Meramec Red Ribbon Trout Area (MRRTA)
Brown Trout Telemetry Study Report – November 2020

Executive Summary

MRRTA brown trout were implanted with radio transmitters in fall of 2019 and winter/spring of 2020 in order to gain insights about their survival and movements post-stocking. We saw approximately 40% survival six months post release, which is consistent with spring 2014 electrofishing survey findings. Specific causes of death were implied based on locations of inactive transmitters. We saw that roughly half of the browns that died appeared to have either been killed by mammalian predators, or their carcasses were preyed upon by mammals. About another third of browns that died were located away from the main channel, and several factors may have put them in those locations, such as bird predation, angler removal, and/or migration during floods. Another approximately 15% appear to leave the MRRTA by unknown sources. The majority of stocked browns do not end up in the spring branch; however, a small portion do find their way into the spring branch. We did see higher instances of mortality post-stream-rise in the spring round of tracking that would lead us to think that something about the rise instigated the mortality. While tracking, we saw evidence that we are losing a small number stocked fish to avian removal/injury and illegal fishing activity. Adjustments we can make to management to try to produce a more consistent trout fishery include avoiding stocking during high water conditions, focus stocking on centrally located stocking locations, encourage fur-bearer trapping activity, continue enforcement of current regulations on bait, daily and minimum length limits, and species fishing methods, encourage ethical fishing tactics, and continue multiple smaller stocking stockings during the fall and winter months.

Introduction

Brown trout are stocked in the Meramec River to produce good catch and release opportunities and a chance to harvest quality-sized trout (a put-grow-take system) as described in the MO Trout Plan and regulated with bait and length restrictions. They are stocked at approximately 10" in length (225g) and have a 15" minimum length limit (MLL). Browns typically need 2 years in the "wild" system to reach the MLL. Suitable year-round coldwater habitat of the MRRTA is limited to the reach with a large spring branch influence (indicated in map, only ~ 6.5 miles in length; the Maramec Spring Branch itself lies adjacent to the MRRTA and is managed under more liberal harvest regulations as a MO Trout Park) (Figure 1). Six-month post stocking survival of stocked browns in the MRRTA has been variable and lower in the last decade (0-10%), much more so than in past decades (20-30%), and not many browns are living past the 2-year post-stocking mark to make it to legal size. This is thought to be attributed to several factors (e.g. extreme flooding & water temperature variations, natural predation, illegal harvest, small size at stocking, inability to adjust to riverine life, etc.).

A previous pilot telemetry study conducted in 2017 on brown trout in the MRRTA used borrowed hydro-acoustic transmitters and receivers to track stocked brown trout in the six months after release and yielded the following findings:

- Brown trout appeared to tolerate internal transmitter implantation well. All survived the implantation process and the 21-day post implantation holding period. Incisions appeared well healed at the end of the holding period and no fish had lost their transmitters.
- Brown trout with transmitters were released into the river and began to "disappear" quickly with over half "missing" after about three months post stocking. However, we are unsure if the undetected transmitters/fish:
    - Left the waterbody via harvest or predation,
    - Moved out of the MRRTA boundaries and the stationary receivers didn't detect them (which is possible since we had historic flooding in spring 2017 which temporarily displaced our in-stream stationary receivers),
    - Hid within the in-stream, complex woody habitat while tracking and we didn't detect them,

    - Died from other causes which we couldn't or didn't detect traces of.
- Transmitters initially were easily detectable with the borrowed equipment (transmitters had a 90 second delay between signals at the beginning of the study), but over time fewer fish were detected (transmitters had gone to a 180 second delay between signals). The time between signals made it difficult to cover adequate distances during an active tracking day since we needed to listen longer in each habitat unit, and might have resulted in non-detections on the stationary receivers due to size of system we're working with. The MRRTA is relatively small with many shallow riffle/run areas where trout would normally hide, and acoustic methods are not ideal to detect fish in those shallow and complex areas.
- Historic flooding might have hampered the stationary receivers' ability to detect transmitter movements past the MRRTA boundaries. Both receivers were displaced during flooding and might not have detected fish moving past them when the river level was extremely high. However, many transmitters were "missing" before the historic flood occurred.

In order to learn more about the fate of the stocked brown trout in the MRRTA, we designed a radio telemetry study to investigate the following questions and to find out if there's something we can address to get more brown trout to reach legal size in a more consistent way. Funding of equipment (including tags, receivers, antennas, batteries, implant equipment totaling $20,000) was generously provided by the Gateway and Mid-MO Trout Unlimited chapters through the MO Conservation Heritage Foundation.

Management questions to answer:

- How long do brown trout survive in the MRRTA after stocking?
    - What are the largest mortality factors they experience (harvest, predation, natural causes)?
    - Where and how quickly do they move/disperse after stocking?
    - Do browns reared at Maramec hatchery move to the spring branch rather than stay in the MRRTA (and thus make themselves unavailable to MRRTA anglers)? Do they "migrate" to the spring branch in the fall to try to spawn?
    - Do browns stocked at the lower end of the RRTA move towards the spring when water temperatures approach 70F?
- How do brown trout react when the river rises after a precipitation event? (Die? Move?)

Methods

Lotek Wireless radio transmitters and receivers were selected for this project. Radio technology would allow transmitters to be detected whether they were in or out of the water and would yield detections even if the transmitter was inside complex habitat structure that hydro-acoustic transmitters would not. Model MST-930-M transmitters weighing 4.5 g, 9.5mm x 32mm in size with 5.5 and 6 sec intervals between signals and approximately 176 days of battery life were chosen as the best transmitter to provide brown trout locations and details about fish status. These transmitters had an external antenna that incorporated the ability to switch from an "active" state to an "inactive" state after 12 hours of no movement, and provided unique identifiers by tag on the same frequency to minimize active tracking time. Twenty-eight transmitters were purchased in summer 2019 and another 28 transmitters were purchased in late 2019.

Two receivers and antennas were also purchased in summer 2019. One receiver was a stationary only model which was installed at the Scott's Ford location on the downstream end of the MRRTA (a 12-volt battery operated SRX800-D model with a four prong Yagi antenna). The other receiver was a dual purpose SRX-800 model, which was stationed at the Maramec hatchery office with a four prong Yagi antenna when not in use as an active, handheld receiver. The Scott's Ford receiver was powered by a 12-volt battery; the battery

generally provided 14-21 days of power then had to be recharged or switched out (Figure 2). The hatchery receiver was plugged directly into the wall when being used as a stationary receiver. There were some gaps in listening coverage at both stationary receiver locations as batteries lost power or power outages occurred. When being used as an active tracker, the SRX-800 receiver required six C batteries which lasted four to five sessions of active tracking depending on the length of session.

The transmitters could be detected approximately 100 yards from the receivers, farther in open terrain and slightly less in more rough surroundings with structure. Transmitter signal strength increased as the distance between the receiver and transmitter decreased. Stationary receivers and antennas were placed to detect any transmitters leaving the MRRTA passing by the Scott's Ford bridge or MDC parking lot or Maramec Spring Park in vehicles or fish cleaning station waste.

Brown trout of the Crawford strain were hatched and reared at Maramec Hatchery. Browns >10" in length and ~ 225 grams in weight were selected to receive transmitters to comply with the recommendation that transmitters be <2% of the animals body weight. Brown trout being implanted were weighed and measured for total length, anaesthetized with MS222, and had a small incision cut in the abdominal cavity with a nearby puncture hole to allow the external antenna to protrude from body cavity. The transmitter and incision implements were sanitized in iodine and alcohol and rinsed with distilled water before being used on or implanted in the fish. Two to three sutures were used to close the incision and were tied with a surgeon's knot. Approximate time that the brown trout were out of water during implantation was about two minutes per fish. On the last implantation round, water was recirculated over the fish's gills accommodate the extra time it took to add a third suture. Fish were then allowed to recover in fresh water and were held for 21 days post implantation (Figure 3).

The first round of implants took place in September 2019 with 20 hatchery reared brown trout, which were ready for release in early October. Eight transmitters were held back to attempt to implant in brown trout found in the river during annual fall electrofishing samples in early October, but only four river brown trout were implanted with transmitters. The remaining transmitters were implanted in hatchery reared fish the day of release. Aqui-S anesthetic, which doesn't require a holding period, was used in place of MS-222 during the same-day-release implantations so fish could be released immediately; all other implant techniques were the same as described above. In January 2020, a similar process happened with 28 hatchery reared brown trout implanted with a new round of transmitters and released at the end of February. See Table 1 for sizes of brown trout implanted. A total of 5,722 (non-implanted) brown trout were released over multiple stocking trips during fall-winter 2019/2020 alongside the implanted browns at multiple locations along the MRRTA.

We attempted to assess transmitter loss and fish recovery/survival with a control group to make better inferences about released brown trout mortality. We held six brown trout that had received a "no incision" treatment and nine brown trout that received some type of "incision" in a covered, flow-through box in the hatchery raceway. (Initially we had four types of treatments, but unfortunately, we did not think ahead to give fin clips or any other external marker to fish to identify which sub-group the "incision" fish belonged to, especially if/when they lost their transmitter. The incision group ended up combining fish with transmitters, a fish that had lost its transmitter during the holding period, and fish that received incisions and sutures but never had a transmitter implanted.) All control fish were separate fish from the ones that were released and tracked in the river. Control fish were not checked as regularly as the other released fish since the emphasis was to document movement and mortality in the wild.

Active tracking took place roughly every 2 weeks, more frequently after transmitter releases and less frequently when there were fewer transmitters to track (Table 2, Figure 4). Weather also postponed some tracking events, due to extreme cold or high precipitation or runoff. During active tracking sessions, the

hatchery receiver was taken by boat, foot, or vehicle around the MRRTA, adjacent Maramec Spring Branch, and/or other possible locations where brown trout may have ended up. During active tracking sessions, notes were made about each transmitter's detection location and active status. If a transmitter signaled inactive, attempts were made to pinpoint its location and recover it (Figure 5). Receiver detection records were downloaded from the stationary receivers about once a month. In August, after transmitters had quit signaling due to battery life constraints, stationary receivers were taken down and detection records downloaded one final time.

Results

During the holding period, we saw two percent of browns lose transmitters. With a low sample size and inconsistent checks on the control fish we could not infer a transmitter loss percentage after release from the control group. When browns with transmitters were released after the 21-day holding period, incisions generally looked well-healed, and all had at least one suture remaining. Some sutures had already fallen out which was expected as the incision healed.

Survival of brown trout decreased over time, most rapidly in the first nine weeks post-release (Figure 6). Fish that were released the same day as implantation had a lower survival rate than fish that had been through a 21-day holding period. (Analysis note: Since the same day release browns showed a different survival pattern than holding period browns and our main purpose was to interpret transmitter fate in terms of what regular stocked browns might be experiencing, we excluded those eight tags from further survival calculations.) Survival rates and trends of fish released in the fall (Oct) and spring (Feb) were similar and seemed to stabilize after nine weeks around 20%. (Note: one transmitter was lost in the raceway, and some went missing and final status truly could not be determined (perhaps we missed them in our tracking efforts or the battery died earlier than expected), but these transmitters were still used in calculating survival percentages reported here since the emphasis is to describe the number of browns available to MRRTA anglers after stocking. If we excluded those transmitters and only used ones with confirmed fates, survival of browns released with transmitters would be as high as 30%). Control fish survival at 5 weeks post "release" was 100% in no incision fish and 70% survival in incision fish, and at 13 weeks post release, survival was 100% in no incision fish and 55% in incision fish.

Survival: Transmitters began displaying inactive signals almost immediately. When inactive transmitters were able to be pinpointed to a specific location, about 65% of the time the transmitter could be recovered. When the transmitter could be recovered, typically there was no carcass to be found alongside or near the transmitter, except in one instance in the fall where the carcass was intact and the fish appeared to have succumbed to a stress related death (no evidence of predation). Transmitter final location or status were grouped in five categories and inferences made about the cause of their mortality as follows: 1) transmitter alive or active status (not applicable to mortality sources), 2) inactive transmitter near shore or at water's edge (attributed to mammal predation (acknowledging that this likely includes an indirect source of death as browns could have been in a weakened state due to another factor but ended up being consumed by mammals) – many times these were found with fish scales, a curled antenna, or teeth marks on transmitter), 3) inactive transmitter on dry land or faint (likely avian predation or washed off-channel during floods), 4) inactive transmitter in deep water (given the low survival of the control-incision fish, we assumed transmitters found in deep water had a similar fate – that the fish died from surgery/stocking stress, or possibly lost its transmitter. We acknowledge that these deep water locations could possibly be due to large piscivorous fish predation (i.e. smallmouth bass) but felt that with the control-fish observations, the deep water locations should be attributed to stress), or 5) missing or undetected (unknown status but may be attributed to angler removal, migration, avian ingestion & removal, or possibly that the transmitter was still active just undetected). The most common category for transmitters at the end of the study was inactive-near shore (31%), followed by inactive-deep water (25%), active-alive (19%), inactive-faint (16%), and missing (9%) (Table

3). (Analysis note: we acknowledge that the mortality-source-categories used here are based on assumption since no carcass was generally present to inspect and provide better insight into cause of death. Even though multiple factors could have influenced where the transmitter ultimately ended up, we considered all available evidence and likely scenarios and grouped transmitters based on those location determinations).

Of the transmitters that we interpreted as experiencing normal mortality sources and representing what normal stocked browns would be subjected to, 55% were found at water's edge, near logs, had teeth marks, or other indications of mammalian direct kills or carcass predation (e.g. otter, mink, raccoon). Another 28% were found on dry land and further from the channel and were attributed to avian, angler, or near-channel migratory loss. Seventeen percent ended up missing, which we believe were probably due to a combination of angler removal, large migration away from the RRTA, possible avian predation/ingestion and being expelled far from the RRTA, or possibly a shortened battery life. All transmitters that went missing occurred in the fall tracking period; all other categorized fates occurred in both seasons.

The majority (85%) of the river-released transmitters were detected within the MRRTA boundaries, including five percent of transmitters that left the boundaries for a time (going into Maramec Spring Branch) but eventually returned. Eight percent of the transmitters entered Maramec Spring Branch and stayed; five percent disappeared almost immediately after stocking and were not detected again; and two percent ended up leaving the lower boundary of the MRRTA at Scotts Ford. (Note: percentages in relation to detections/locations differ from survival percentages as some of the missing and same-day-implantation transmitters did provide a few locations before becoming inactive or considered missing.) Regarding detection locations, one unique occurrence was a fish that was detected in the Meramec R upstream of the spring branch confluence, but still within the MRRTA boundaries; this was also one of the fish that moved into Maramec Spring Branch but ended up back in the MRRTA.

We did not attempt tracking individual trout movements during a 24-hour period, nor attempt to define specific, in-stream habitat structures that individual trout were using. It was difficult to pinpoint live fish's locations within 10 ft as it appeared that fish moved with the presence of a boat floating in the stream near them. Rough estimates were made of specific habitat locations for most detections, and we recorded that active transmitters were found in "riffle" habitat 53% of the time compared to finding 47% in "pool" habitats.

Assessment of movements were grouped into several categories: 1) relative distances moved, 2) direction up or downstream and from stocking location and 3) conditions or seasons in which movement occurred. These categories describe unique aspects of fish movements but do overlap to a great extent.

Distances: We designated three zones within the MRRTA to describe general movements, and group stocking locations and typical habitat available: 1) upper (above the Dry Fork confluence), 2) middle (Dry Fork to Shannafeld bluff), and 3) lower (end of Shannafeld bluff pool through Richart Spring area). Approximately 2/3 of the trout stayed in the zone they were stocked in, but if they moved between zones, the most movement occurred between upper and middle zones or the upper zone into the Maramec Spring Branch (Table 4). Only one fish from the middle zone was detected in the lower zone, crossing the large bluff pool at Shannafeld, and no fish from the lower zone were detected in the upper or middle zone. Large movements were generally considered between zones and accounted for 33% of the movements in the fall and 50% of the movements in the spring (Table 5). Small movements were within a zone and accounted for 56% of movements in the fall and 38% of movements in the spring. (Analysis note: although we noted that some fish made movements that would fall in multiple categories, for this analysis we categorized each fish's overall behavior to describe the relative occurrence of stocked fish's habits, not the percentages of individual movements since we did not have around the clock or satellite based surveillance to determine every movement made.)

Direction: Direction away from stocking location varied with season and water conditions; we saw both upstream and downstream movements occur consistently, with < 15% designated as not moving at all (Analysis note: we did exclude transmitters that became inactive relatively quickly to attempt to remove influence of early deaths assumed mostly to be due to surgery stress on whether browns were moving after stocking or not.) After stocking, most fish seemed to disperse through the receiving pool or riffle, or make some exploratory movements within the stocking zone, then settle in their respective zones. During base flows, fish tended to move upstream twice as often as downstream (Table 6). During rises, fish tended to move downstream twice as often as upstream. We did see upstream movements during rises and downstream movements during base flow, but they weren't as common as the reverse.

In the upper zone, 57% of the fish stocked there stayed there; if they left, they mostly went upstream into the spring branch (60% stayed in spring branch once they were there, and 40% returned to the MRRTA) and a few moved downstream and died. In the middle zone, 62% of the fish stocked there stayed there; of the ones that left, 80% moved upstream and 20% moved downstream. In the lower zone, 85% of the fish stocked there stayed there; of the ones that left, all moved downstream (Table 4).

Stream conditions/seasons: After large rises, fish tended to be found downstream from their previous location twice as often as they were found upstream (Table 7), and more of these movements were considered large movements. More large rises happened in the spring than in the fall, and correspondingly, we saw more large movements in the spring than in the fall (although some fish still moved a notable distance in the fall). During base flows, the distances moved tended to be smaller than during rises; with the river at base blow most of the fall, movements tended to cover smaller distances. Both seasons were consistent in up or downstream direction during rises and base flows (See Figure 7 for data on stream flows).

Survival through rises and associated movement during a rise differed between seasons. Fall browns did not experience a large rise until many months after stocking and although it was the largest rise during this study, almost 70% of the browns did not move in either direction, with only 8% found inactive after the rise (Table 7). The other 30% did move downstream, but were found active. No browns moved upstream during that largest rise. Browns stocked in the spring experienced their first rises within a month of stocking. About 75% of them were found inactive after numerous mid-sized rises. The ones that became inactive since the previous tracking event were found upstream (~15%), downstream (~30%) and near (~30%) their respective stocking locations. The surviving ones were found upstream (~10%) and near (~15%) their respective stocking locations.

Discussion and management implications

- **How long do brown trout survive in the MRRTA after stocking?**

We used the locations and status of the browns released with transmitters as surrogates to make conclusions as to what happens to other stocked brown trout. However, with relatively low survival of control-incision fish, survival of browns with transmitters appears to have been impacted by the implantation process itself. Control fish were not exposed to predation or angling nor allowed to migrate and only survived at 55% three months post stocking, which leads us to believe that a portion of the mortality we captured in transmitter locations of released browns should be attributed to surgical stress. In addition, we saw a lower survival rate for fish implanted on the same day as released, and believed that the added stress of surgical recovery in a "wild" setting likely had a larger than normal influence in whether a fish survived; so again, we excluded the fish released on the same day as implantation in the survival estimates. In the river-released fish, we saw 25% of transmitters end up in a location that would correspond with a fish dying from surgical stress (deep water locations). Brown trout without transmitters would not have been subject to this stress, so survival rates of other browns are believed to be higher than those of browns released with transmitters. The six-month survival rate of browns released with transmitters was around 19% between the two seasons. If we account for the surgical stress mortality factor by grouping the inactive, deep water detection with the active-alive

ones, we are looking at approximately 40% survival six months post release, which is consistent with spring 2014 electrofishing survey findings (Note: most routine electrofishing surveys assess 10 -12 month post release survival, and have shown <10% survival at that time interval).

- **What are the largest mortality factors they experience (harvest, predation, natural causes)?**

Considering only the fish that we considered to have experienced mortality influences similar to what normal stocked browns would have had, the evidence leads us to conclude that roughly half of browns dying after stocking where either directly killed by mammalian predators (likely otters and mink, possibly raccoon), or their carcasses were preyed upon by mammals. About a third of the stocked browns may end up far from the main channel of the RRTA. There is some uncertainty about how they may end up in such locations - some of the locations seemed likely to have been taken by birds to dry land around perch-trees; other possibilities include anglers removing the fish from the system or that during rises fish moved into off-channel habitat that left them stranded as the waters receded. Another 15% appear to leave the MRRTA by unknown sources, some of which may be similar to the previous category (angler removal, avian deposition elsewhere), but we also think that fish may leave the system as they explore new habitats and that the disappearances don't always equate to immediate death, but do constitute removal from the system as they are seemingly no longer available for MRTTA anglers.

- **Where and how quickly do they move/disperse after stocking?**

Most browns seem to stay around their stocking location, especially in the lower part of the MRRTA. Even so, the majority do make some exploratory movements from the stocking points even if they are not traveling great distances. Several of them do make relatively large movements away from the stocking location. Both the large and small movements can occur both upstream and downstream. During certain conditions one direction is more likely to have occurred than the other – upstream movements during base flows and downstream movements during rises.

- **Do browns reared at Maramec hatchery move to the spring branch rather than stay in the MRRTA (and thus make themselves unavailable to MRRTA anglers)? Do they "migrate" to the spring branch in the fall to try to spawn?**

The majority of stocked browns do not end up in the spring branch; however, a small portion do find their way into the spring branch. Interestingly, we did not locate any browns with transmitters in the portion of the spring branch that is open to fishing despite listening in that section multiple times, but all ended up in the sanctuary portion of the branch at the top of the park. Not all browns that enter the spring branch stay there and some do return to the MRRTA and are available to anglers again. We did not witness a large migration upstream in the fall into the spring branch as we thought we might.

- **Do browns stocked at the lower end of the RRTA move towards the spring when water temperatures approach 70F?**

Unfortunately, we did not get great insights to this question given the timeframe and battery life limitations that we had to work with. Few fish were alive with working batteries in the July through September timeframe and we had limited tracking opportunities to locate them.

- **How do brown trout react when the river rises after a precipitation event? (Die? Move?)**

We were surprised to see that there weren't a higher number of fish gone from the MRRTA boundaries following stream rises. There were movements that indicated that some of the fish were gradually being swept downstream but there were also simultaneous or subsequent movements upstream in those same timeframes. So, we would conclude that rises do not remove browns by carrying them out of or stimulating migration out of the MRRTA boundaries; however, rises to seem to stimulate movement within the MRRTA.

We did see higher instances of mortality post-rise in the spring round of tracking that would lead us to think that something about the rise instigated the mortality. Some transmitters that were found inactive after a rise appeared to have moved or been moved off-channel, while some inactive transmitters remained in the main channel. Since we were not able to safely track during the actual rise and usually had to wait a few days for safe boating conditions to return, we cannot make clear conclusions about the specifics of mortality for these fish. It seems unlikely that the rises lead to acute deaths because of changes in temperature or water quality, as some fish survived the rises with seemingly no problems. It seems that forced or voluntary migration to off-channel locations that were subsequently dried or unsuitable at the return to base flow, which could have also lead to increased predation chances, or in-stream habitat shifts during the rise (i.e. rootwad being dislodged) would be likely ways that the rise would have stressed the fish to the point of death.

Also, it was interesting to see that some of the transmitters that were in the spring branch sanctuary appeared to be missing after rises, but eventually were found again, usually in the same location were they were before the rise. We are unsure if the fish were simply undetected, or if they moved and returned by the next tracking session.

Other mortality observations during active tracking trips: While we were active tracking, we made additional anecdotal observations on non-transmitter-ed trout survival and carcasses. We found four 2019 stockers dead in the stream bottom with no obvious wounds; this was a relatively low number of fish considering the thousands that were stocked, but some fish do not survive much longer than a day off the truck with no obvious wounds to indicate that they died from anything besides stress. We also found two 2019 stockers and five 2018 stockers dead on the stream bottom with puncture wounds during the fall and winter. The wound trajectories were from the side or from the top in different carcasses, and we did not feel we could make a definite determination about cause of injury, but we assumed that the wounds likely came from eagles/herons or gigs/snags. On one trip, we also saw several other suckers and game fish dead with similar evenly spaced marks from above (errant giggers were suspected in that case). So, even though we did not find any transmitter-ed brown trout carcasses with these wounds, we saw evidence that we are losing a small number stocked fish to avian removal/injury and illegal fishing activity. Brown trout behavior during spawning season (primarily October-November) is to be in riffles and shallow areas during a time of year when the river is at its clearest. This behavior likely makes the browns easy targets when other prey items gather in deeper pools with the colder weather and interference with gigging/snagging activity is high. However, the fall also seems to be the best time to put fish in stream from the perspective of staff time, driving conditions, and providing the browns maximum time to adjust before large spring rises occur.

Other movements observations: we didn't detect every movement that each fish made. For example, we did not locate any transmitters in the fishing section of the spring branch but did find browns that had been stocked in river above the spring branch fishing section in the sanctuary area. They had to move through the area at some point, but it was not during a time when we tracked them, so there could be other movement patterns that we did not detect given the frequency of tracking that we were able to do. The locations we did find the fish in are assumed to be places the fish liked, rather than coincidentally catching them as they moved through an area.

- **What adjustments can we make to rearing/holding/stocking management or harvest regulations that will effectively produce a more consistent trout fishery?**
    - Avoid stocking during high water conditions or previous to predicted rises if schedules can accommodate it.

- Focus stocking towards more centrally located stocking locations to minimize browns leaving the MRRTA.
- Encourage furbearer trapping activity.
- Continue enforcement of the current minimum length limit, daily limits, bait restrictions, and game fish harvest methods, and encourage ethical fishing tactics (identify your target before you gig or snag).
- Continue multiple, smaller stockings spread out over as many months as staff schedules will allow.
- Consider other stocking or rearing options that would enhance "wildness" of browns, such as:
    - Introduction of natural foods or cover/substrate to hatchery raceway prior to release
    - Stocking smaller fingerling sizes instead of 8"+ browns
    - Working with hatcheries to explore the efficiencies of different brown trout strains or using broodstock from the wild to enhance survival of stocker size fish

Notes on what to try or modify in the future if funding and time allows for more telemetry work:

- Very happy with technology. Seemed to record and decode locations well.
    - Could adjust signal frequency for longer battery life (10+? sec between signals)
    - Are tags with no external antenna available with radio frequency? Is it worth the tradeoff for mortality signal?
- Consistent tracking efforts (more time solely dedicated to tracking): pinpoint "new" inactive tags ASAP. Track with larger antenna if/when there are missing tags. Figure out if "active" tag repeatedly in same location is alive (approach with boat and see if transmitter moves away?). May want to limit the number of transmitters released at the same time at the same location to 3 or less (around 20 total each month seemed to be ideal) – we had difficulty pinpointing individual tags when there were multiples in the same area, and when we had 20+ to locate and complete a float through the entire area we could not afford much searching time per individual transmitter.
- If we attempt to study late summer movements and/or mortality, we would need to have transmitters and/or settings that have longer battery life. We would also need to think through how many fish to implant to have an appropriate number that we would expect to be still alive and swimming July – Aug (e.g. 20% survival "long" term and we would want at least 5 alive in the summer, so that would be about 25 transmitters implanted to start with). It would be hard to hold browns in the hatchery till June to stock with current transmitters' leftover battery life, but that might be a possibility if we cannot find transmitters with a longer battery life.
- Need to study long-term tag retention (are fish losing or expelling tags?)
    - "control" design: 3 groups (5+? fish each) – fish with transmitters & sutures, fish with sutures only, fish with no incisions. Mark groups differently (e.g. upper caudal, left pelvic, and right pelvic fin clips). Hold in raceway covered box. Check weekly, recover any lost tags & note mortalities from each group.

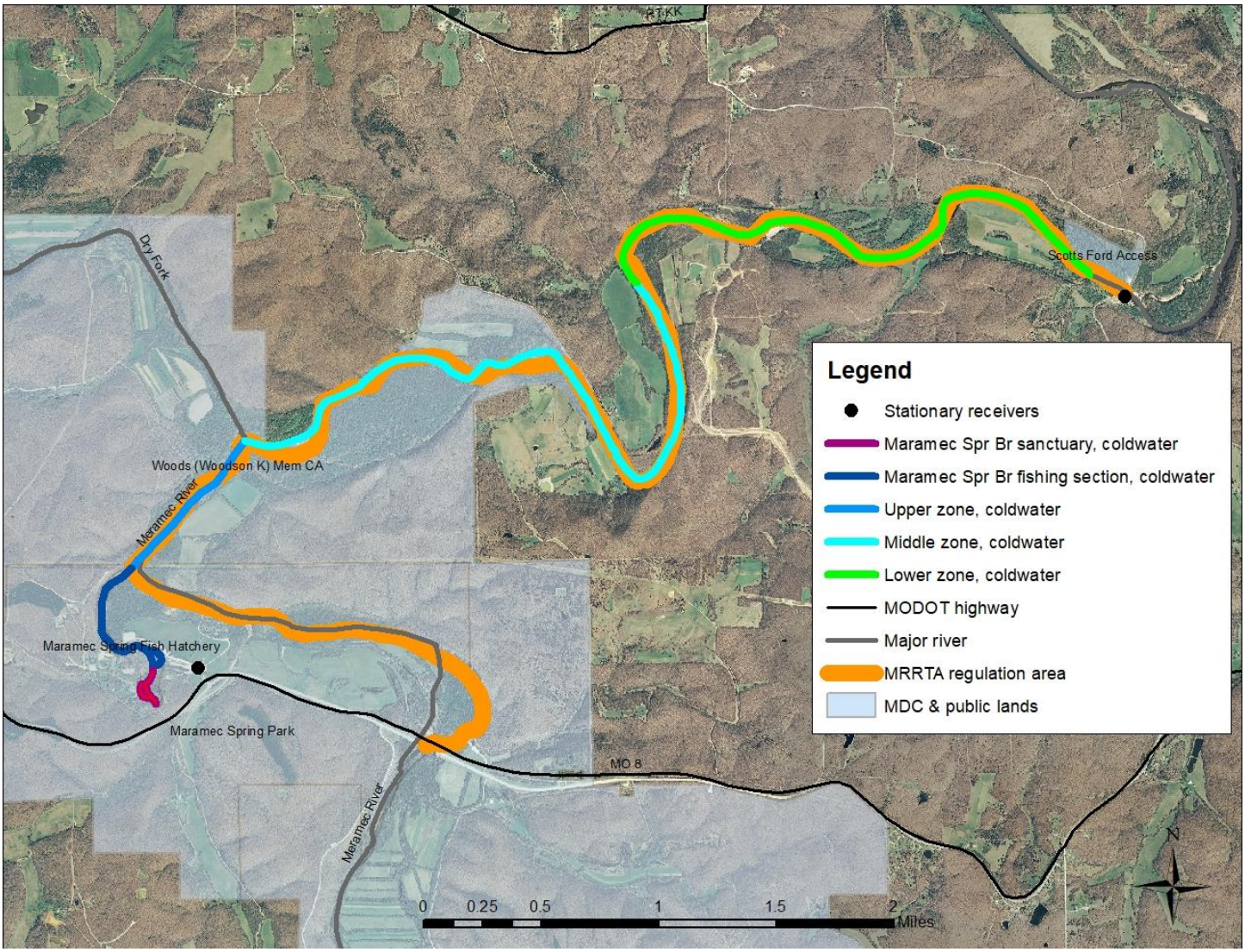

Figure 1. MRRTA map with stocking zones, stationary receiver locations, MRRTA boundaries, and coldwater portions.

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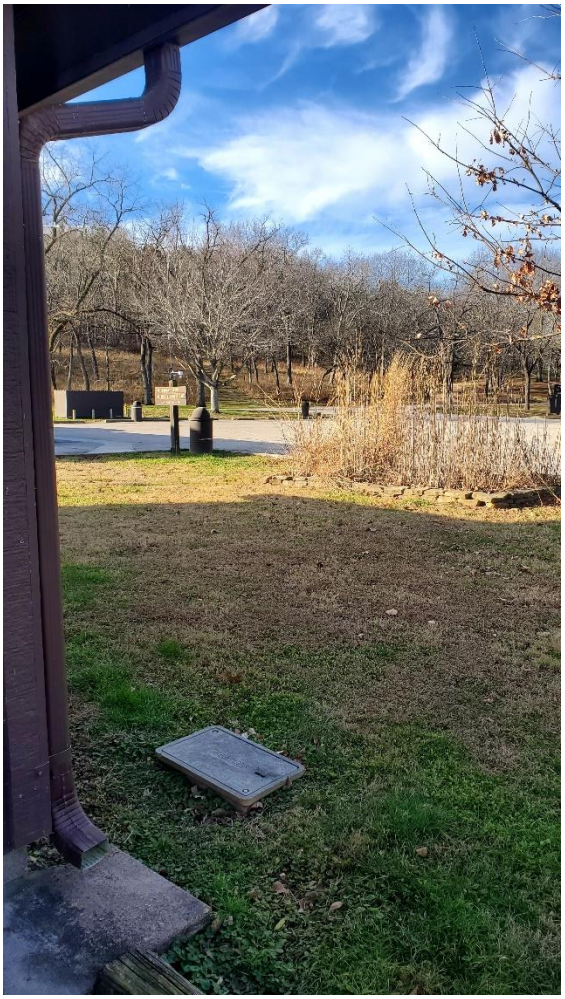

Figure 2: Stationary Receiver locations at Scotts Ford (upper) and Maramec Hatchery (lower).

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Figure 3: Transmitter implantation process and healing of sutures.

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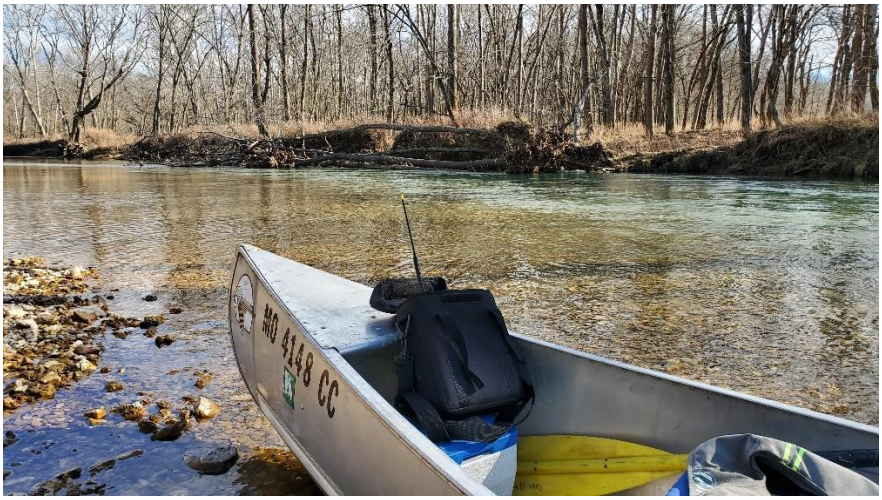

Figure 4: Active tracking session receiver and transport modes.

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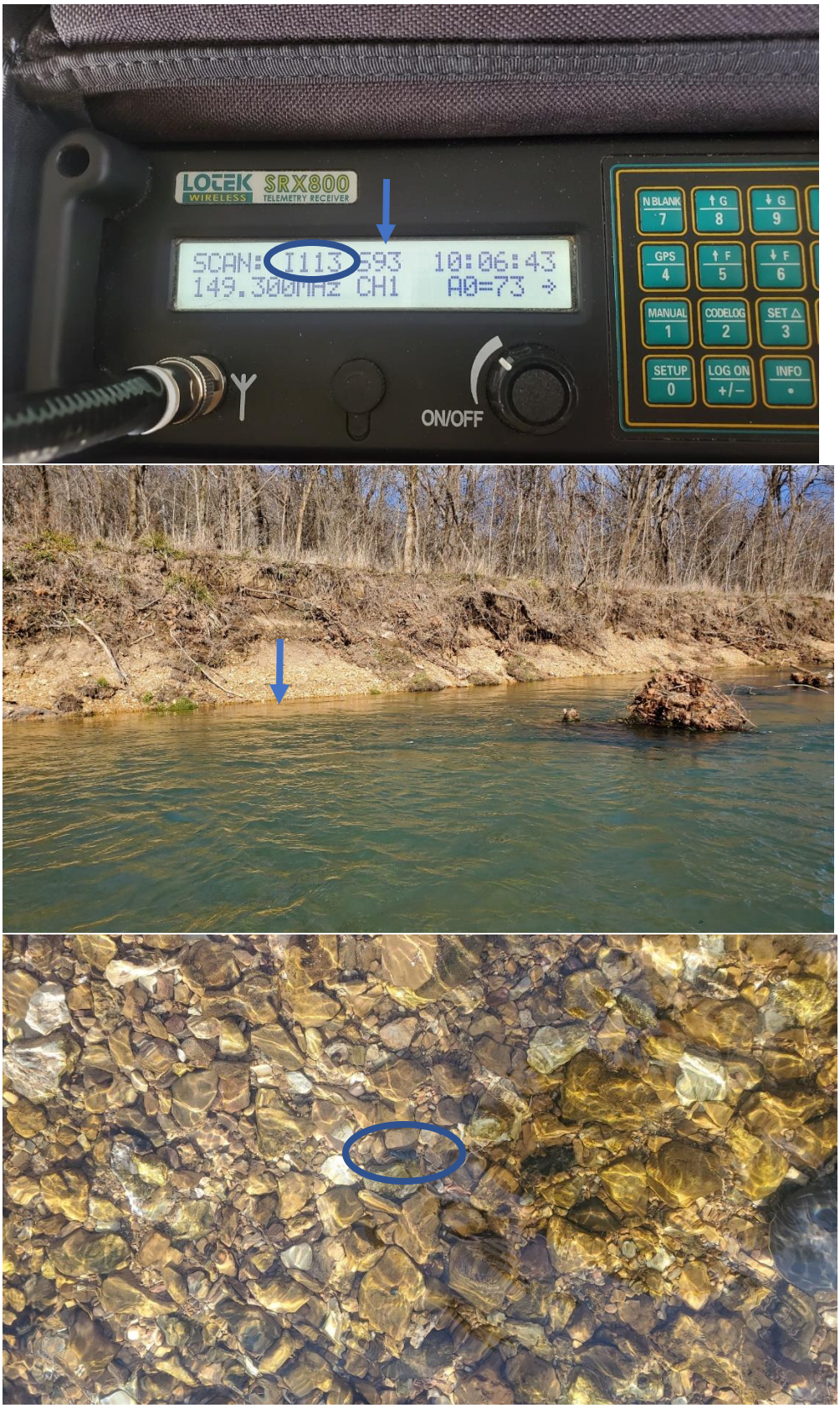

Figure 5: Inactive transmitter recovery process. Transmitter would signal with an "I**1**xx" code; signal strength would increase as we got closer to the transmitter; grid searches to find highest signal strength; visual searching to recover tag.

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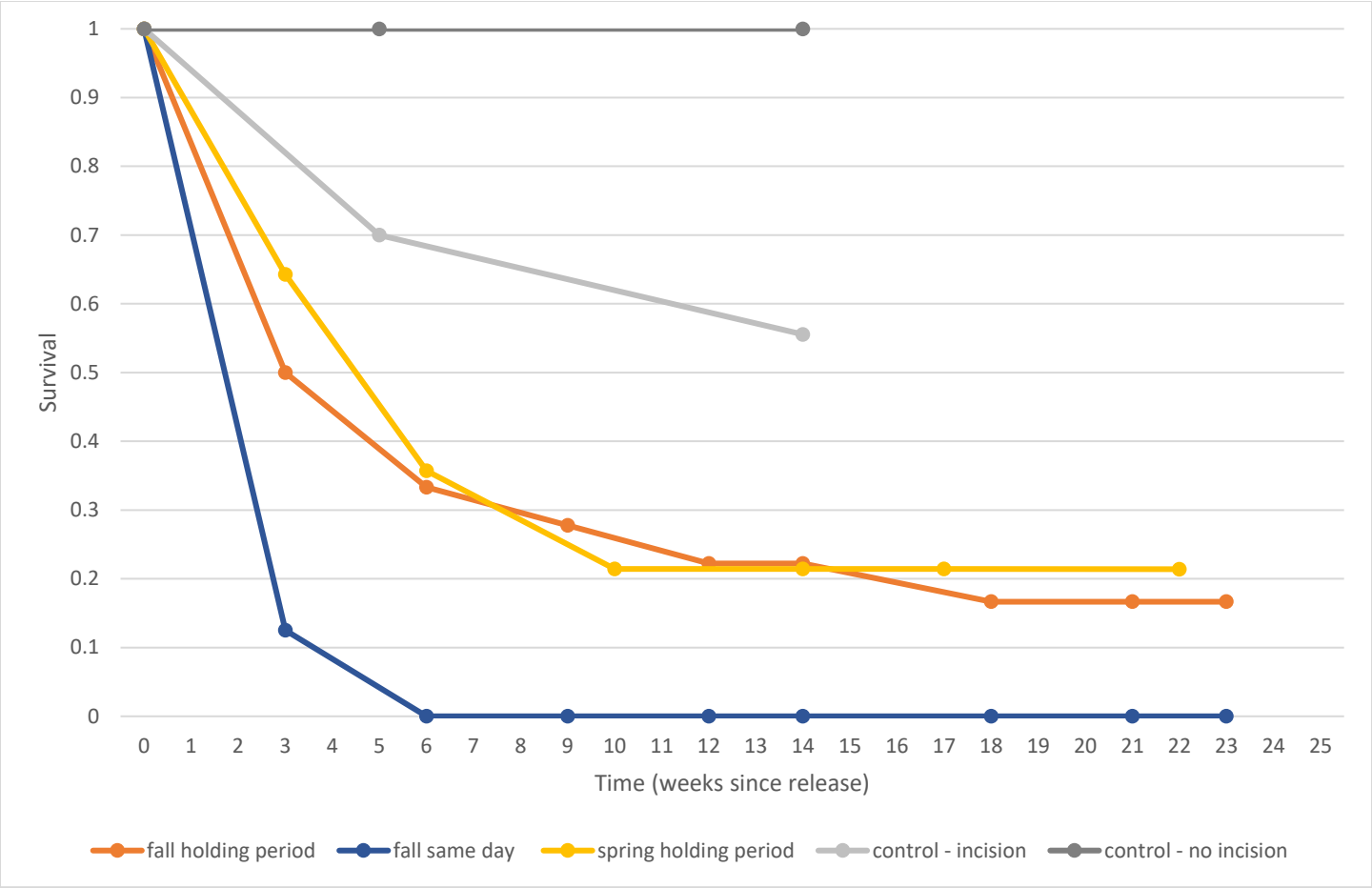

Figure 6: Survival of brown trout individuals by season and treatment through time.

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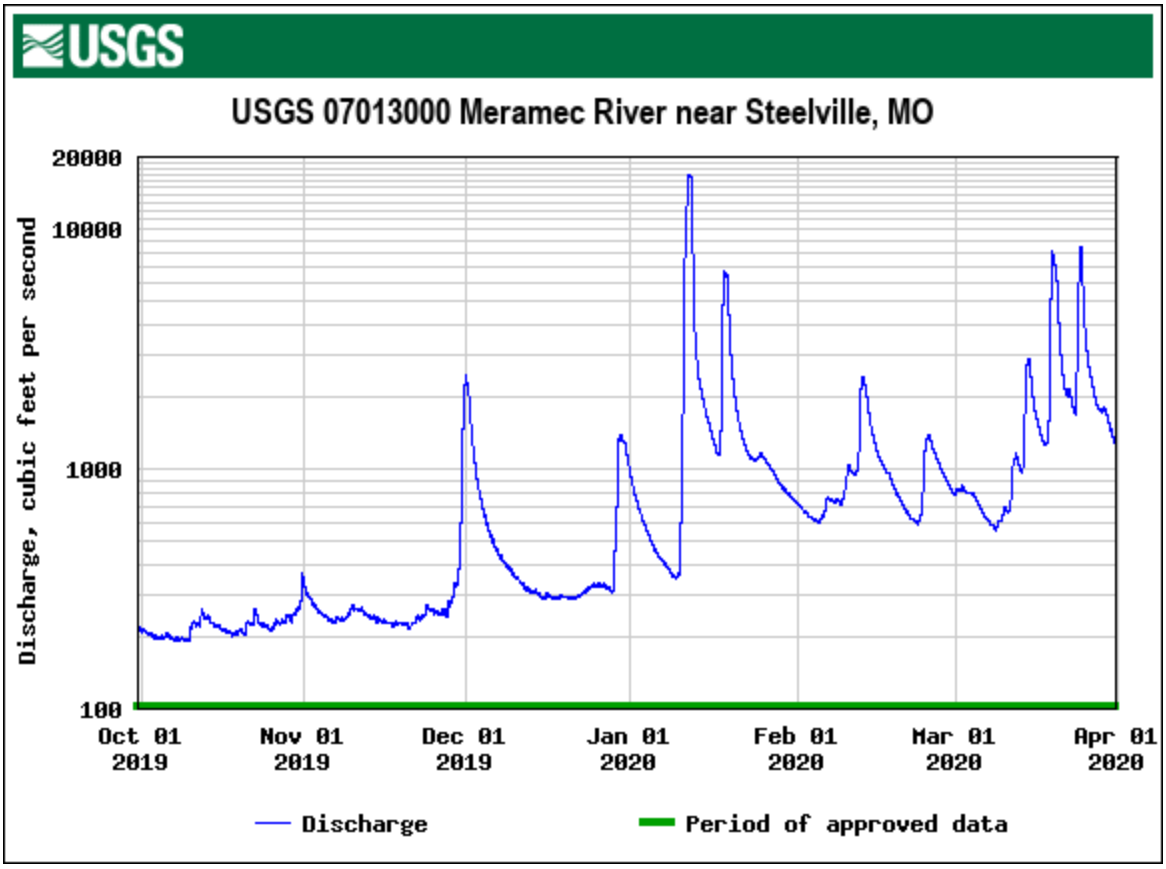

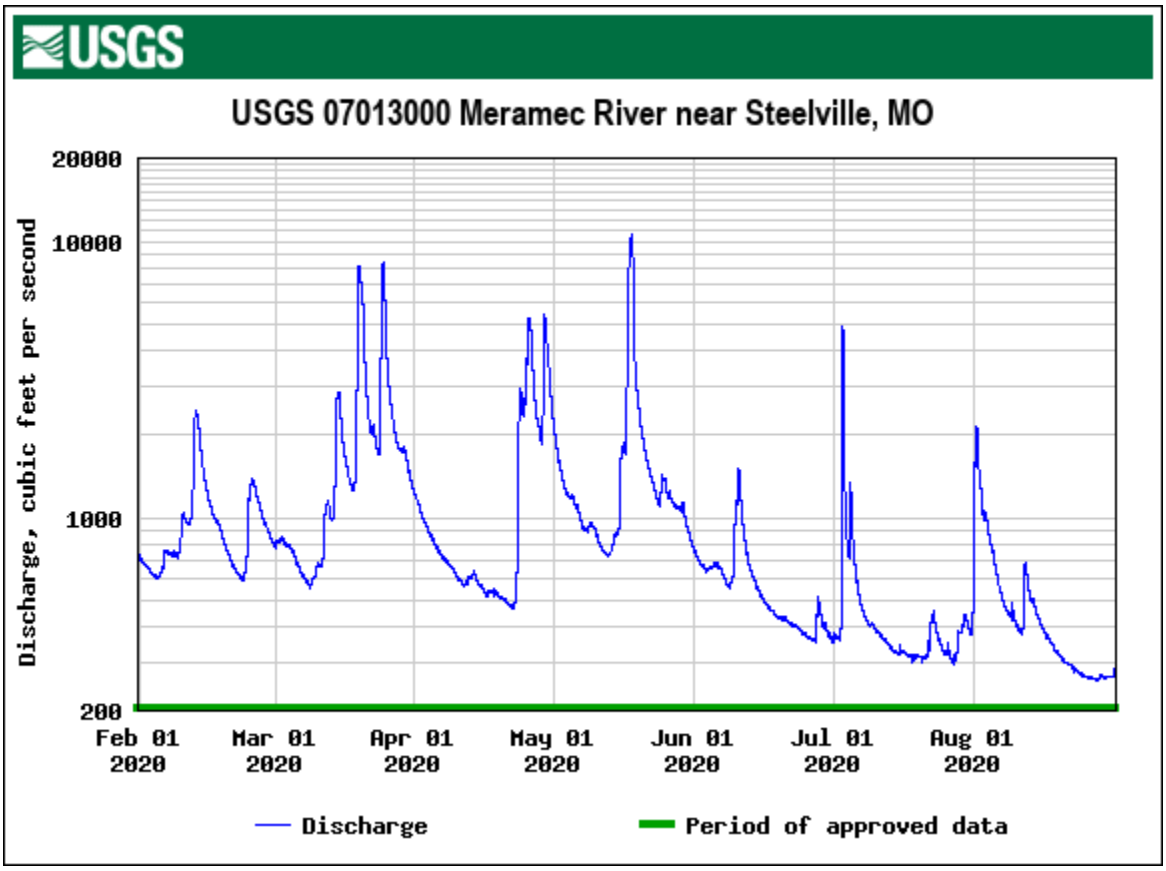

Figure 7. Stream discharge measurements during tracking months from Meramec River at Steelville.

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Table 1. Sizes of brown trout implanted with transmitters.

Transmitter #	Fish total length (mm)	Fish weight (g)
11	280	332
12	322	448
13	285	341
14	275	232
15	303	428
16	285	336
17	280	325
18	285	370
19	300	333
20	280	327
21	350	612
22	290	296
23	300	331
24	288	308
25	270	278
26	270	254
27	292	377
28	290	383
29	309	362
30	288	339
31	457	1995
32	360	553
33	345	453
34	320	323
35	381	644
36	272	283
37	290	305
38	323	387

Transmitter #	Fish total length (mm)	Fish weight (g)
39	352	589
40	354	504
41	296	352
42	344	517
43	336	547
44	290	299
45	340	848
46	363	576
47	356	501
48	372	640
49	319	476
50	310	358
51	314	369
52	346	602
53	336	472
54	334	413
55	360	671
56	285	671
57	345	480
58	342	462
59	331	434
60	355	364
61	315	405
62	292	318
63	325	372
64	338	456
65	316	379
66	342	554

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Table 2. Active tracking sessions.

Date	Activity and location
2-Oct	tags implanted and released in river
4-Oct	tracked from spring pool to Scotts Ford in coldwater section
8-Oct	tags released in river
8-Oct	listened at stocking locations for other fish
9-Oct	tags released in river
9-Oct	listened at stocking locations for other fish
11-Oct	tracked from spring pool to Scotts Ford in coldwater section
14-Oct	tracked upper part of coldwater section
16-Oct	tracked upper part of coldwater section
18-Oct	tracked from spring pool to Scotts Ford in coldwater section
22-Oct	tracked upper part of coldwater section
25-Oct	tracked from spring pool to Scotts Ford in coldwater section
28-Oct	tracked around spring pool and branch, upstream to Gin Beach campground, and in gut pile dump field
1-Nov	tracked from spring pool to Scotts Ford in coldwater section
7-Nov	tracked spring branch to cabin riffle - walking
14-Nov	tracked from spring pool to Scotts Ford in coldwater section
25-Nov	tracked from spring pool to Scotts Ford in coldwater section
6-Dec	tracked from spring pool to Scotts Ford in coldwater section
11-Dec	listened at spring branch pool/refuge
12-Dec	listened at spring branch pool/refuge
17-Dec	listened at spring branch pool/refuge
18-Dec	listened at spring branch pool/refuge
19-Dec	listened at spring branch pool/refuge
20-Dec	tracked confluence pool to Scotts Ford in coldwater section
26-Dec	tracked confluence pool to Scotts Ford in coldwater section
30-Dec	listened at spring branch pool/refuge
9-Jan	listened at spring branch pool/refuge & during stocking runs
14-Jan	listened at spring branch pool
14-Feb	tracked from spring pool to Scotts Ford in coldwater section
28-Feb	listened at spring branch pool
6-Mar	tracked from spring pool to Scotts Ford in coldwater section
10-Mar	listened at spring branch pool/refuge
17-Mar	tracked from spring pool to Scotts Ford in coldwater section
2-Apr	tracked from spring pool to Scotts Ford in coldwater section
7-Apr	listened at spring branch pool
9-Apr	tracked from spring pool to Scotts Ford in coldwater section, lower end of campground
23-Apr	listened at spring branch pool
5-May	tracked from spring pool to Scotts Ford in coldwater section, almost to hwy 8
29-May	listened at spring branch pool
5-Jun	tracked from spring pool to Scotts Ford in coldwater section, almost to hwy 8
25-Jun	tracked from spring pool to Scotts Ford in coldwater section, almost to hwy 8
28-Jul	listened at spring branch pool

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Table 3. Relative percentage of released transmitter fate categorized by final status or location from both seasons.

		Season		
Fate of transmitters	Assumed cause of death	Fall	Spring	Combined
Alive	n/a	17%	21%	19%
Tag in deep water	Surgery/stress death	22%	29%	25%
Chewed on/water's edge/logs	Mammal predation	33%	29%	31%
Dry land/faint	Bird/angler/flood migration (?)	11%	21%	16%
Missing	Angler/migration (?)	17%	0%	9%

Table 4. Movement patterns of brown trout individuals described by stocking location zones, both seasons combined.

Stocking location	Stayed	Moved
Upper	57%	43%
Middle	62%	38%
Lower	85%	15%

Table 5. Movement patterns of brown trout individuals described by distance moved and season.

	Season	
Movement distance	Fall	Spring
Large (out of or nearly out of zone)	33%	50%
Small (within zone)	56%	38%
None	11%	13%

Table 6. Individual movements of brown trout described by direction and water conditions, both seasons combined.

	Water conditions between tracking events	
Movement direction	Base flow	Water rise
Upstream	64%	33%
Downstream	36%	67%

Table 7. Movement patterns and survival of brown trout individuals after large rises described by season.

	Season	
Status and movement	Fall	Spring
Active & moved up	0%	8%
Active & moved down	31%	0%
Active & no move	61%	15%
Inactive & no move	8%	31%
Inactive & moved up	0%	15%
Inactive & moved down	0%	31%

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