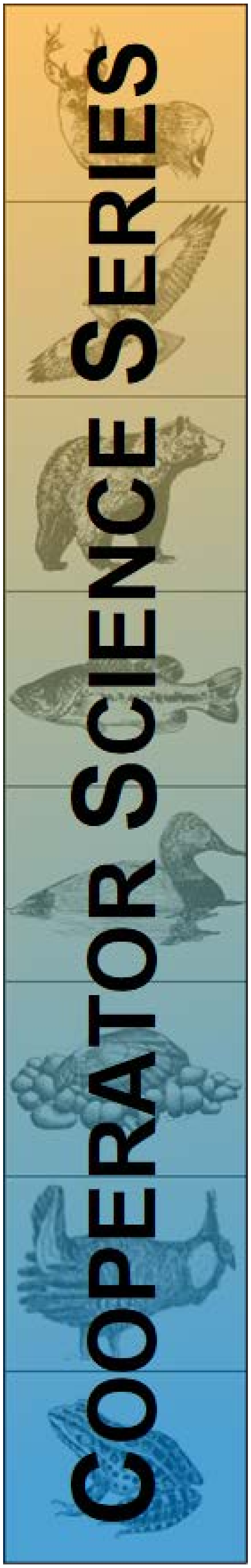

Assessing Wild Juvenile Trout Ecology in the Lower Mountain Fork

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ASSESSING WILD JUVENILE TROUT ECOLOGY IN THE LOWER MOUNTAIN FORK

Final report to the Oklahoma Department of Wildlife Conservation

F16AF00236

August 2018

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EXECUTIVE SUMMARY

Reservoir tailwaters can be valuable fisheries for Rainbow Trout (*Oncorhynchus mykiss*), which is commonly stocked as mitigation for the altered habitat because it performs well as a put-and-take species in these thermally depressed systems. These fisheries are usually sustained by stocking due to flow fluctuations and lack of suitable spawning habitat that may limit natural reproduction. The Lower Mountain Fork River (LMFR) below Broken Bow Dam in southeastern Oklahoma is one of two year-round trout fisheries in the state and wild, juvenile Rainbow Trout were documented beginning in 2006, prompting speculation about the potential for a self-sustaining population. To determine this potential, we searched several sites over two years throughout the LMFR for wild, juvenile Rainbow Trout to estimate several parameters related to their population status (e.g., age, growth, time of spawning and hatching, and prey use). We also assessed the availability of macroinvertebrate prey to determine how food resources may affect trout sustainability. We found wild, juvenile Rainbow Trout each year, but only at sites within the first 4.5 km of the 19-km tailwater. Juvenile trout were the result of spawning that took place from late January through mid-April. Growth and body condition were variable between years, but similar to other systems. Weekly survival estimates using catch curves were low (<80%), suggesting limited potential for recruitment; however, declining catchability of larger juvenile fish likely biased these estimates. Wild, juvenile Rainbow Trout ate a variety of food items, but selected for Amphipoda and Diplostraca and against Trichoptera. Overlap in diet with adult Rainbow Trout was low (Bray-Curtis dissimilarity = 0.70). Macroinvertebrate prey resources available to trout varied among management zones, being most abundant in Zone 1 and Zone 3. Potential for a wild fishery may exist in the upper portion of the LMFR but additional research on recruitment to adulthood would be required to provide a more definitive answer.

INTRODUCTION

Broken Bow Dam was completed in 1968 about 4 kilometers (km) east of the community of Hochatown, Oklahoma, forming Broken Bow reservoir (Harper 1994; Figure 1). Prior to the construction of Broken Bow Dam, the Lower Mountain Fork River (LMFR) was a warm water fishery that supported a native fish community (Eley et al. 1981). Hypolimnetic release from the Broken Bow reservoir formed a coldwater, tailrace stream below the dam, reducing the number and abundance of many of the native fishes. Non-native trout (Salmonidae) was thus considered for stocking to mitigate the loss of native fishes.

Reservoir tailwaters can be a valuable resource for creating trout fisheries, particularly in regions not normally favorable to coldwater species (Dreves et al. 2016). Rainbow Trout (*Oncorhynchus mykiss*) is commonly stocked in tailwater streams because it performs well as a put-and-take species and is very receptive to sportfishing (Swink 1983). The Oklahoma Department of Wildlife Conservation (ODWC) began stocking Rainbow Trout in the LMFR in 1989, designating approximately 19 km of the stream and its tributaries, from the Broken Bow Reservoir spillway dam downstream to the U.S. 70 bridge, as a year-round put-grow-and-take fishery (Harper 1994). Beginning in 1991, Brown Trout (*Salmo trutta*) was also stocked to expand fishing opportunities (O'Donnell 1996).

Trout populations in many cold tailwater streams are often maintained by stocking because flow fluctuations and lack of suitable spawning habitat can limit natural reproduction (Pender and Kwak 2002). However, wild, juvenile Rainbow Trout was first found in the LMFR in 2006 by the ODWC (P. Balkenbush, ODWC, unpublished data) and again in 2014 in the vicinity of Spillway Creek (K. James, ODWC, unpublished data). Additionally, Long et al. (2016) found wild, juvenile Rainbow Trout in 2015 and 2016 in two different tributaries of the

LMFR, all in Zone 1 of the fishery (Figure 1). Furthermore, the Lower Mountain Fork River Foundation (LMFRF) began placing Whitlock-Vibert boxes with Brown Trout eggs in the river in 2009 to encourage wild production of this species (http://lmfrfoundation.org/vibist-box-brown-trout-egg-planting/). Wild trout fisheries are uncommon in southeastern U.S. tailwaters, with 10 of 49 fisheries surveyed in 2005 supporting wild trout (SARP, Mitigation Fisheries Workgroup 2005). But, almost half of these 49 fisheries support put-grow-and-take fisheries, including the LMFR, suggesting suitable conditions for growth for any wild fish that are produced. Therefore, we sought to determine the feasibility of wild-produced trout persisting in the LMFR

OBJECTIVES

1) Determine hatching times, growth, and survival of wild juvenile trout in the lower Mountain Fork
2) Determine invertebrate prey resource availability in relation to use and overlap between wild juvenile trout and stocked trout in the lower Mountain Fork.

METHODS

Study site – The LMFR is a tailwater stream below Broken Bow Dam in the Ouachita Mountains of southeastern Oklahoma (Figure 1). Broken Brow Lake was impounded, among other reasons, for hydropower production, flood control, and recreation. The LMFR trout fishery is a 19-km stretch of stream originating from the Broken Bow Spillway dam discharge into Spillway Creek. Discharge for power generation comes from the Powerhouse dam, through the power house and into the river approximately 7 km downstream from the spillway discharge.

This upper section of the fishery exists within Beavers Bend State Park surrounded by U.S. Forest Service land of the Ouachita National Forest. Beavers Bend State Park attracts approximately 1 million visitors annually, including trout anglers (Caneday et al. 2010) who fish mostly within the state park (Harper 1994). Approximately three quarters of the trout anglers at LMFR in 2010 came from out of state, had high annual household income ($105,000), and spent an average of $543 per trip (Reilley 2011), resulting in an economic benefit multiplier of 2.29 to the community (i.e., $1 spent by anglers = $2.29 benefit to local economy; Boyer and Long 2012).

Objective 1 – The 19-km portion of the LMFR designated as a trout stream was sampled according to the three management zones established by the ODWC (Figure 1). We sampled for juvenile trout at 4-5 sites in zone 1, and 3 sites each in zones 2 and 3 with backpack electrofishing. Samples were conducted monthly in 2016 from April through August and bi-monthly in 2017 from March through July, to coincide with post-hatching time of juvenile Rainbow Trout (Long et al. 2008; 2016). Each site was sampled in 150-meter transects with 30 minutes of effort in representative available habitat types (runs, riffles, pools, and undercut banks). At the end of each transect, all juvenile trout (< stocking size of 229 millimeters [mm] total length [TL]) were counted, euthanized, stored in 70% alcohol, and transported to the lab for further analysis.

In the lab, we recorded total length (mm) and weight (g) and extracted sagittal otoliths under a dissecting scope. We mounted otoliths to slides with thermoplastic cement and sanded with 600-2000 grit sandpaper to reveal rings near the core and the edge. To estimate age, we counted daily rings in each otolith twice, by one reader, under 40X magnification (Campana

1992). We averaged counts that fell within 10% of each other to estimate final total age and we excluded counts outside of the 10% range (Neilson 1992).

Rainbow Trout otoliths exhibit multiple primordia, with daily rings pre- and post-hatch, when a prominent check is often visible (Moyano et al. 2012). When a hatch check was prominent, we counted the number of rings since the check and assigned a hatch date as the number of rings minus the capture date. For all otoliths, with and without hatch checks, we counted total number of rings, added 15, and subtracted from capture date as an estimate of spawning date (Salem and Omura 1998; Long et al. 2008).

We determined growth rates (*a*, mm/day) by regressing total length (mm) against age (days) since hatch using a linear model: length = $y0 + a$*age, where $y0$ is the intercept. Age since hatch was determined directly for fish with an identifiable hatch mark as total age minus age before hatch. For fish without a hatch mark, we subtracted the average pre-hatch age of fish with a hatch mark (captured in similar settings and years) from total age. Body condition was assessed by regressing weight on length with a power model, weight = a*length^b, using Sigma Plot v.13.0 software, where *a* is the intercept and *b* is the slope. Differences in growth and condition were assessed by calculating 95% confidence intervals and comparing slope values for overlap.

Too few fish for each daily age were available to calculate daily survival (Starks et al. 2016) so we assessed weekly survival for the Evening Hole (sites 2, 3, and 13 combined) in 2016 and 2017 and the unnamed intermittent tributary in 2016 by grouping fish into weekly cohorts based on spawning date (e.g., spawn date 1/20/2017 = week cohort 3) and subtracting the week of sampling to calculate age in weeks. The abundance of each cohort for each week was *ln* transformed, plotted against weekly age, and the slope of the descending limb (*Z*, the instantaneous total mortality rate) was used to estimate weekly survival (*S*) based on the equation $S = e^{-Z}$ (Van Den Avyle 1993).

Objective 2 – To determine prey resource availability, we collected macroinvertebrates monthly from May – August 2016 and March – July 2017, from multiple sites in all three zones within the designated trout area of the LMFR (Figure 1). Thirteen sites were sampled in 2016 and, because juvenile trout were found in the intermittent tributary (IT), we added this site for macroinvertebrate collection in 2017. We utilized kick seines in riffles in conjunction with Hester Dendy (HD) multiplate samplers in runs to collect the entire range of macroinvertebrates available (Carter and Resh 2001). We employed a rectangular frame kick seine frame, in one riffle, at each sample site ($N = 14$). Macroinvertebrates were dislodged from the benthos by kicking or agitating submerged substrate or hand scrubbing, then removing larger substrate followed by kicking, for 1 minute, in a 1-square meter (m^2) area immediately upstream of the kick seine.

We employed HD samplers in deeper run areas near kick-seine sampled riffle areas at 10 sites (4 in zone 1 and 3 in both zone 2 and 3) as complementary sampling techniques (Carter and Resh 2001). Each 14-plate round HD sampler covered 0.13 m^2 and 3 HD samplers were attached to a cinder block at each site with poly-coated wire and secured with stainless steel wire clamps. In areas of high flow, we used flat cinder blocks or pavers to hold samplers in place. We positioned each cinder block and sampler on the substrate of the river and covered it with nearby available rocks. After a colonization period of approximately 4 weeks, we detached samplers to collect macroinvertebrates from plate surfaces and then replaced them (Guild et al. 2014).

To decrease laboratory sorting time, we removed large organic debris and stones in the field and then hand-picked macroinvertebrates for either 5 minutes or until no macroinvertebrates remained. We pooled kick samples and HD samples for each site. Samples were preserved in the field in 70% ethyl alcohol and transported to the lab where they were sorted and identified to lowest practical taxon.

Examination of the LMFR established that adult and juvenile Rainbow Trout co-occur in similar habitats. Therefore, to identify prey overlap between juvenile and adult Rainbow Trout, we acquired adults from anglers and with backpack electrofishing at the Evening Hole sites, bi-monthly from April - July 2017. We attempted to collect 7 adults each sample trip. In the field, adults were euthanized, measured (total length in mm), and heads and stomachs were removed, stored in 70% alcohol, and transported to the lab.

In the laboratory, we removed the stomachs of juvenile and adult Rainbow Trout and identified stomach contents to the lowest practical taxonomic level by examination under a dissecting microscope. For substantially digested prey items, identification was based on heads (for invertebrates) or vertebral columns (for fish). We used keys by Merritt et al. (2008), Smith (2001), Triplehorn and Johnson (2005), and Wiggins (2014) to identify terrestrial and aquatic invertebrates.

We evaluated diet patterns of juvenile Rainbow Trout using a graphical representation of prey composition developed by Amundsen et al. (1996). The Amundsen method plots specific-prey abundance (P_i) against frequency of occurrence (F_i), using the equations:

$$P_i = (\sum S_i / \sum S_{ti}) \times 100$$

$$F_i = (N_i / N) \times 100$$

where P_i is the prey-specific abundance of prey i, S_i represents the quantity of prey item i in stomachs, S_{ti} is the total prey quantity in trout that contain prey i in their stomach, F_i is the frequency of occurrence of prey type i, N_i equals the number of trout with prey item i in their stomach, and N is the total number of trout with stomach contents.

Macroinvertebrate sampling from the environment in conjunction with gut content analysis allows for prey electivity analysis (Strauss 1979) indicating the taxa groups trout are selecting to eat. We implemented Strauss' electivity index (L), which compares the utilization of food with respect to its availability in the environment and is calculated as:

$$L = r_i - p_i$$

with r_i and p_i representing the relative abundance of prey in the gut and then the environment. Index values range from −1 to +1, with positive values indicating preference, negative values indicating avoidance, and zero indicating a random feeding pattern (Strauss 1979).

We implemented a zero adjusted Bray-Curtis dissimilarity test (Clarke et al. 2006) to examine the degree of dietary overlap between juvenile and adult Rainbow Trout, collected in 2017. We condensed consumed prey into 24 prey groups that included both aquatic and terrestrial invertebrates. We excluded non-food items such as rocks, sticks and leaves, and unidentifiable prey from this analysis. The formula to calculate Bray-Curtis dissimilarity (D) is:

$$D = \frac{\Sigma i \ |yi1 - yi2|}{2 + \Sigma i \ (yi1 + yi2)}$$

where $yi1$ and $yi2$ represent the number of items of prey group i in juvenile and adult Rainbow Trout, respectively, and Σi represents the total number of prey items summed across all i prey groups. A value of 1 indicates that the prey communities eaten are totally different between adult and juvenile trout and a value of 0 indicates prey communities are identical.

RESULTS

Objective 1 – From the 12-13 sites sampled for trout in the lower Mountain Fork in 2016 and 2017, wild, juvenile trout were only captured in Zone 1 upstream of the Bee Branch confluence (sites 2, 3, 13, and IT; Figure 1; site 1 not sampled for fish, only for macroinvertebrates). Scour from the flood of 2015 (ODWC 2015) made Spillway Creek (e.g., site 1) unsafe for backpack electrofishing. From sampling April through August of 2016, we found 58 wild, juvenile Rainbow Trout; 32 from in an intermittent tributary that flows into lower Spillway Creek and 26 just downstream, from the Evening Hole (Sites 2-3 and 13; Table 1). No juvenile Brown Trout were captured. In 2017, we sampled from March through June capturing 27 juvenile trout (24 Rainbow Trout and 3 Brown Trout) in the Evening Hole area (sites 2, 3, and 13). In the intermittent tributary, only 1 juvenile Rainbow Trout was captured in 2017. Combined between years, juvenile Rainbow Trout from the Evening Hole averaged ~56 mm TL and 3.5 g weight, compared to ~45 mm TL and 2 g weight in the intermittent tributary. The three juvenile Brown Trout were larger than the Rainbow Trout, averaging 105 mm TL and 25 g weight.

From analysis of otoliths, we were able to estimate spawning dates and hatching dates for most fish, although only Rainbow Trout in the Evening Hole in 2016 and 2017 and in the intermittent tributary in 2016 provided more than 3 data points (Table 2; Figure 2 and 3). In 2016, spawning and hatching occurred earlier in the intermittent tributary than in Evening Hole. Generally, spawning occurred from mid-January to the end of March and hatching from late-February to mid-April in 2016. In 2017, spawning in the Evening Hole occurred from late-January to mid-April and hatching from late-February to mid-May. The single Rainbow Trout that was captured from the intermittent tributary in 2017 was estimated to have hatched on

March 25. We were able to estimate the hatching dates of two of the three juvenile Brown Trout captured from the Evening Hole in 2017 (February 9 and March 25).

Juvenile Rainbow Trout sampled from Evening Hole in 2016 had average daily growth rates of 0.46 mm/day compared to those from the Intermittent tributary, which averaged 0.24 mm/day (Table 3; Figure 4). In 2017, the growth rate of wild, juvenile Rainbow Trout from the Evening Hole was much greater than 2016, at 1.15 mm/day. Only one fish was captured from the Intermittent tributary in 2017 (36 mm TL, 0.59 g weight, 26 days old since hatch on 3/25/2017), preventing an estimate of growth using regression procedures. Condition of fish varied among sites and years with juvenile wild Rainbow Trout having the best condition in 2016 from the Evening Hole and worst condition in 2017 from the same site (Table 4; Figure 5).

Weekly survival estimates for wild, juvenile Rainbow Trout ranged from 61% to 77%, although only the estimate for the Evening Hole in 2017 was significantly different from 0 (Table 5; Figure 6). Put into context, extrapolating from an arbitrary 1 million offspring produced during week 10, the first full week where the fish recruited to the gear in 2017, and assuming constant survival and catchability thereafter, none of the fish would remain past week 40 at the 61% survival rate; none past week 45 at the 66% survival rate; and 20 would be left alive by the end of the first year at the 77% survival rate.

Objective 2 – From May through August of 2016 we collected 5,546 macroinvertebrates representing 41 unique taxa (15 orders, 28 families, and 30 genera) from kick seine and HD samplers (Table 6; Appendix A). Trichoptera, Isopoda, Diptera, Ephemeroptera, and Plecoptera comprised the dominant components of the benthic macroinvertebrate community accounting for 91% of total individuals collected. From March through July of 2017 we collected 7,854 macroinvertebrates representing 47 unique taxa (17 orders, 30 families, and 35 genera) from kick seine and HD samplers (Table 7; Appendix B). Trichoptera, Diplostraca, Isopoda, Diptera, and Ephemeroptera comprised the dominant components of the benthic macroinvertebrate community accounting for 84% of total individuals collected. Longitudinal trends in macroinvertebrate community composition were evident in both years. Isopoda predominated the community in Zone 1 in both years, whereas Trichoptera and Diplostraca predominated in zones 2 and 3.

We analyzed stomach contents from 83 juvenile Rainbow Trout (58 in 2016 and 25 in 2017) from 2 sites (Evening Hole and the intermittent tributary) and 23 adult Rainbow Trout in 2017 from Evening Hole. Two juveniles and 3 adults had empty stomachs. Items unidentifiable to a lower taxonomic unit (e.g., insect wing) and non-prey items (e.g., sticks, fish hooks) collectively comprised 3.7% and 5.5% of stomach contents for juvenile and adult Rainbow Trout, respectively, were excluded from all further calculations. We identified 53 prey categories, but the most commonly consumed by juvenile Rainbow Trout were Diplostraca, Amphipoda, Ephemeroptera, and Diptera (Table 8; Figure 7). The most commonly consumed prey items for adult Rainbow Trout with food items (N = 21) included terrestrial and aquatic phases of Trichoptera and Ephemeroptera in addition to Isopoda and Coleoptera (Table 9).

Differences in prey use were apparent between locations and years. In 2016, for fish that contained identifiable prey items, juvenile Rainbow Trout in the intermittent tributary (N = 32) consumed a mean of 7 prey items (± 0.8 SE) per fish compared to 22 (± 4.5 SE) per fish in Evening Hole (N = 25). In 2017, Rainbow Trout with indefinable prey items in Evening Hole (N = 24) consumed a mean number of 30 (± 9.4 SE) items. Only one wild juvenile Rainbow Trout was captured from the intermittent tributary in 2017, which consumed 15 prey items. Adult

Rainbow Trout from the Evening Hole that contained identifiable prey (N = 21) consumed a mean of 13 (± 3.1 SE) prey items per fish.

We computed the Strauss' feeding electivity index from stomach contents of 49 juvenile Rainbow Trout from the Evening Hole site (25 in 2016 and 24 in 2017) that contained identifiable prey items by comparison to prey identified at nearby sites (site 2 in 2016 and sites 2 and 13 in 2017). In 2016, juvenile Rainbow Trout exhibited a preference for Amphipods, while selecting against Trichoptera. In 2017, fish exhibited a preference for Diplostraca, while again selecting against Trichoptera (Table 10).

Between juvenile and adult Rainbow Trout in 2017, the zero adjusted Bray-Curtis dissimilarity index (0.70) indicated that diets were moderately dissimilar (Table 11). Prey items consumed by juveniles but not adults included Diplostraca, Hygrobatoidea, Oligocheata, and Phlaeothripidae. Conversely, prey items consumed by adults but not juveniles included fish, Diptera pupae, Odonata, and Trichoptera pupae.

DISCUSSION

Juvenile wild Rainbow Trout were found in both years, but only in Zone 1, within Beavers Bend State Park, and only above the confluence with Bee Branch, suggesting limited, but sustained reproduction. Due to safety concerns, we were not able to survey Spillway Creek, which represents another ~2 km of stream habitat, but photographs of apparently wild-produced juvenile Rainbow Trout taken by anglers indicate potential reproduction in this area as well. Variation in habitat quality, as inferred by variation in prey use and availability, growth rates, and body condition, was evident spatially and temporally. Coupled with variable survival estimates, these data suggest that some level of recruitment to the trout fishery in the first 4.5 km of the tailwater is possible.

Spawning dates are difficult to precisely estimate because of variability in timing of hatching, which is temperature dependent (Crisp 1981). Additionally, daily otolith rings form before hatch in trout (Moyano et al. 2012), making an estimate of spawning date difficult because it is not known when the first pre-hatch ring is formed. The spawning date estimates we relied upon were based on total number of rings in the otolith and assumed a fixed period of time (15 days) for the first pre-hatch ring to form since spawning (Salem and Omura 1998; Long et al. 2008). To compare, we used a set of equations developed by Crisp (1981) that related hatching time with water temperature. Using the best fitting equation from Crisp (1981) for Rainbow Trout (1b; $\log D = b \log (T - \alpha) + \log a$), where D is the number of days since fertilization, a and b are constants obtained from Crisp (1981) Table 2 ($\log a = 4.0313$ and $b = -2.0961$), T is the water temperature ($T = 10.4$°C, which was mean water temperature of Evening Hole in January and February 2016 when spawning likely occurred, D. Groom, ODWC, unpublished data), and α is a temperature correction factor from Crisp (1981; Table 2) ($\alpha = -6.0$), suggests 31 days to hatch from spawning. Subtracting 31 from hatch dates to estimate spawning dates produced spawning dates that differed from our age-based estimates in 2016 (the year when water temperature data were available) by an average of -5 days (range from -13 to +4-day difference). Thus, the spawning date estimates we produced through otolith microstructure examination were consistent within approximately 1 week with the temperature-based estimates from Crisp (1981).

Our estimates of juvenile survival suggest minimal ability for recruitment to adulthood, but the catch curve model we relied on assumes equal catchability throughout the age cohorts included in the model (Van Den Avyle 1993), which was unlikely in our study. We often found larger, presumably older, fish avoided stunning by the electricity of the backpack electrofisher. Thus, we view the weekly survival estimates as conservative, representing the minimum value. Future investigations could use methods better able to catch larger fish, such as tow-barge electrofishing, or blocking sections of the stream to improve capture efficiency. However, these methods could be problematic in the upper LMFR because anglers are frequently encountered in the upper reaches of the fishery. Alternatively, mark-recapture studies could be used to estimate survival more precisely (e.g., Olsen and Vollestad 2001; Mitro and Zale 2002) and otolith microchemistry studies could elucidate the proportion of adult Rainbow Trout that were produced in the LMFR instead of being stocked (e.g., Bickford and Hannigan 2005).

Spawning by Rainbow Trout, as indicated by capture of wild juveniles was limited to the upper portion of the LMFR trout fishery, but the factors limiting reproduction in other areas are unknown. In a survey of biologists in the southeastern U.S. who manage trout tailwaters, spawning habitat in the LMFR was considered “inadequate” (SARP, Mitigation Fisheries Workgroup 2005), but there is clearly adequate spawning habitat (i.e., gravel substrate) in the upper portion of the fishery given the consistent production of wild juveniles. We are unaware of any formal assessments of spawning habitat availability in the LMFR, although rapid assessments, such as side-scan sonar (e.g., Kaeser and Litts 2010; Walker and Alford 2016), would be useful for defining zones where sufficient spawning habitat exists. Such an effort, combined with monitoring, could then help identify other factors that may be limiting trout reproduction (e.g., prey availability, temperature, and dissolved oxygen).

Apart from any differences in habitat that may exist, differences in macroinvertebrate food availability were evident among zones, with zone 2 exhibiting considerably lower macroinvertebrate abundance than zones 1 and 3. Such differences could cause differential trout reproduction success. In the Evening Hole, juvenile Rainbow Trout grew from 0.46 to 1.15 mm/day which is comparable to, or better than, other systems with consistent trout reproduction. For example, juvenile Rainbow Trout exhibited a peak of 0.46 mm/day in the Lees Ferry reach of the Colorado River (Korman et al. 2011) and an average of 0.7 mm/day in the Clinch River, Tennessee (Bettoli and Bohm 1997). Thus, in this area of the LMFR, macroinvertebrate prey resources do not appear to be limiting. However, juvenile Rainbow Trout grew much more slowly (0.24 mm/day) in the intermittent tributary, Spillway Creek, which is similar to small tributaries of other southeastern U.S. tailwater systems (Long et al. 2008) where recruitment potential was considered limited.

Our results suggest that if the ODWC is interested in promoting a wild fishery, in at least a portion of the LMFR, Zone 1 would be best as it is the only portion of the river with any indication of successful reproduction. Promoting a wild fishery would likely be positively received by some anglers, such as those affiliated with the LMFRF, who are already stocking Brown Trout eggs to encourage wild-born fish as part of the fishery. In some cases though, stocked fish have suppressed wild production (Vincent 1975; 1987) and an experimental cessation of stocking in Zone 1 could be used to study the potential for a wild fishery (e.g., O'Rouke and Martin 2011). Even though the benefits of stocking outweigh the costs at the LMFR trout fishery (Boyer and Long 2012), reducing stocking to promote a wild fishery could save money that could be allocated elsewhere. Under a stocking cessation scenario, catchability of trout by anglers may decline (Bettinger and Bettoli 2002; Young and Hayes 2004), but see O'Rouke and Martin (2011) who found no decline in catchability. Subsequent creel surveys could be used to monitor this effect and resulting angler satisfaction. Whether reduced catch rate is viewed favorably by anglers in exchange for catching wild fish is unknown, but may be related to differences among angler types (e.g., avidity) that likely exist in the LMFR fishery (Boyer and Long 2012).

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TABLES

Table 1. Summary statistics of wild, juvenile trout from the lower Mountain Fork River, Oklahoma in 2016-2017. *N* = number of fish; TL = total length; SD = standard deviation.

Site	Year	Species	*N*	Mean TL (mm)	SD TL	Mean weight (g)	SD weight
Evening Hole	2016	Rainbow Trout	26	57.4	16.6	4.9	4.7
Intermittent Tributary	2016	Rainbow Trout	32	46.3	6.0	2.0	0.5
Evening Hole	2017	Rainbow Trout	24	55.9	17.3	2.1	1.8
Intermittent Tributary	2017	Rainbow Trout	1	36.0	NA	0.6	NA
Evening Hole	2017	Brown Trout	3	105.0	69.3	25.1	38.7

Table 2. Spawning and hatch date estimates based on counts of rings in otoliths of wild, juvenile Rainbow Trout from the lower Mountain Fork River, Oklahoma in 2016-2017. *N* = number of fish used to estimate the parameter. See Figure 3 for graphical representation.

Site	Year	Parameter	*N*	Mean	Min	Max
Evening Hole	2016	Spawn	25	2/25	2/2	3/31
Evening Hole	2016	Hatch	7	3/24	3/11	4/11
Intermittent Tributary	2016	Spawn	31	2/9	1/9	3/16
Intermittent Tributary	2016	Hatch	10	3/11	2/17	4/5
Evening Hole	2017	Spawn	24	3/4	1/20	4/17
Evening Hole	2017	Hatch	17	3/29	2/22	5/8

Table 3. Parameter estimates (*y*0 and *a*) and 95% lower and upper confidence intervals (in parentheses) of the linear model (length = *y0* + *a**age) indicating growth of wild, juvenile Rainbow Trout from the lower Mountain Fork River, Oklahoma in 2016-2017. See Figure 4 for graphical representation.

Site	Year	*y*0	*a*	*N*	r^2
Evening Hole	2016	30.23 (23.75-36.72)	0.46 (0.03-0.88)	25	0.18
Intermittent Tributary	2016	32.59 (30.75-34.44)	0.24 (0.11-0.37)	31	0.34
Evening Hole	2017	7.76 (3.69-11.84)	1.15 (0.82-1.48)	24	0.71

Table 4. Parameter estimates (*a* and *b*) and confidence intervals (CI) of power model (weight = a*length^b) indicating body condition of wild, juvenile Rainbow Trout from the lower Mountain Fork River, Oklahoma in 2016-2017. For intercept values, lower confidence intervals less than 0 were truncated to 0.0 as indicated by "*". See Figure 5 for graphical representation.

Site	Year	*a*	*b*	*N*	r^2
Evening Hole	2016	<0.01 (0.0*-0.40)	2.58 (2.55-2.60)	26	0.96
Intermittent Tributary	2016	0.01 (0.0*-0.15)	1.36 (1.34-1.39)	32	0.48
Evening Hole	2017	<0.01 (0.0*-0.11)	2.84 (2.38-2.85)	24	0.98

Table 5. Coefficients of catch curve analysis estimating instantaneous weekly mortality (*Z*) and subsequent survival (*S*) estimates of wild, juvenile Rainbow Trout captured from two sites in the lower Mountain Fork River in 2016 and 2017. SE = standard error of *Z* estimate. *P* = p-value and r^2 = coefficient of determination. See Figure 6 for graphical representation.

Site	*Year*	*Z*	SE	*P*	r^2	Weekly survival (*S*)
Evening Hole	2016	-0.42	0.12	0.07	0.86	66%
Intermittent tributary	2016	-0.26	0.19	0.24	0.32	77%
Evening Hole	2017	-0.50	0.03	<0.01	0.99	61%

Table 6. Percentage of macroinvertebrate orders by zone from the 19-km study area of the lower Mountain Fork River (from kick seine and Hester-Dendy samples) for May – August 2016. 151 items could not be identified (2.7% of total; not shown). *N* = total number of macroinvertebrates. See Figure 1 for map of zone locations.

Order	Zone 1 (*N* = 2188)	Zone 2 (*N* = 538)	Zone 3 (*N* = 2743)	Total (*N* = 5546)
Trichoptera	28.3%	66.7%	54.2%	42.6%
Isopoda	29.7%	7.4%	6.7%	15.8%
Diptera	26.2%	0.7%	6.1%	13.9%
Ephemeroptera	8.6%	11.5%	11.2%	10.0%
Plecoptera	0.5%	2.8%	17.0%	8.9%
Amphipoda	2.4%	3.7%	1.2%	1.9%
Tricladida	2.3%	0.9%	0.3%	1.4%
Coleoptera	0.4%	0.4%	1.5%	0.9%
Haplotaxida	0.6%	2.2%	0.2%	0.6%
Neuroptera	0.1%	1.9%	0.4%	0.5%
Arhynchobdellida	0.1%	0.7%	0.3%	0.3%
Odonata	0.6%	0.2%	-	0.3%
Lepidoptera	-	0.2%	0.2%	0.1%
Trombidiformes	<0.1%	-	0.2%	0.1%
Diplostraca	-	0.6%	-	<0.1%

Table 7. Percentage of macroinvertebrate orders by zone from the 19-km study area of the lower Mountain Fork River (from kick seine and Hester-Dendy samples) for March – July 2017. *N* = total number of macroinvertebrates. See Figure 1 for map of zone locations.

Order	Zone 1 (*N* = 2962)	Zone 2 (*N* = 1719)	Zone 3 (*N* = 3173)	Total (*N* = 7854)
Trichoptera	18.1%	25.1%	41.4%	29.0%
Diplostraca	1.3%	40.4%	21.7%	18.1%
Isopoda	30.7%	4.8%	3.4%	14.0%
Diptera	18.1%	4.3%	10.7%	12.1%
Ephemeroptera	13.6%	8.9%	8.5%	10.5%
Plecoptera	2.6%	8.1%	8.6%	6.3%
Tricladida	6.9%	1.9%	1.3%	3.6%
Amphipoda	7.0%	2.8%	0.6%	3.5%
Coleoptera	0.6%	1.5%	1.0%	1.0%
Neuroptera	0.1%	0.5%	1.1%	0.6%
Anthomedusae	-	0.2%	0.9%	0.4%
Haplotaxida	0.6%	0.2%	0.3%	0.4%
Arhynchobdellida	0.2%	0.9%	0.3%	0.4%
Lepidoptera	-	-	0.2%	<0.1%
Odonata	<0.1%	-	<0.1%	<0.1%
Trombidiformes	<0.1%	<0.1%	<0.1%	<0.1%
Calanoida	-	0.2%	-	<0.1%

Table 8. Proportional abundance of prey (order) in wild juvenile Rainbow Trout stomachs from two locations in the lower Mountain Fork River, 2016 and 2017. The total number of prey items is given on the bottom row as Total. *N* = number of fish examined. Some items in 2016 could not be identified and are not included in calculations (21 items from 8 fish from Evening Hole and 6 items from 4 fish from intermittent tributary). See Figure 1 for locations on map.

Prey item	Evening Hole 2016 *N* = 25	Evening Hole 2017 *N* = 24	Intermittent Tributary 2016 *N* = 32	Intermittent Tributary 2017 *N* = 1
Amphipoda	41.7%	4.8%	-	-
Araneae	-	0.1%	-	-
Astacoidea	-	0.4%	-	-
Coleoptera *	0.5%	1.0%	1.4%	-
Coleoptera	0.5%	-	0.9%	-
Collembola	0.4%	-	0.9%	-
Diplostraca	0.2%	65.5%	-	-
Diptera *	3.6%	0.6%	6.5%	-
Diptera	15.7%	7.5%	14.0%	-
Ephemeroptera *	1.6%	1.5%	2.3%	-
Ephemeroptera	17.5%	5.2%	40.7%	-
Erythraeidae	0.2%	-	-	-
Haplotaxida	0.5%	0.3%	-	-
Hemiptera *	2.4%	0.3%	5.1%	-
Hymenoptera *	2.4%	1.2%	7.5%	-
Hygrobatoidea	-	0.4%	-	-
Isopoda	2.4%	2.2%	8.4%	6.7%
Lepidoptera	0.4%	-	-	-
Orthoptera *	0.4%	-	0.5%	-
Phlaeothripidae *	-	0.1%	-	-
Plecoptera *	0.4%	0.1%	-	-
Plecoptera	<0.1%	0.3%	0.5%	-
Trichoptera *	3.6%	6.4%	4.2%	93.3%
Trichoptera	5.6%	2.1%	7.0%	-
Total number of prey items	549	724	214	15

***** adult life stage of prey where prey location will vary depending on life stage (e.g., aquatic larval stage and terrestrial adult stage); otherwise, prey items are larval or otherwise fully occurring in aquatic habitats.

Table 9. Proportional abundance of prey in adult Rainbow Trout stomachs from the lower Mountain Fork River (Evening Hole) 2017. The total number of prey items is given on the bottom row as Total. *N* = 21 fish with identifiable prey. 16 items in 9 fish were considered non-prey, but found in the stomach (e.g., stick and fishing hook), are not shown.

Prey item	Percentage of total prey eaten
Fish	2.2%
Amphipoda	4.7%
Araneae	0.4%
Astacoidea	3.6%
Coleoptera *	5.4%
Coleoptera	0.4%
Diptera *	1.4%
Diptera	5.1%
Diptera **	0.7%
Ephemeroptera *	1.8%
Ephemeroptera	7.9%
Hemiptera *	0.4%
Hymenoptera *	9.0%
Isopoda	10.1%
Odonata	0.4%
Plecoptera *	0.4%
Plecoptera	0.4%
Trichoptera *	33.9%
Trichoptera	2.5%
Trichoptera **	9.4%
Total number of prey items	277

***** adult life stage of prey where prey location will vary depending on life stage (e.g., aquatic larval stage and terrestrial adult stage); otherwise, prey items are larval or otherwise fully occurring in aquatic habitats.

** pupa life stage of prey where prey location may vary depending on life stage (e.g., benthic larvae and drifting pupae).

Table 10. Strauss electivity indices (*L*) for prey items assessed for availability in the environment (site 2 in 2016 and sites 2 and 13 in 2017) and consumed by juvenile Rainbow Trout (*N*) at the lower Mountain Fork River.

Prey Item	2016 (*N* = 25)	2017 (*N* = 24)
Amphipoda	0.5	0.0
Diplostraca	N/A	0.7
Diptera	0.0	-0.1
Ephemeroptera	0.2	-0.2
Haplotaxida	0.0	0.0
Isopoda	0.0	-0.1
Plecoptera	N/A	0.0
Trichoptera	-0.7	-0.3

Table 11. Diet overlap between juvenile and adult Rainbow Trout (RBT) in the lower Mountain Fork River in 2017. Bray-Curtis dissimilarity index between the two RBT groups = 0.70. *N* = number of fish.

Prey Item	Number in juvenile RBT (*N* = 24)	Number in adult RBT (*N* = 21)
Fish	0	6
Macroinvertebrates	724	271
Amphipoda	35	13
Araneae	1	1
Astacoidea	3	10
Coleoptera *	4	15
Coleoptera	3	1
Diplostraca	474	0
Diptera *	4	4
Diptera **	0	2
Diptera	54	14
Ephemeroptera *	11	5
Ephemeroptera	38	22
Hemiptera *	2	1
Hygrobatoidea	3	0
Hymenoptera *	9	25
Isopoda	16	28
Odonata	0	1
Oligochaeta	2	0
Phlaeothripidae *	1	0
Plecoptera *	1	1
Plecoptera	2	1
Trichoptera *	46	94
Trichoptera **	0	26
Trichoptera	15	7
Sum	724	277

***** adult life stage of prey where prey location will vary depending on life stage (e.g., aquatic larval stage and terrestrial adult stage); otherwise, prey items are larval or otherwise fully occurring in aquatic habitats.

** pupae life stage of prey where prey location may vary depending on life stage (e.g., benthic larvae and drifting pupae).

FIGURES

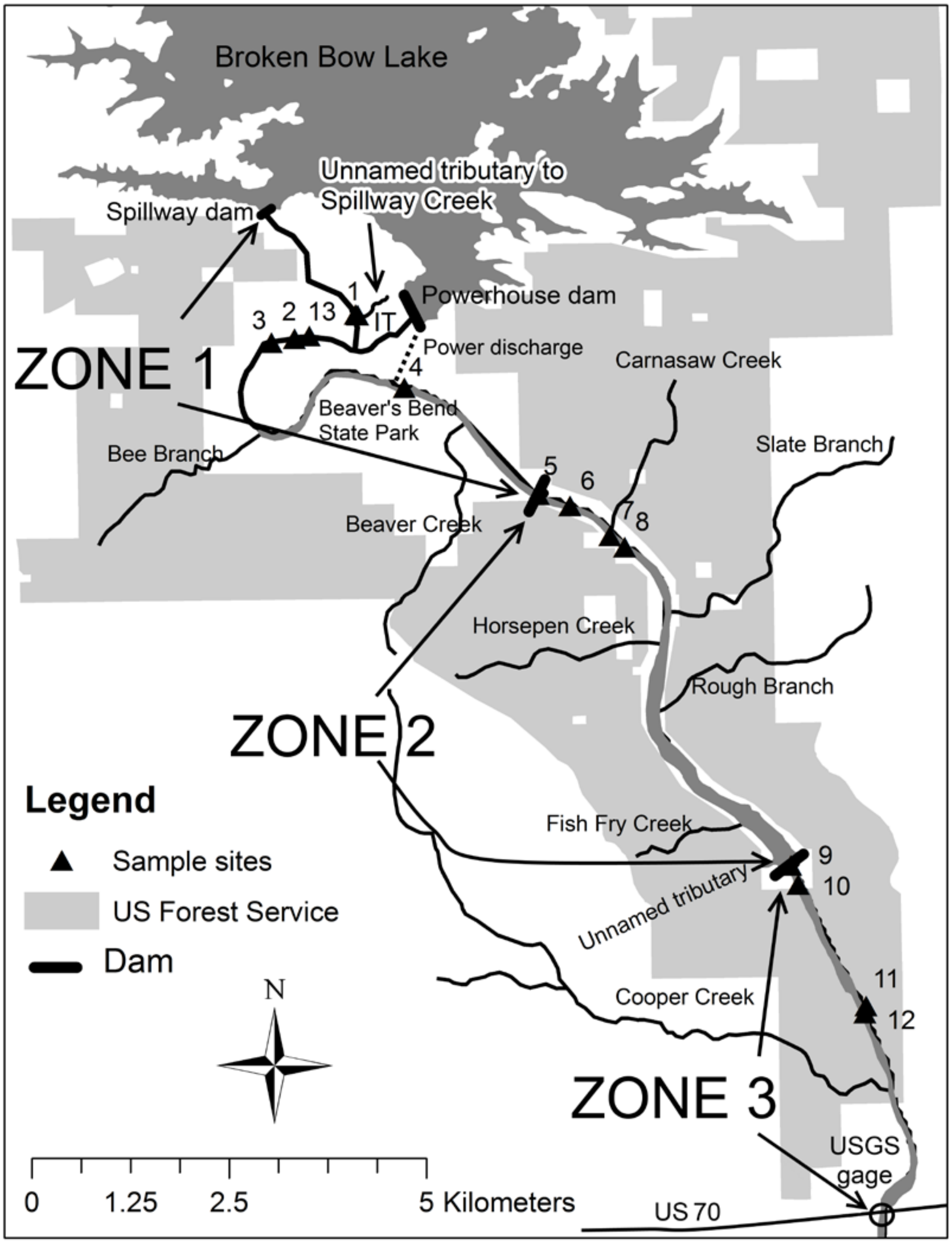

Figure 1. Study area and sample locations for trout and macroinvertebrates in the lower Mountain Fork River. Wild, juvenile trout were found at the unnamed Intermittent Tributary (IT) to Spillway Creek and the Evening Hole (sites 2, 3, and 13). USGS gage = U.S. Geological Survey water survey gage #07339000.

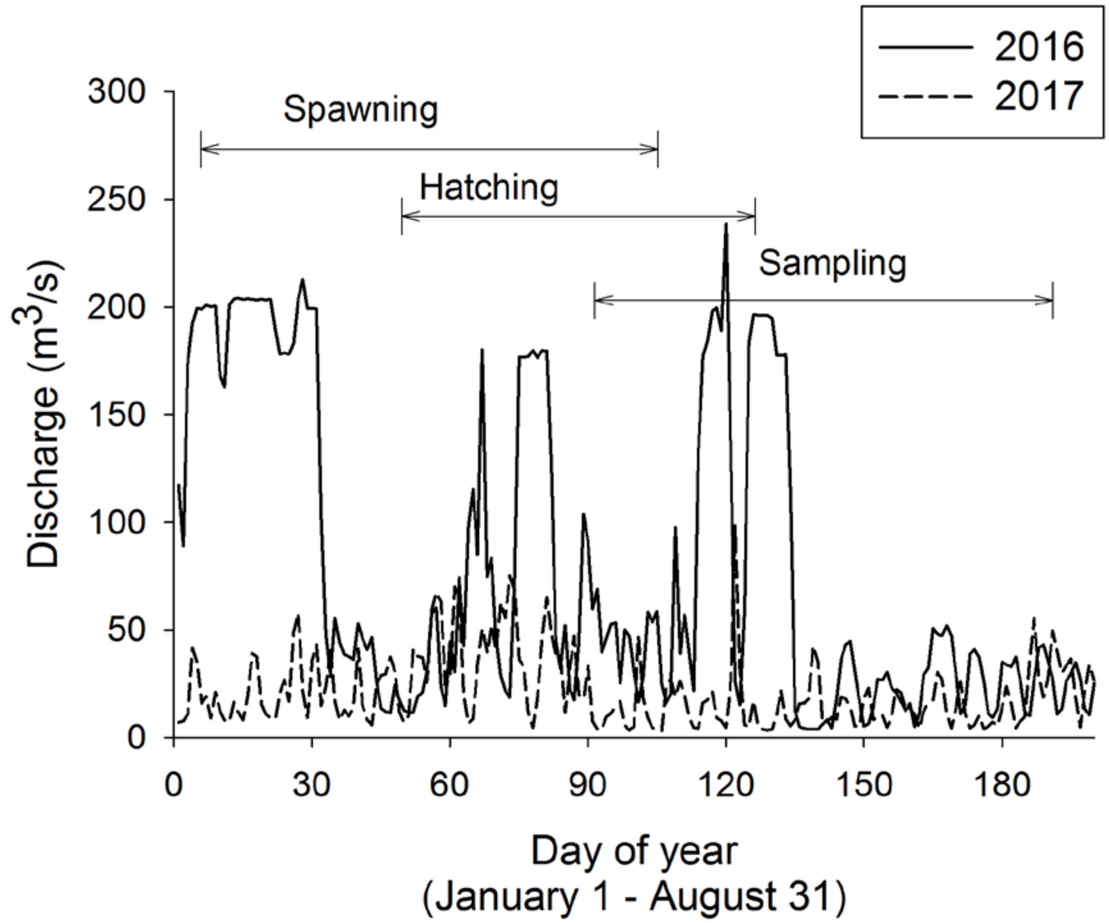

Figure 2. Discharge in the lower Mountain Fork River, Oklahoma in 2016-2017 in relation to wild, juvenile Rainbow Trout reproduction and sampling. Discharge data from U.S. Geological Survey gage #07339000, Mountain Fork near Eagletown, OK, located at State Highway 70 (Figure 1; https://waterdata.usgs.gov/ok/nwis/inventory/?site_no=07339000).

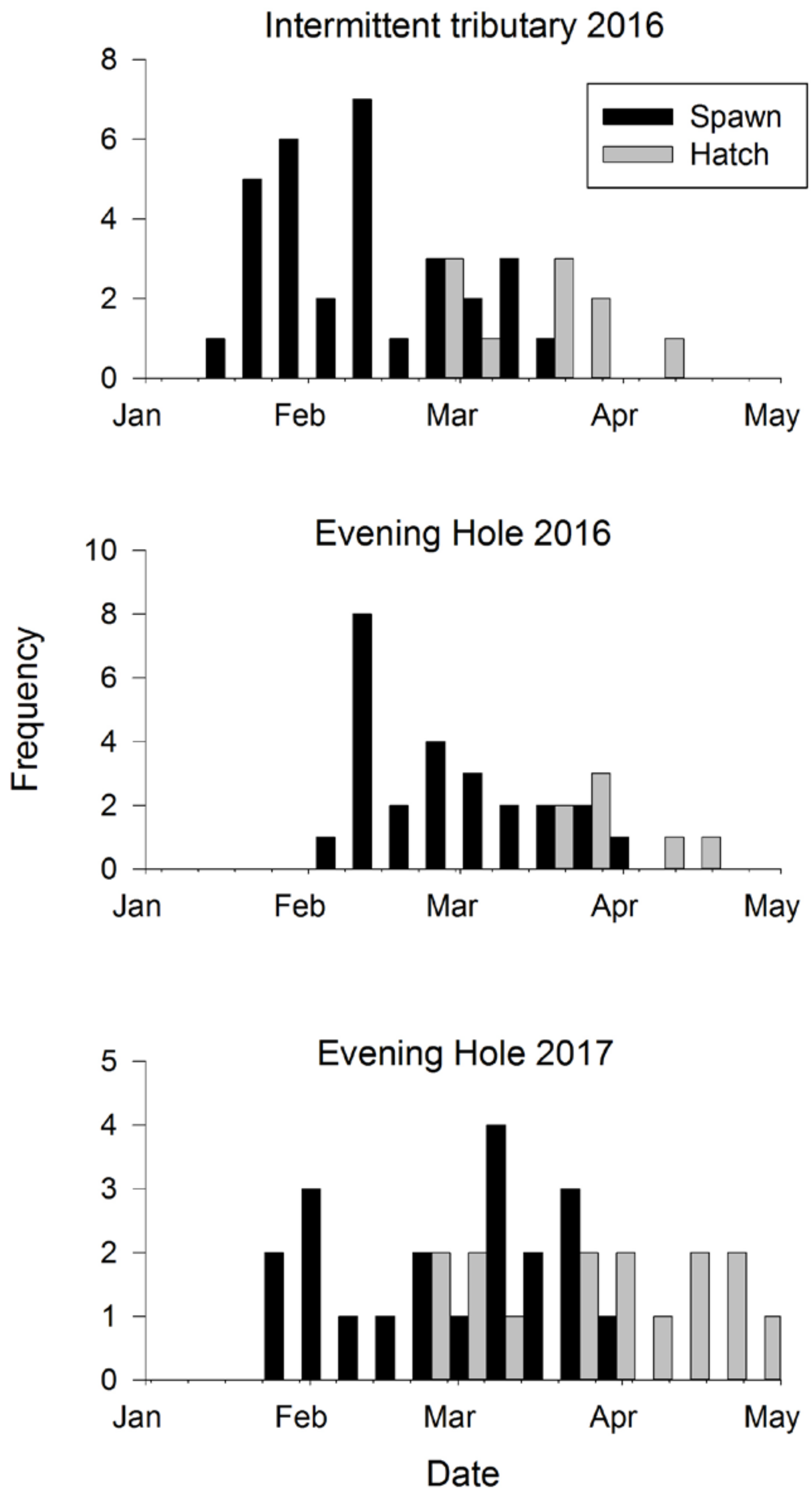

Figure 3. Estimated dates and frequency when wild, juvenile Rainbow Trout were spawned and hatched at two sites in the lower Mountain Fork River in 2016 and 2017.

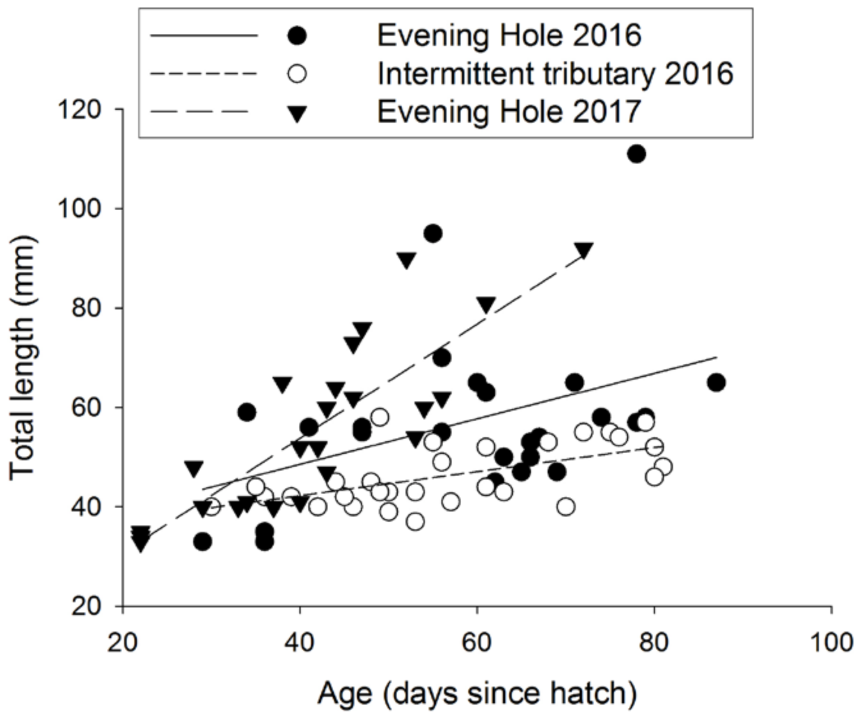

Figure 4. Length at age since hatch of wild, juvenile Rainbow Trout from the lower Mountain Fork River, Oklahoma in 2016-2017.

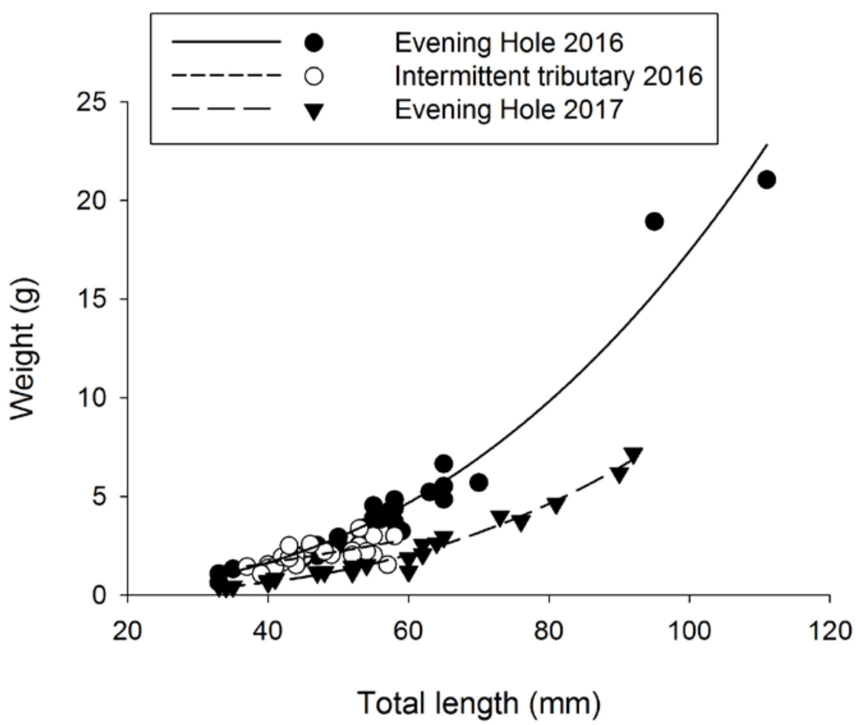

Figure 5. Power model (weight = a*length^b) graph for body condition of wild, juvenile Rainbow Trout from the lower Mountain Fork River, Oklahoma in 2016-2017.

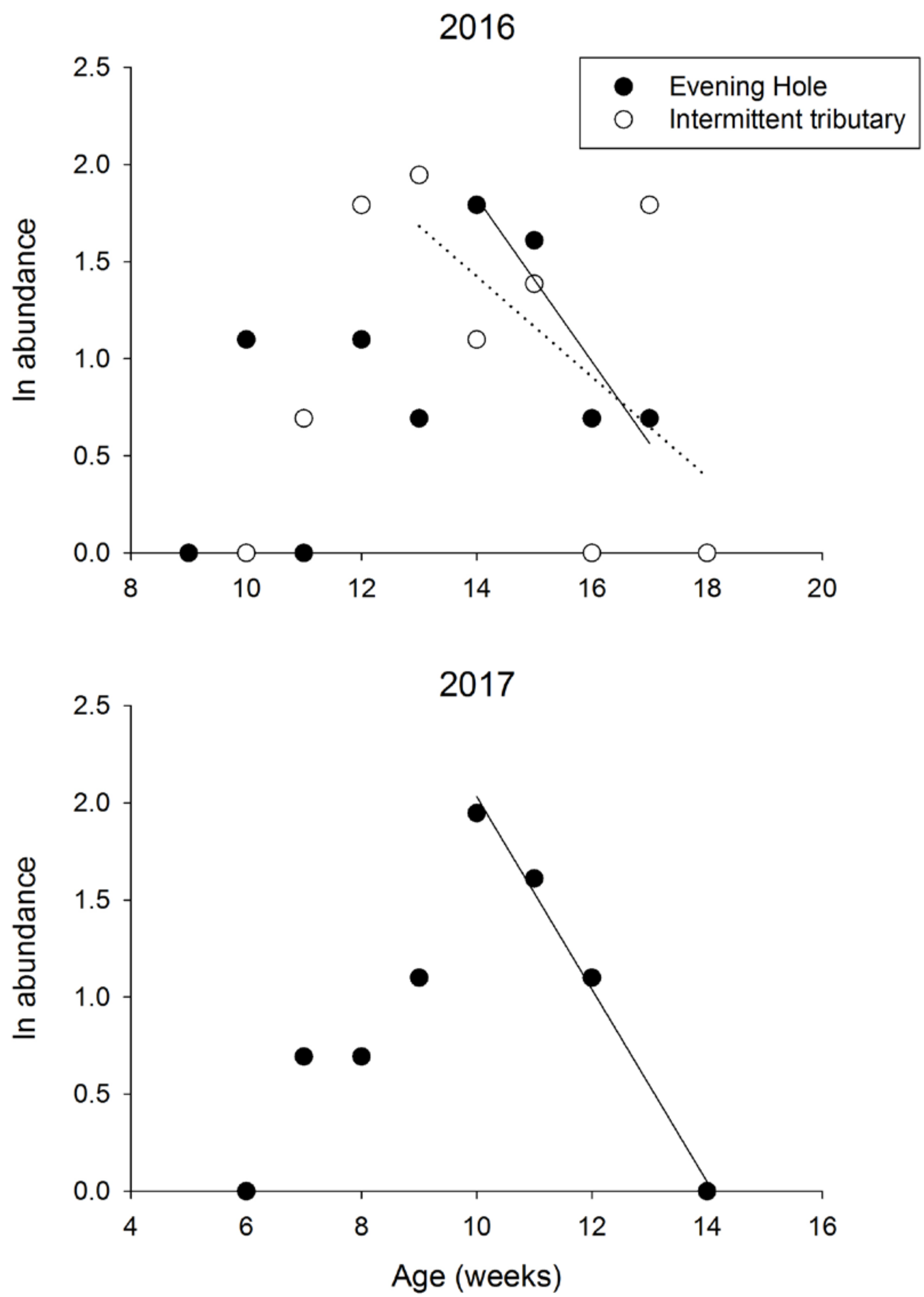

Figure 6. Catch curves of wild, juvenile Rainbow Trout captured from two sites in the lower Mountain Fork River to estimate weekly survival in 2016 and 2017. See Table 5 for estimates.

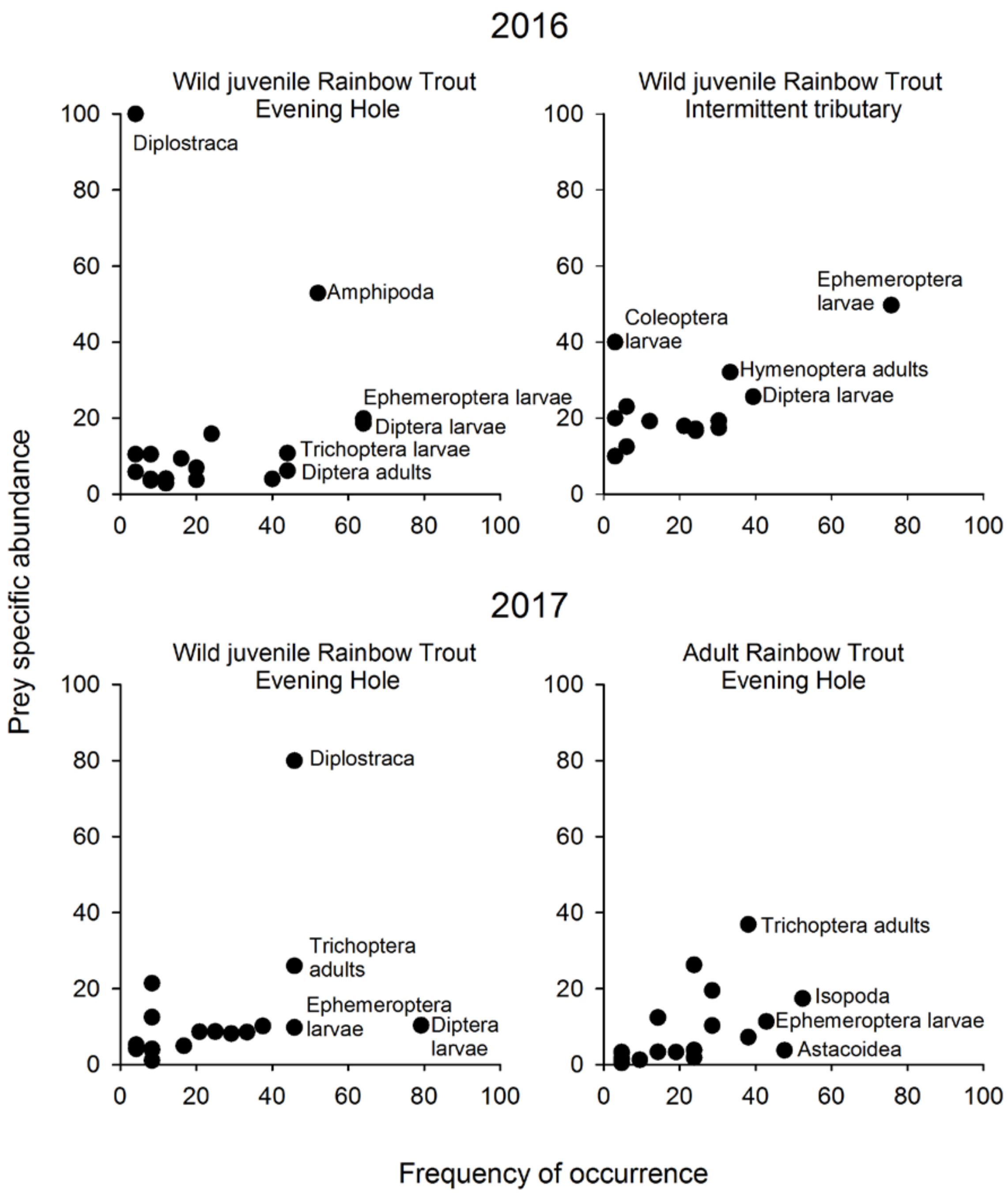

Figure 7. Prey use by Rainbow Trout (wild juvenile and stocked adults) in the lower Mountain Fork River at two sites where wild juvenile Rainbow Trout were captured (Evening Hole and Intermittent tributary to Spillway Creek) in 2016 and 2017. Prey items in high abundance or high frequency in trout stomachs are labeled. The remaining items were found in low abundance in trout stomachs. Locations of sites can be located on the map (Figure 1) and identity of all prey items in Tables 8 and 9.

APPENDICES

Appendix A. Counts of macroinvertebrate taxa by zone (1-3) and sample site (1-S1) from the 19-km study area of the lower Mountain Fork river below Broken Bow Dam (from kick seine and Hester-Dendy samples) for May – August 2016. Vertical lines denote zones: Zone 1 includes sites 1, 2, 3, 4 and 13; Zone 2 includes sites 5, 6, 7 and 8; and Zone 3 includes sites 9, 10, 11, and 12. See Figure 1 for locations on map.

Order	**Family**	**Genus**	**1**	**2**	**3**	**4**	**13**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Tricladida	Dugesiidae		47	2	1			5					15	5		75
Haplotaxida				4	5	5		3	7		1		3	3		32
Arhynchobdellida	Erpobdellidae			2	1			2	2			5	3	1		16
Diplostraca	Daphniidae							3								3
Isopoda	Asellidae	*Lirceus*	578	30	3	31	8	35	2	1	2	39	50	29	67	875
Amphipoda	Hyalellidae	*Hyalella*	34	6	2	11		16		3	1	19	6	7		105
Trombidiformes	Hygrobatoidea*					2						4	1			7
Ephemeroptera	Baetidae	*Acentrella*	3		2			3				1	1	3	7	20
		Diphetor hageni					2									2
		Pseudocentroptiloides	2			2										4
	Heptageniidae	*Leucrocuta*								1						1
		Maccaffertium				11	3	2	7	6	1	6	16	12	8	72
		Stenacron	1			33	2	1	1	11	7	6	19	6	18	105
		Sternonema femoratum		7	9	58	39	2	1	9	6	127	13	5	1	277
	Isonychiidae	*Isonychia*		8		6		2	1	1			12	24	21	75
Odonata	Calopterygidae					12										12
	Gomphidae					1			1							2
Plecoptera	Perlidae	*Acroneuria pictet*				2				1				1	2	6
		Claassenia wu												2	3	5
		Neoperla needham	1	1	1	6		2	1	9	2	2	10	184	259	478
		Perlesta											1	1	2	4
Neuroptera	Corydalidae	*Corydalus latreille*				3		7	2		1		3	4	5	25
Trichoptera	Helicopsychidae	*Helicopsyche*				1										1
	Hydropsychidae	*Cheumatopsyche*	55	177	107	150	2	71	68	6	12	95	624	325	174	1866
		Hydropsyche	5	2	49	19		63	4		14		58			214
		Macrostemum												1		1
	Hydroptilidae	*Hydroptila*	20			13		5				38	31		4	111
	Lepidostomatidae	*Lepidostoma*	5	1								8	18	8	6	46
	Leptoceridae	*Ceraclea*										1				1
		Oecetis	7									1	2	1		11
	Philopotamidae	*Chimarra*		1	2	1		7	4				17	53	16	101
	Polycentropodidae	*Polycentropus*				2		3			2	6				13
Lepidoptera	Crambidae	*Petrophila*						1					4	1	1	7
Coleoptera	Dryopidae	*Helichus*	3													3
	Elmidae	*Stenelmis*		1	1	1			1			7	6	4	25	46
	Gyrinidae	*Dineutus*			1	1										2
Diptera	Athericidae		2			2		1								5
	Ceratopogonidae											17				17
	Chironomidae	*Unknown*	38	6	18	22		19	5	4		31	41	10	12	206
		Rheotanytarsus		3	2	6							4			15
	Simuliidae		283	28	162	1	1	1					51		1	528
Total			**1084**	**279**	**366**	**402**	**57**	**254**	**107**	**52**	**49**	**413**	**1009**	**690**	**632**	**5395**

Appendix B. Counts of macroinvertebrate taxa by zone (1-3) and sample site (1-13 and IT) from the 19-km study area of the lower Mountain Fork river below Broken Bow Dam (from kick seine and Hester-Dendy samples) for March – July 2017. Vertical lines denote zones: Zone 1 includes sites 1, 2, 3, 4, 13 and IT (Intermittent Tributary); Zone 2 includes sites 5, 6, 7 and 8; and Zone 3 includes sites 9, 10, 11 and 12. See Figure 1 for locations on map. IT = intermittent tributary.

Order	**Family**	**Genus**	**1**	**2**	**3**	**4**	**13**	**IT**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Anthomedusae	Hydridae	*Hydra*									4			25	1	2	32
Tricladida	Dugesiidae		178	11	9	4	6		13	10	5	5	5	4	13	20	283
Haplotaxida			1	3	2	9	4			2	1		1	2	6	1	32
Arhynchobdellida	Erpobdellidae			1	2	3				7	4	4	1		1	7	30
Diplostraca	Daphniidae		20			12	6		4	533	109	40	4	580	89	15	1412
Calanoida										3	1						4
Isopoda	Asellidae	*Lirceus*	701	38	28	63	49	29	14	21	13	35	17	14	58	19	1099
Amphipoda	Hyalellidae	*Hyalella*	124	47	8	12	16		23	5	11	9	9	4		5	273
Trombidiformes	Hygrobatoidea*						2				1			1			
Ephemeroptera	Baetidae	*Acentrella*	16	1		1	1							1	6	3	29
		Pseudocentroptiloides	74	22	2	2	7		1			1				1	110
	Heptageniidae	*Leucrocuta*		1		1						3				1	6
		Maccaffertium		1		11			1	4	6	1	3	6	18	10	61
		Stenacron	1	1	2	13	1	3	24	9	19	8	8	3	2	8	102
		Sternonema femoratum		1	4	8	5	1	38	11	8	3	8	28	3	8	126
	Isonychiidae	*Isonychia*	63	65	14	9	65	8	5	7	2	2	15	13	83	39	390
	Leptophlebidae	*Neochoroterpes*													1		1
Odonata	Aeshnidae					1											1
	Coenagrionidae													1	1		2
	Gomphidae															1	1
Plecoptera	Chloroperlidae	*Unknown*	1														1
		Haploperla									1					1	2
	Perlidae	*Acroneuria pictet*					1		1	1				1		9	13
		Claassenia wu				3									3	5	11
		Hansonoperla														1	1
		Neoperla needham	2	1		32	1	1	20	45	54	13	8	7	101	127	412
		Perlesta	3	17	11	3	1		2	2			1	3	2	5	50
	Pteronarcyidae	*Pteronacys*						1									1
Neuroptera	Corydalidae	*Corydalus latreille*				1	2		2	1	2	3	1	5	18	11	46
	Sisyridae								1								1
Trichoptera	Helicopsychidae	*Helicopsyche*											1				1
	Hydropsychidae	*Cheumatopsyche*	14	11	34	17	48		67	97	52	42	105	54	105	51	697
		Hydropsyche	10	1		4	7		5	3	1	5		34	3	1	74
		Macrostemum												2			2
	Hydroptilidae	*Hydroptila*	1			4								1	4	2	18
	Lepidostomatidae	*Lepidostoma*	3	6	7									3	5	6	30
	Leptoceridae	*Unknown*	3														3
		Oecetis												2			2
		Trianodes												1			1
	Philopotamidae	*Chimarra*	85	61	37	26	142	6	74	40	18	24	52	31	665	173	1434
	Polycentropodidae	*Neureclipsis*												1			1
		Polycentropus		1	1	1				2	2		8	1		1	17
Lepidoptera	Crambidae	*Petrophila*											1		2	2	5
Coleoptera	Elmidae	*Stenelmis*	1			10		1	3	92	21		5	8	14	4	78
	Gyrinidae	*Gyrinus*				1											1
	Psephenidae	*Psephenus*						6								2	8
Diptera	Athericidae			1													1
	Chironomidae	*Unknown*	120	57	19	29	22	8	9	30	22	11	57	64	134	22	604
		Rheotanytarsus	15	9		1	4		1				2	4			36
	Simuliidae		233	10	1		6	2			1		1	35	20		309
Total			**1671**	**371**	**187**	**289**	**422**	**94**	**318**	**937**	**372**	**225**	**331**	**959**	**1380**	**587**	**7854**