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MANAGEMENT BRIEF

Effects of Wintertime Stocking of Rainbow Trout on the Forage Community of an Oklahoma Impoundment

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Abstract
Rainbow Trout *Oncorhynchus mykiss* are sometimes stocked to create put-and-take fisheries in small impoundments. Information about the effects of these stockings on existing piscivores is poorly understood. Therefore, we performed a study to evaluate the forage consumption by Rainbow Trout stocked in Lake Carl Etling, Oklahoma. A creel survey during the 2014–2015 trout season determined that angling pressure was low, which left the majority of stocked trout in the lake until their thermal maximum was exceeded in late May–June. Rainbow Trout stomach contents were collected monthly from November through April annually (2015–2018) via gastric lavage. Gizzard Shad *Dorosoma cepedianum* were consumed during most months, but their occurrence in Rainbow Trout stomachs was highest in January and December. A sharp decline in Gizzard Shad consumption was followed by an increase in detritus consumption each year. Using either Gizzard Shad numbers observed in monthly Rainbow Trout diets or the estimated monthly abundance of Rainbow Trout, we postulated that Rainbow Trout substantially affected age-0 Gizzard Shad biomass (reducing it by 66.7 or 54.6 kg/ha, respectively), potentially negatively affecting growth rates of other piscivores in the system. This study demonstrates the unintended consequences of stocking an additional predatory fish into small impoundments and the importance of evaluating angler harvest of these stocking programs to ensure the stocked species receives sufficient angler harvest to match stocking rates and prevent negative impacts on the fish community (both forage and other piscivorous species).

Rainbow Trout *Oncorhynchus mykiss* are stocked in aquatic systems throughout the southeastern United States to create popular put-and-take winter recreational fisheries (Metcalf et al. 1997; Weaver and Kwak 2013; Ward et al. 2018). State agencies stock catchable-sized Rainbow Trout in rivers, streams, and small impoundments to provide unique sportfishing opportunities when water temperatures allow Rainbow Trout to survive (Alexander and Shetter 1967; Barwick 1985; Cunningham and Anderson 1992). Fishery managers tend to view winter trout stocking programs as temporary in nature because the trout eventually succumb to warm water temperatures by late spring or early summer, leading to high trout mortality. However, introductions of nonnative or exotic species can result in significant changes to the existing fish community (Ogutu-Ohwayo 1990; Gurevitch and Padilla 2004;

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Pimentel et al. 2005; Rahel and Olden 2008); therefore, the effects of trout introductions on native or resident fish species should be considered.

When stocked in rivers and streams, Rainbow Trout are opportunistic feeders (Tay et al. 2007) that quickly convert to a natural feeding regime, typically selecting for invertebrates (Odenkirk and Estes 1991; Metcalf et al. 1997; O'Rouke 2014). Fenner et al. (2004) found that trout rarely competed with other top-level predators in lotic systems; however, competition could occur with other insectivorous fish such as some darters, sculpins, and cyprinids. However, Metcalf et al. (1997) suggested that if trout persist past April, they could impact the recruitment of Smallmouth Bass *Micropterus dolomieu* through competition for forage. Although Rainbow Trout can be piscivorous, it appears they rarely affect native piscivores in lotic systems (Metcalf et al. 1997; Fenner et al. 2004; Weaver and Kwak 2013).

The effects of stocked Rainbow Trout on native fishes has been well studied in reservoirs in Australia and New Zealand where predation on native aquatic species is substantial (Crowl et al. 1992; Fuller et al. 2001; Morgan et al. 2004; Tay et al. 2007; Blair et al. 2012). However, conflicting results are reported from studies in the United States where stocked Rainbow Trout often are insectivorous. In Argyle Lake, Illinois, stocked Rainbow Trout competed with juvenile Largemouth Bass *M. salmoides* and Bluegills *Lepomis macrochirus* in seasons when aquatic insects and zooplankton were their primary food source (Jahn and Lendman 1993). Conversely, Kruse and Durham (1989) found that stocked Rainbow Trout did not compete for invertebrates with juvenile warmwater species in three small Illinois impoundments. Beauchamp (1990) found that fish prey, rather than invertebrates, were the dominant diet items of trout >250 mm in Lake Washington, Washington, suggesting that some trout populations may behave more like Australian and New Zealand populations where negative effects due to trout piscivory have been observed. The lack of consistent information about the role of winter-stocked Rainbow Trout in impoundments in the USA suggests a need for additional research.

Rainbow Trout are commonly stocked in small Oklahoma impoundments to provide anglers additional fishing opportunities during the winter months. Presumably, managers expect most stocked trout to be caught soon after stocking. However, many stocked trout in impoundments may not be caught, due to the size of the system or lower-than-anticipated angling pressure, and those fish will presumably survive until water temperatures become too warm (typically late spring or early summer in Oklahoma). During this time, trout may compete with resident sport fish for forage resources. Stocking additional predatory piscivores in reservoirs commonly leads to unexpected prey limitations (Evans et al. 2014). This could be particularly important for winter stockings of coldwater species as the stocked species will forage when the forage base is at its lowest abundance of the year and could reduce prey availability needed to sustain warm-season piscivores as the forage species prepare to spawn and produce new forage for the year. Therefore, it is important to consider the consumptive demand of winter put-and-take fisheries to avoid unnecessary competition for the warmwater sport fish during the critical spawning season. In this study, we evaluated the consumption of prey by Rainbow Trout stocked in a southern impoundment in Oklahoma to determine whether these stockings could substantially alter forage-fish abundance such that they could be deleterious to the warmwater piscivores in the system.

METHODS

Study area.— South Carrizo Creek, Oklahoma, was impounded in 1958 to form Lake Carl Etling, which is located in the northwestern tip of Oklahoma's panhandle (Cimarron County). Lake Carl Etling is found within the diverse Mesa de Maya–Black Mesa ecoregion. At normal pool Lake Carl Etling has a surface area of 64.4 ha and 8 km of shoreline. Lake Carl Etling is considered hypereutrophic with a mean depth of 1 m and maximum depth of 5.5 m. The lake has historically supported popular Largemouth Bass and Walleye *Sander vitreus* fisheries. The fish community comprises mostly Gizzard Shad *Dorosoma cepedianum*, Bluegill, Green Sunfish *L. cyanellus*, Redear Sunfish *L. microlophus*, Black Bullheads *Ameiurus melas*, Common Carp *Cyprinus carpio*, and Channel Catfish *Ictalurus punctatus*. Additionally, the Oklahoma Department of Wildlife Conservation (ODWC) stocks Rainbow Trout to create winter angling opportunities. Stocked trout survive until temperatures at the thermocline exceed the thermal maximum for trout survival. Summer sampling further confirms that trout do not survive later than May in any year.

Sampling.— Rainbow Trout were collected once a month from Lake Carl Etling during three sampling seasons from November through April of 2015–2016, 2016–2017, and 2017–2018 by using boat electrofishing (pulsed DC, high voltage; Model 7.5 GPP, Smith Root, Vancouver, Washington). Sites were randomly selected to reduce potential bias in Rainbow Trout food habits. Furthermore, equal sampling effort was applied during day and night to account for any diel differences in diets. All Rainbow Trout encountered were netted and held in a 114-L live well for no longer than 30 min to minimize regurgitation.

After capture, all Rainbow Trout were measured (mm) and had stomach contents removed by gastric lavage (Fowler and Morris 2008). After stomach contents were removed, food items were place into a Ziplock plastic bag and labeled. Bags containing diet items were placed on ice until they could be frozen. In the laboratory, food items were thawed and identified to species when possible using taxonomic keys: aquatic invertebrates were identified following Merrit et al. (2008), fish fillets and scales identified with Oats et al. (1993), cleithrum identified with Traynor et al. (2010), and intact fish identified with Miller and Robison (2004). Stomach samples were analyzed by percentage of empty stomachs and frequency of occurrence (Bowen 1996; Chipps and Garvey 2007).

To determine angler harvest and the number of Rainbow Trout in Lake Carl Etling each month, a creel survey was performed in winter 2014–2015. We followed guidelines in the Oklahoma Department of Wildlife Conservation Standardized Sampling Procedures. In short, a roving survey method was conducted via boat and vehicle. Dates and times were randomly selected for November through March. A minimum of 20 survey days per quarter was used with 12 weekend days and 8 weekdays chosen randomly. A random 2-h block of time was set up for each day that occurred between sunrise and sunset. Creel survey data were not available for April, so April harvest was estimated using the average harvest from November and February, the 2 months with the highest fish harvest. Actual harvest in April was likely lower than this estimate, so this produced a conservative estimate of Gizzard Shad consumption (i.e., would suggest fewer trout were consuming Gizzard Shad than what actually occurred).

When creel clerks conducted a survey, they completed a circuit around the lake multiple times, stopping to survey all anglers encountered. Rainbow Trout harvested and released were enumerated and measured. Data collected from the creel were used to determine total monthly harvest of Rainbow Trout (using average weekday and weekend harvest rates).

To estimate consumption of Gizzard Shad by Rainbow Trout, we first needed to determine the median number of Rainbow Trout present in the system each month (i.e., monthly population size). In short, this was calculated by adding the number of fish stocked to any existing population (i.e., starting with the second month as no trout were present during the first stocking month because they cannot survive summer temperatures), then subtracting the number of fish expected to die from stocking mortality, natural mortality, and harvest. Specifically, two size-classes of Rainbow Trout (<350 mm and >350 mm, TL) were stocked during the last week of each month from October–March (Table 1). We assumed a stocking mortality rate of 1.6% occurred at the time of stocking (Barwick 1985; Cunningham and Anderson 1992), so the number of Rainbow Trout present at the beginning of the month was the sum of the fish surviving the previous month (calculation method below) and the number of fish stocked adjusted for stocking mortality. The number of Rainbow Trout alive at the end of the month was calculated by removing the mean number of fish harvested (estimated from the creel survey) in each size-class and applying an annual natural mortality rate of 8% (equivalent to 0.69%/month). We are unaware of any published natural mortality rates for Rainbow Trout. However, Schill (1996) reported instantaneous mortality of 1.3 for nonangled fish in a 2-month study designed to evaluate postrelease mortality (i.e., nonangled fish were control fish). The study was conducted when water temperatures were 9.5–13.5°C, which is similar to the water temperatures that would be expected during the winter fishing season at Lake Carl Etling. We therefore used an annualized mortality rate of 8% (the annualized equivalent of a 2-month instantaneous mortality rate of 1.3). The midpoint between the number of fish present at the beginning and end of the month was used to calculate Gizzard Shad consumption for the month.

TABLE 1. Schedule for stocking Rainbow Trout in Lake Carl Etling, Oklahoma, from 2015 to 2018.

Month	Size-class (mm)	Number stocked		
		2015–2016	2016–2017	2017–2018
October	<350	3,100	2,250	2,925
	>350	50	125	125
November	<350	2,300	2,248	2,500
	>350	80	93	90
December	<350	2,600	2,243	2,350
	>350	80	93	150
January	<350	1,200	1,925	4,265
	>350	50	85	200
February	<350	1,100	4,900	2,100
	>350	50	215	100
March	<350	1,400	0	2,100
	>350	60	0	100
Total	<350	11,700	13,566	16,240
	>350	370	611	765

We used observed diet data to estimate daily Gizzard Shad consumption by Rainbow Trout. The median number of Rainbow Trout present in each size-class during the month was multiplied by the frequency of occurrence of Gizzard Shad in the diets to determine the number of Rainbow Trout that ate shad on a given day. This is likely a conservative estimate as only fish with identifiable Gizzard Shad remains in their stomachs were counted (50% stomach evacuation rates for Rainbow Trout range from 7 to 18 h at temperatures ranging from 15°C to 5°C, respectively [Windell et al. 1976], so it is likely that more Rainbow Trout ate Gizzard Shad than we were able to document). The estimated number of Rainbow Trout that had consumed Gizzard Shad each day was then multiplied by the mean number of Gizzard Shad observed in stomachs of Rainbow Trout (based on size-class, i.e., >350 and <350 mm) for that month as measured from stomachs that had Gizzard Shad present. This produced the mean number of Gizzard Shad consumed by the population on a given day. This estimate was then multiplied by the mean weight of shad observed in the diets and the number of days in the month to arrive at the total monthly Gizzard Shad consumption.

Because precise mortality estimates were not available for stocked Rainbow Trout and estimated exploitation of this fishery were lower than most put-and-take trout fisheries, we conducted additional scenarios to provide a greater context for the potential effect of winter trout fisheries on prey abundance. First, we produced a more conservative estimate of Gizzard Shad consumption by using the lowest realistic trout densities that might be expected from our stocking rates. We chose an annual natural mortality rate of 50%, a stocking mortality rate of 10%, and used twice our observed angler harvest (1.4%/month was observed, so we used 2.8% in this scenario) for harvest mortality. This should set a realistic lower bound on the amount of Gizzard Shad that must have been consumed by Rainbow Trout in Lake Carl Etling. Second, to consider the effects of Rainbow Trout stocking if stocking rates had more closely matched angler harvest rates, we produced a higher exploitation scenario that used the same rates as the base scenario, but with 80% monthly harvest of all stocked fish in the system. Gizzard Shad consumed by Rainbow Trout for each of these additional scenarios was calculated as described above.

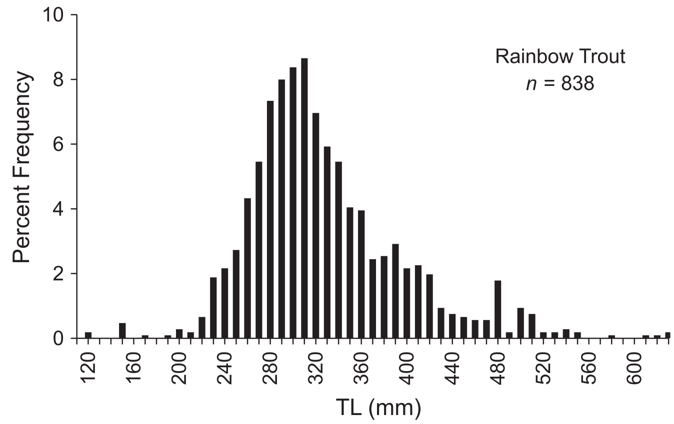

FIGURE 1. Length frequency (%) histogram of Rainbow Trout collected from Lake Carl Etling, Oklahoma, for diet evaluation. This graph represents all Rainbow Trout encountered during 2015–2017 (November–April annually).

TABLE 2. Sample size (*n*) and percent empty stomachs (% empty) of Rainbow Trout collected for diet analysis from Lake Carl Etling, Oklahoma. ND = no data; during January 2018 the lake was ice covered, so no data were collected.

	2015–2016		2016–2017		2017–2018	
Month	*n*	% empty	*n*	% empty	*n*	% empty
November	35	42.9	17	47.1	42	31.0
December	58	24.1	87	27.6	55	12.7
January	159	28.3	58	25.9	ND	ND
February	61	59.0	31	58.1	37	62.2
March	24	70.8	20	60.0	45	48.9
April	54	24.1	23	51.9	32	21.9
Total	391	41.5	236	45.1	211	35.3

RESULTS

During sampling water temperature fluctuated from 12°C in November to a low in February (4.61°C). After February water temperature increased to 15.94°C by April. A total of 838 Rainbow Trout ranging from 125 to 639 mm TL (Figure 1) were collected from Lake Carl Etling from November through April for diet analysis during 2015–2018. Diets of Rainbow Trout were fairly simplistic, and depending on the year, only eight to nine prey types were observed. Of the 838 fish collected for diet analysis, 322 had empty stomachs (41%; Table 2). Rainbow Trout rarely consumed most prey types, resulting in a low frequency of occurrence of most diet categories (Table 3). However, there were monthly spikes in a few diet categories (e.g., hemipterans in December 2015, northern watermilfoil *Myriophyllum sibiricum* in January and February 2017, and detritus in November 2017). Gizzard Shad and detritus were the most common items found in Rainbow Trout diets during all three sampling seasons. Rainbow Trout consumed Gizzard Shad during most months, but occurrence was highest in midwinter (January 2015 [52.2%] and in December 2016 and 2017 [56.3% and 50.4%, respectively]). The size of the shad consumed varied based on trout size (<350 and >350 mm). Rainbow Trout <350 mm consumed shad that averaged 66 mm TL (SE = 5.6) (maximum size consumed was 126 mm), whereas Rainbow Trout >350 mm consumed larger shad that averaged 103 mm TL (SE = 5.4) (maximum size consumed was 132 mm), which are the size-classes of shad that occur in the highest abundances (Figure 2). A sharp decline in Gizzard Shad consumption each year was followed by an increase in detritus in diets. Other fish prey consumed by Rainbow Trout included Bluegills, Green Sunfish, tiger muskellunge (Muskellunge *Esox masquinongy* × Northern Pike *E. lucius*), and other unidentified fish remains (Table 4).

The creel survey indicated Lake Carl Etling was visited by a total of 278 trout anglers during the 2014–2015

TABLE 3. Frequency of occurrence (%) by month for common diet items collected from Rainbow Trout at Lake Carl Etling from 2015 through 2018. ND = no data; lake was frozen for entire month and could not be sampled.

	Month					
Diet category	November	December	January	February	March	April
2015–2016						
Gizzard Shad	5.7	10.3	52.2	4.9	8.3	0.0
Bluegill	5.7	3.4	0.0	0.0	0.0	0.0
Green Sunfish	2.9	1.7	0.6	0.0	0.0	1.9
Unidentified fish	8.6	5.2	6.3	9.8	0.0	0.0
Diptera	0.0	0.0	0.6	0.0	0.0	0.0
Hemiptera	2.9	20.7	0.0	0.0	0.0	5.6
Odonata	5.7	0.0	0.0	0.0	0.0	0.0
Fishing baits[a]	0.0	0.0	5.1	0.0	0.0	3.7
Detritus[b]	2.9	8.6	3.8	21.3	12.5	55.6
2016–2017						
Gizzard Shad	10.6	56.3	14.7	3.2	5.0	4.3
Bluegill	0.0	8.0	0.2	0.0	5.0	2.2
Tiger muskellunge	0.0	0.0	0.0	0.0	5.0	4.3
Unidentified fish	0.0	0.0	1.7	3.2	0.0	2.2
Hemiptera	0.6	0.0	1.7	0.0	0.0	0.0
Gastropoda	0.0	0.0	0.0	0.0	0.0	2.2
Northern watermilfoil	0.0	0.0	28.8	32.3	0.0	4.3
Fishing baits[a]	0.0	6.8	1.7	6.5	0.1	0.0
Detritus[b]	0.0	0.0	15.7	0.0	30.0	19.6
2017–2018						
Gizzard Shad	2.4	50.4	ND	0.1	1.9	0.0
Bluegill	0.0	4.2	ND	0.0	0.0	0.0
Unidentified fish	2.4	1.9	ND	4.1	0.0	4.1
Hemiptera	2.4	0.2	ND	0.0	4.7	10.2
Diptera	0.0	0.0	ND	0.0	6.5	13.8
Northern watermilfoil	16.7	14.4	ND	7.8	0.0	22.7
Fishing baits[a]	0.0	2.1	ND	0.0	5.1	3.3
Detritus[b]	45.2	16.3	ND	17.2	41.2	33.9

[a]Includes hooks, fishing line, corn, salmon eggs, paste bait, fish feed, and lures (all types).
[b]Includes rocks, sticks, leaves, seeds, and sand.

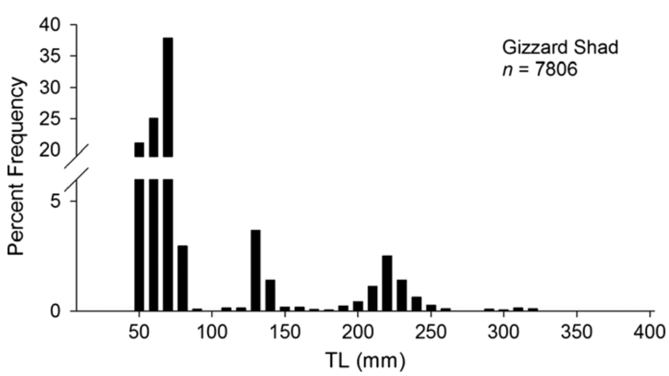

FIGURE 2. Length frequency (%) histogram of Gizzard Shad sampled by boat-mounted electrofishing during fall 2015–2017 from Lake Carl Etling, Oklahoma.

winter trout season (November–April). On average, 1.53 anglers fished for trout daily and spent 1.46 h actively fishing to catch 2.24 Rainbow Trout per angler. Over the duration of the survey, we estimated that of 744 Rainbow Trout caught, 16.2% were released, resulting in the harvest of 623 fish. All trout that were released were <350 mm, and no trout >350 mm were released, indicating anglers preferred to keep larger fish. Total Rainbow Trout harvest (623 fish) in the 2014–2015 season amounted to 8.3% of the 7,500 Rainbow Trout stocked, resulting in an accumulation of 6,877 fish by the end of the season.

Our base scenario, determined by using estimates that most closely matched those observed in Lake Carl Etling, suggested that median Rainbow Trout densities were 35–46 fish/ha after the first stocking each year and climbed

TABLE 4. Estimated number of Rainbow Trout present and the estimated biomass of Gizzard Shad they consumed monthly in Lake Carl Etling, Oklahoma, from fall 2015 to spring 2018 using three different scenarios: (1) base scenario (8% annual natural mortality, 1.6% stocking mortality, observed harvest mortality = 1.4%/month); (2) conservative scenario (50% annual natural mortality, 10% stocking mortality, 2× observed harvest mortality = 2.8%/month); (3) base with higher exploitation (base scenario rates but 80% monthly harvest mortality).

	2015–2016		2016–2017		2017–2018		Mean of all years	
Month	Median number fish/ha	Shad consumed (kg/ha)	Median number fish/ha	Shad consumed (kg/ha)	Median number fish/ha	Shad consumed (kg/ha)	Median number fish/ha	Shad consumed (kg/ha)
Base scenario								
November	46	1.4	35	0.1	45	0.3	42	0.6
December	81	5.9	68	52.3	82	54.8	77	37.7
January	120	69.2	103	4.7	119	0.0	114	24.6
February	137	1.8	131	1.1	185	0.0	151	0.9
March	152	3.5	207	2.7	216	0.1	191	2.1
April	172	0.0	204	2.3	246	0.0	207	0.8
Annual total		81.8		63.1		55.2		66.7
Conservative scenario								
November	40	1.2	29	0.1	39	0.2	36	0.5
December	67	4.9	56	42.9	68	45.4	64	31.1
January	98	56.3	83	3.8	97	0.0	93	20.0
February	107	1.4	103	0.8	150	0.0	120	0.7
March	113	2.6	164	2.2	168	0.0	149	1.6
April	124	0.0	152	1.7	186	0.0	154	0.6
Annual total		66.5		51.5		45.7		54.6
Base with higher exploitation								
November	29	0.9	22	0.1	28	0.2	26	0.4
December	28	2.0	26	19.7	29	19.5	28	13.7
January	30	17.5	27	1.2	29	0.0	28	6.2
February	17	0.2	24	0.2	47	0.0	29	0.1
March	14	0.3	52	0.7	29	0.0	32	0.3
April	16	0.0	10	0.1	26	0.0	17	0.0
Annual total		20.9		21.9		19.7		20.8

monthly to a peak of 172–246 fish/ha by April (Table 4). This resulted in monthly Gizzard Shad consumption estimates of 0–69.2 kg/ha for the entire season, depending primarily on the monthly patterns in the frequency of occurrence of Gizzard Shad in Rainbow Trout diets. Total annual consumption of Gizzard Shad averaged 66.7 kg/ha (range, 55.2–81.8 kg/ha) across the 3 years. Each year, most of the consumption occurred in a single month, either December or January, at a point in time when Rainbow Trout biomass was not yet at its peak. During these months, the frequency of occurrence of Gizzard Shad in Rainbow Trout diets was high, and the average number of Gizzard Shad observed in these diets varied by trout size: <1–4.76 shad/d for trout <350 mm and 3.6–11.5 shad/d for trout >350 mm.

Our more conservative scenario (50% annual natural mortality, double the harvest estimate to 2.8% per month, and 10% stocking mortality) still estimated that median Rainbow Trout densities increased to 124–186 fish/ha by April (Table 4). This resulted in monthly Gizzard Shad consumption estimates of 0–56.3 kg/ha and an average annual consumption of 54.6 kg/ha (range, 45.7–66.5 kg/ha) across the 3 years. Our high-exploitation scenario (80% monthly harvest on Rainbow Trout) produced much more moderate Rainbow Trout abundances (monthly densities ranged from 10 to 32 fish/ha), resulting in monthly Gizzard Shad consumption rates of 0–19.7 kg/ha and an average annual consumption of 20.8 kg/ha (range, 19.7–21.9 kg/ha) across the 3 years (Table 4).

DISCUSSION

Most previous investigations evaluating the effects of stocking Rainbow Trout focused on the effects of stockings on native stream species (Metcalf et al. 1997; Fenner et al. 2004; Weaver and Kwak 2013). Few studies have reported on the effects of stocking Rainbow Trout in small impoundments to establish wintertime fisheries. Our study indicates the importance of monitoring these wintertime fisheries, as our results showed Rainbow Trout consumed a large biomass of Gizzard Shad such that they likely had a meaningful effect on forage abundance in Lake Carl Etling. Gizzard Shad were the primary prey for Rainbow Trout for 2 to 3 months following the initial stocking. Our results suggest Rainbow Trout consumed an average of 66.7 kg/ha of Gizzard Shad (range, 55.2–81.8 kg/ha). This is a substantial biomass of Gizzard Shad for any system. Although we do not know the true biomass of Gizzard Shad in Lake Carl Etling, Evans et al. (2014) found the median Gizzard Shad biomass obtained from a literature review to be 85 kg/ha and the interquartile range to be 28.5–146.8 kg/ha. Therefore, Rainbow trout would have removed 78% of the Gizzard Shad biomass if the lake were at the median abundance for this species. Even if Lake Carl Etling was at the 75th percentile of Gizzard Shad abundance, Rainbow Trout would have removed over 45% of the biomass. The suggestion that Rainbow Trout decreased prey availability is further supported by the observation that as densities of trout increased throughout the winter stocking program, the abundance of edible sizes of Gizzard Shad declined. By spring, <3% of Gizzard Shad sampled were <150 mm TL compared with the 96.3% observed each fall before stocking Rainbow Trout (R. Snow, unpublished data). Although low, age-0 Gizzard Shad abundance in spring could be caused by high overwinter mortality related to extreme temperature or starvation (Fetzer et al. 2011), our evaluation of Rainbow Trout diets indicated a substantial portion of the decline of age-0 Gizzard Shad was likely caused by Rainbow Trout consumption. Further, every year after a large number of Gizzard Shad had been consumed, Rainbow Trout switched to foraging on detritus, presumably because low Gizzard Shad abundance caused the trout to seek alternate food sources. Although we cannot say for sure that prey were limiting the piscivore community in Lake Etling, our observations indicate this was likely the case.

The effect Rainbow Trout had on age-0 Gizzard Shad biomass was substantial for the base and conservative scenarios used in this study. New predator species should not be introduced into food-limited piscivore communities if maintaining existing piscivores is an important management objective. Evans et al. (2014) provided an easy-to-use method to estimate predator demand for age-0 Gizzard in order to assess the ability of a system to sustain additional piscivore species. Using the Evans et al. (2004) approach, Lake Carl Etling would need at least 42 kg/ha of Gizzard Shad to support the three main piscivores in this system: Largemouth Bass (1-2-3-3), saugeye (Walleye × Sauger *S. canadense*; 1-1-1-3), and hybrid Striped Bass (White Bass *Morone chrysops* × Striped Bass *M. saxatilis*; 2-1-1-3); the four-digit codes in brackets represent the Evans et al. (2004) coding we used for each population's growth rate, mortality rate, population size, and proportion of Gizzard Shad, respectively, in the diet. This is a conservative predator-demand estimate for Lake Carl Etling as it does not account for consumption by tiger muskellunge and Black Bullheads, which are present but are not covered by Evans et al. (2004), so they could not be included in the native predator demand estimate. Using this predator-demand estimate of 42 kg/ha derived from Evans et al. (2004) and our base scenario Gizzard Shad consumption estimate of 67 kg/ha, the total predator demand for Gizzard Shad in Lake Carl Etling must be at least 109 kg/ha; Rainbow Trout accounted for over half of this consumption. Assuming Lake Carl Etling has an average age-0 Gizzard Shad abundance (85 kg/ha was the median Gizzard Shad abundance reported by Evans et al. 2014), Rainbow Trout stockings are likely not sustainable at the current stocking rates in Lake Carl Etling. Even with our conservative scenario where angler harvest of Rainbow Trout was twice what we observed in creel surveys, total predator demand was 63 kg/ha (i.e., 42 + 21 kg/ha); Rainbow Trout used over a third of the consumed Gizzard Shad biomass. However, this conservative scenario would be sustainable if the lake has an average Gizzard Shad biomass (85 kg/ha: Evans et al. 2014). Clearly, the amount of Gizzard Shad consumed by Rainbow Trout in Lake Carl Etling could have negative effects on the native predators, especially in years when limited harvest of Rainbow Trout occurs or in years where Gizzard Shad reproduction or recruitment is low. This likely would negatively affect several sport fish species in the lake.

Our estimates of the biomass of Gizzard Shad consumed by Rainbow Trout are likely conservative. We intentionally used conservative estimates for several parameters to ensure we did not inflate our final estimates. First, we estimated angler harvest for April, a month for which no creel data existed, based on the average of the 2 months with the highest harvest. Second, our method for calculating Gizzard Shad consumption used diet observations, so Gizzard Shad consumed earlier in the day may have been missed if digestion was rapid enough for the stomach to be evacuated by the time we collected the Rainbow Trout and checked it for stomach contents. Further, the conversion of the number of Gizzard Shad consumed to the biomass consumed was made based on the weight of fish observed in the diets. We attempted to use weights of relatively intact fish, but these weights would be expected to be biased low because some digestion likely already had occurred. Despite all of these conservative biases, we still demonstrated extremely high Gizzard Shad consumption rates by the Rainbow Trout population because of the high densities of stocked fish. In actuality, it is likely the situation is even more extreme than our calculations indicated.

Clearly, the stocked Rainbow Trout have a meaningful effect on the biomass of Gizzard Shad in Lake Carl Etling; however, environmental conditions may also further reduce Gizzard Shad availability. Gizzard Shad also experience winter die-offs when water temperatures are below 4°C (Porath 2006). During January 2018, Lake Carl Etling was completely iced over. Although ice cover is variable from year to year, it is clear that cold water could lead to winter Gizzard Shad die-offs, at least in some years. During such years, Odenkirk and Estes (1991) found that Rainbow Trout consumed large numbers of Threadfin Shad *D. petenense* during winter months in the stilling basin below Center Hill Dam, Tennessee. During this time, when many age-0 Threadfin Shad pass through the dam, many were dead or dying due to low temperatures (<9°C; Sammons et al. 1998), giving the Rainbow Trout an almost limitless winter forage base. Therefore, it is possible that some of the heavy consumption of Gizzard Shad by trout observed in our study was related to a die-off of Gizzard Shad during prolonged cold events. In these cases, forage-size Gizzard Shad would be removed from the system regardless of whether Rainbow Trout were stocked. However, our calculations still demonstrate that in years when temperatures are moderate and the overwinter survival of Gizzard Shad would otherwise be higher, Rainbow Trout had a meaningful effect on the abundance of forage-size Gizzard Shad, essentially ensuring that limited numbers of forage-size Gizzard Shad persist through spring.

Gizzard Shad can be valuable forage for piscivorous fishes, but they can also be undesirable for small impoundments (Neely et al. 2018). Gizzard Shad can influence zooplankton and phytoplankton densities, resulting in interspecific competition with juvenile and adult sport fish, especially at high abundances (Aday et al. 2003). Additionally, Gizzard Shad can significantly increase phytoplankton, nutrient levels, and suspended solids, which increases turbidity (Schaus and Vanni 2000; Aday et al. 2003) and potentially affects the foraging ability of visual predators (Shoup and Wahl 2009; Carter et al. 2010; Shoup and Lane 2015). Therefore, Gizzard Shad can negatively affect aquatic environments, and fisheries managers have attempted to reduce their numbers to improve the growth of resident sport fish in small impoundments (Neely et al. 2018). If Rainbow Trout can affect age-0 Gizzard Shad biomass in other small impoundment as they did in Lake Carl Etling, they may serve as a feasible biological control of overabundant Gizzard Shad in these systems. The appeal of using a species such as Rainbow Trout as a predator is their abundance can be controlled by stocking and they will die when water temperatures become too warm in southern impoundments (by spring or early summer), preventing their natural reproduction. Furthermore, we caution management biologists to monitor water quality by measuring dissolved oxygen and temperature at different depths throughout the year to ensure that introduced trout will die from thermal stress. Due to gape limitation of stocked trout, its likely they will only control age-0 Gizzard Shad, so suitable levels of Gizzard Shad reproduction may still prevent adequate predatory control by trout of Gizzard Shad populations that have fast growth, large adult biomass, and limited abundance of age-0 fish (Michaletz 2017). However, managers should be careful to ensure Rainbow Trout cannot survive in thermal refugia during summer or they may become difficult to control and simply trade one problem for another.

This study demonstrates strong unintended consequences of stocking a predatory fish. Even in our higher exploitation scenario, a substantial portion of age-0 Gizzard Shad biomass was consumed by stocked Rainbow Trout. This makes the underutilization of Rainbow Trout by anglers at Lake Carl Etling a cause for concern (i.e., 91% of the stocked Rainbow Trout remained in the system until they died of nonangling mortality sources). Harvest benchmarks for put-and-take Rainbow Trout fisheries are often set by state management agencies at 50% to 60% of the fish stocked (Johnston and Rebert 1982; Ott 1985; Johnson et al. 1995) in order to best allocate stocking resources. If angler survey results suggest that harvest pressure does not exceed these standards on a particular waterbody, biologists can reallocate those trout to different systems where they are more likely to be fished. Stocking Rainbow Trout is expensive (ODWC spends ~US$500,000 annually to stock trout); therefore, it is critical to manage these resources as effectively as possible. Another alternative, which is being explored by ODWC, is to create an area of the lake where Rainbow Trout can be confined specifically for trout fishing. In the case of Lake Carl Etling, this could be accomplished by damming the creek that flows into the reservoir just before it flows into the main lake. This would allow fewer fish to be stocked annually, it will concentrate trout in a smaller area and be more accessible to anglers, ultimately lowering overall cost while increasing harvest and angler satisfaction and minimizing the forage consumed by the put-and-take fishery. Although this example is specific to Lake Carl Etling, it demonstrates that managers sometimes need to alter management strategies if a stocking program is going to be continued. In summary, management biologists should evaluate the forage base before stocking, conduct angler surveys to ensure harvest benchmarks are being met following stocking, and be open to altering management strategies to avoid unintended negative effects caused by stocking a predator into aquatic systems. Failure to consider these factors could lead to wasted resources and potential harm to the natural fisheries where stocking occurs.

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