbow trout stocked during January than during March or early-April. Additionally, rainbow trout grow very slowly ($\leq 0.2\% \text{ d}^{-1}$) in Tennessee reservoirs between December and mid-March (Bergthold and Bettoli 2009). They are therefore subject to predation for a longer period of time (i.e., until they assume a faster growth rate) when stocked in early winter.

A larger proportion of walleyes collected from Dale Hollow

Lake had non-empty stomachs during January and February (41%) than during March and April (14%). An almost identical pattern was described by Libbey (1969): the proportion of walleye with non-empty stomachs in that earlier study in Dale Hollow Lake decreased abruptly from 48% during January and February to 17% in March and 7% in April. Muench (1966) observed a total cessation of walleye feeding activity in March in nearby Center Hill Lake, Tennessee. This decline in feeding activity is likely due to walleye fasting associated with spawning behavior. In Dale Hollow Lake, spawning has been observed between mid-March and late-April (Libbey 1969). Many of the walleye collected during diet collections in April 2008 and March 2009 released milt or eggs upon removal from the net, indicating that spawning had commenced.

It is important to note that conclusions drawn in this study are only applicable to recently stocked small catchable-sized rainbow trout during the winter and early-spring. Epilimnetic water temperatures $> 21\text{ C}$ (which usually occurs in Dale Hollow Lake by the end of May) force rainbow trout to move deeper in the water column (Horak and Tanner 1964). Ontogenetic shifts in habitat utilization (Landry et al. 1999) and prey selectivity (Bergthold and Bettoli 2009) have also been noted for rainbow trout in lentic systems; therefore, behavior and survival of older (and larger) trout might not correspond with behaviors observed in this study. Our findings suggest that survival of recently-stocked rainbow trout in a reservoir is mostly affected by natural mortality (i.e., predation), as opposed to fishing mortality. Effective stocking strategies should therefore focus on reducing predation by stocking larger individuals or by stocking later in the winter when predation risk is minimized.

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